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MILITARY STANDARD

ENVIRONMENTAL TEST METHODS

FSC MISC

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Environmental Test Methods

MIL-STD-810C

1. This Military Standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Recommended corrections, additions, or deletions should be addressed to Commander, Aeronautical Systems Division, Attn: ASD/ENYESA, Wright-Patterson Air Force Base, Ohio 45433.

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ENVIRONMENTAL TEST METHODS

1. SCOPE

1.1 Purpose. This standard establishes uniform environmental test methods for determining the resistance of equipment to the effects of natural and induced environments peculiar to military operations. It provides environmental test methods in order to obtain, as much as possible, reproducible test results. The test methods described herein are intended to be applied by the contractual documents.

1.2 Application of test methods. Test methods contained in this standard apply to all items of equipment. WHEN IT IS KNOWN THAT THE EQUIPMENT WILL ENCOUNTER CONDITIONS MORE SEVERE OR LESS SEVERE THAN THE ENVIRONMENTAL LEVELS STATED HEREIN, THE TEST MAY BE MODIFIED BY THE EQUIPMENT SPECIFICATION.

1.3 Numbering system. The test methods are numbered sequentially as they are introduced into this standard with the first method being number 500.

1.4 Revision of standard. Any general revision of this standard which results in a revision of sections 1, 2, or 3 will be indicated by revision letter after this standard number, together with the date of the revision.

1.5 Revision of test methods. Any revision of test methods is indicated by a decimal following the method number. For example, the original number assigned to the first test method is 500; the first revision of that method is 500.1, the second revision is 500.2, etc.

1.6 Method of reference. Test methods contained herein shall be referenced by specifying:

a. This standard number

b. Method number

c. Procedure number of required

d. Other data as called for in the individual test method.

(For example: MIL-STD-810C, Method 500.1, Procedure I including Method 500.1 paragraph entitled, Summary.)

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of this standard to the extent specified herein:

SPECIFICATIONS

Military

MIL-P-116	Preservation-Packaging, Methods of
MIL-S-901	Shock Tests, H.I. (High Impact), Shipboard Machinery, Equipment and Systems, Requirements for
MIL-G-5572	Gasoline, Aviation, Grades 80/87, 100/130, 115/145
MIL-A-8591	Airborne Stores and Associated Suspension Equipment, General Specification for
MIL-C-9435	Chamber, Explosion-Proof Testing
MIL-C-45662	Calibration System Requirements

STANDARDS

Federal

FED-STD-101	Preservation, Packaging, and Packing Materials, Test Procedures

Military

MIL-STD-167	Mechanical Vibrations of Shipboard Equipment
MIL-STD-210	Climatic Extremes for Military Equipment
MIL-STD-331	Fuze and Fuze Components, Environmental and Performance, Test For

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

American Society for Testing and Materials

E-297-70	Standard Methods for Calibration of Ionization Vacuum Gauge Tubes
E-491-73	Standard Recommended Practice for Solar Simulation for Thermal Balance Testing of Spacecraft

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.)

American Geophysical Union

"The Relation of Raindrop Size to Intensity" - Laws and Parsons, Transactions of the American Geophysical Union, Part II, paragraphs 452-459, 1943.

(Copies of the above publication may be obtained from the American Geophysical Union, 2100 Pennsylvania Ave., N.W., Suite 435, Washington, D.C. 20037.)

American National Standards Institute, Inc.

S1.1 (1960 issue)	Acoustical Terminology (Including Mechanical Shock and Vibration)
S1.6	Preferred Frequencies for Acoustical Measurements
Z24.10	Octave-Band Filter Set for the Analysis of Noise and Other Sounds

(Application for copies should be addressed to the American National Standards Institute, Incorporated; 1430 Broadway; New York, New York 10018.)

U.S. Committee on Extension to the Standard Atmosphere

U.S. Standard Atmosphere, Supplement, 1966.

(Copies of the above publication may be obtained from the Superintendent of Documents, Government Printing Office, Washington, DC 20402.)

3. GENERAL REQUIREMENTS

3.1 Test conditions. Unless otherwise specified herein or in the equipment specification, measurements and tests shall be made at standard ambient conditions. Standard ambient conditions are:

a. Temperature — 23° ± 10°C (73° ± 18°F)

Relative humidity — 50 percent ± 30 percent

Atmospheric pressure — 725 $^{+50}_{-75}$ mm. Hg. (28.5 $^{+2.0}_{-3.0}$ in. Hg.)

When these conditions must be closely controlled, the following shall be maintained:

b. Temperature — 23° ± 1.4°C (73° ± 2.5°F)

Relative humidity — 50 percent ± 5 percent

Atmospheric pressure — 725 $^{+50}_{-75}$ mm. Hg. (28.5 $^{+2.0}_{-3.0}$ in. Hg.)

3.1.1 Measurements of test conditions. All measurements of test conditions shall be made with instruments of the accuracy specified in 3.1.3.

3.1.2 Tolerance of test conditions. Unless otherwise specified, tolerance of test conditions shall be as follows:

a. Air temperature at the control sensor ±1.4°C (±2.5°F). The equipment sensor response time (T) shall be 20 seconds or less. Temperature gradient across the cross-sectional area occupied by the test item shall not exceed 0.3°C (0.5°F) per foot in any direction, but never more than 2.2°C (4°F) total (equipment nonoperating).

b. Pressure: When measured by devices such as manometers, ±5 percent or ±1.5 mm. (0.059 inch) of mercury, whichever provides the greatest accuracy. When measured by devices such as ion gages, ±10 percent to 10^{-5} Torr.

c. Relative humidity at the control sensor: ±5 percent.

d. Vibration amplitude: Sinusoidal: ±10 percent
Random: See Method 514.2.

e. Vibration frequency: ±2 percent, or ±1/2 Hz below 25 Hz.

f. Acceleration: ±10 percent.

NOTE: (T) is the time required for the sensing system to respond to 62.3 percent of a step change in temperature in the measured environment.

3.1.3 Accuracy of test apparatus. The accuracy of instruments and test equipment used to control or monitor the test parameters, shall be verified and shall satisfy the requirements of MIL-C-45662 to the satisfaction of the procuring activity. All instruments and test equipment used in conducting the tests specified herein shall:

a. Conform to laboratory standards whose calibration is traceable to the prime standards at the U.S. Bureau of Standards.

b. Have an accuracy of at least one-third the tolerance for the variable to be measured. In the event of conflict between this accuracy and a requirement for accuracy in any one of the test methods of this standard, the latter shall govern.

3.1.4 Stabilization of test temperature

3.1.4.1 Operating. Unless otherwise specified, temperature stabilization will have been attained when the temperature of the part of the test item considered to have the longest thermal lag is changing no more than 2.0°C (3.6°F) per hour. Exceptions may occur on large test items.

3.1.4.2 Nonoperating. Unless otherwise specified, temperature stabilization will have been attained when the temperature of the part of the test item considered to have the longest thermal lag reaches a temperature within 2.0°C (3.6°F) of the prescribed temperature, except that any critical component (e.g., battery electrolyte for engine starting test) will be within 1°C (1.8°F). Exceptions may occur on large test items. When changing temperatures, the temperature of the chamber air may be adjusted up to 5°C (9°F) beyond the desired end point for a period of time of up to 1 hour to reduce stabilization time, provided that the stabilization requirements of this paragraph are ultimately attained relative to the specified end point temperature, and provided the extended chamber temperatures will not cause damage to the test item.

3.2 Performance of test

3.2.1 Pretest performance record. Prior to proceeding with any of the environmental tests, the test item shall be operated under standard ambient conditions (see 3.1) to obtain data for determining satisfactory operation of the item as specified in the equipment specification, before, during and after the environmental test, as applicable. A record of specific pretest data shall be made to determine that the test item performs within prime item specification requirements. The pretest record shall also include the following, as applicable:

a. The functional parameters to be monitored during and after the test, if not specified in the equipment specification. This shall include acceptable functional limits (with permissible degradation) when operation of the test item is required.

3.2.2 Installation of test item in test facility. Unless otherwise specified, the test item shall be installed in the test facility in a manner that will simulate service usage, making connections and attaching instrumentation as necessary. Plugs, covers, and inspection plates not used in operation, but used in servicing shall remain in place. When mechanical or electrical connections are not used, the connections normally protected in service shall be adequately covered. For tests where temperature values are controlled, the test chamber shall be at standard ambient conditions when the test item is installed. The test item shall then be operated to determine that no malfunction or damage was caused due to faulty installation or handling. The requirement for operation following installation of the test item in the test facility is applicable only when operation is required during exposure to the specified test.

3.2.3 Performance check during test. When operation of the test item is required during the test exposure, suitable tests shall be performed to determine whether the test exposure is producing changes in performance when compared with pretest data.

3.2.4 Post-test data. At the completion of each environmental test, the test item shall be inspected in accordance with the equipment specification and the results shall be compared with the pretest data obtained in accordance with 3.2.1.

3.2.5 Test data. Test data shall include complete identification of all test equipment and accessories. The data shall include the actual test sequence used and ambient test conditions recorded periodically during the test period. The test record shall contain a signature and data block for certification of the test data by the test engineer.

3.2.6 Failure criteria

a. The item shall have failed the test when any of the following occur:

(1) Monitored functional parameters deviate beyond acceptable limits established in 3.2.1.

(2) Catastrophic or structural failure.

(3) Mechanical binding or loose parts, including screws, clamps, bolts, and nuts, that clearly result in component failure or a hazard to personnel safety.

(4) Malfunction.

(5) Degradation of performance beyond pretest record or equipment specification requirements established in 3.2.1 (record to be made after test).

NOTE: Certain types of equipment (e.g., propellants and electrically driven devices) are often expected to demonstrate lesser performance at an environmental extreme, particularly low temperature. A failure would occur only if degradation is more than expected.

(6) Any additional deviations from acceptable criteria established before the test and recorded according to 3.2.1.

(7) Deterioration, corrosion, or change in tolerance limits of any internal or external parts which could in any manner prevent the test item from meeting operational service or maintenance requirements.

b. Any additional or different failure criteria shall be as specified in the equipment specification.

3.3 Test facilities and apparatus. Test facilities, chambers, and apparatus used in conducting the tests contained in this standard shall be capable of meeting the conditions required.

3.3.1 Test chamber

3.3.1.1 Volume of test chamber. The volume of the test chamber shall be such that the bulk of the item under test will not interfere with the generation and maintenance of the test conditions. When testing multiple sample items simultaneously, the test chamber shall be of sufficient size so that each test unit is provided uniform environmental conditions and is not subjected to nontest environments.

3.3.1.2 Heat source. The heat source of the test facility shall be so located that radiant heat from the source will not fall directly on the test item, except where application of radiant heat is one of the test conditions.

3.3.1.3 Location of temperature sensors. Unless otherwise specified, thermocouples or equivalent temperature sensors utilized to determine or control the specified chamber temperature shall be located centrally within the chamber, in the supply airstream, or in the return airstream whichever provides the specified test conditions at the bulk under test and shall be baffled or otherwise protected against radiation effects.

3.3.1.4 Internal air circulation. The conditioned air flow shall be suitably baffled to provide uniform air flow around the test item. If multiple test items are tested, they shall be so spaced as to provide free circulation between the test items and the chamber walls.

3.4 Test data. Test data shall include complete identification of all test equipment and accessories. The data shall include the actual test sequence used and ambient test conditions recorded periodically during the test period. The test record shall contain a signature and date block for certification of the test data by the test engineer.

4. TEST SEQUENCE

4.1 See table I for recommended test sequence.

TABLE I. Recommended test sequence
(Read down)

Test Method		Group I (see notes 1, 2)					Group II (see notes 1, 3)									
		A	B	C	D	E	a	b	c	d	e	f	g	h	i	j
500.1	Low Pressure (Altitude)	1	1	1	3	3	4	2[1]	2	2	2	3	4	3	2	3
501.1	High Temp.	2	2	2	2	2	1	1	1	3	1	1	1	1	1	2
502.1	Low Temp.	4	4	3	1	1	2	3[1]	3	1	4	2	3	2	3	1
503.1	Temperature Shock	5[1]	5[1]	5[1]	5[1]	5[1]	3[1,2]	5[1,2]	5[1,2]	5[1,2]	3[1,2]	5[1,2]	2	4	5[1,3]	5[1,2]
504.1	Temperature-Altitude	--	--	--	--	--	5[5]	4[5]	4[5]	4[5]	5[1,3,5]	4[5]	5[5]	5[5]	4[5]	4[5]
505.1	Solar Radiation (Sunshine)	3[1]	3[1]	4[1]	4[1]	4[1]	--	--	--	--	--	--	6[3]	--	--	--
506.1	Rain	8[1]	8	7	11[1]	11	--	7[1]	7[1]	8[1]	7[1,3]	--	--	7[1,3]	--	--
507.1	Humidity	9	9	8	12	12	8	8[1]	8	9	8	7	9	8	7[1]	12
508.1	Fungus	10	10	9	13	13	9	9[1]	9	10	9[1,3]	8	10	9	8[1,3]	13
509.1	Salt Fog	11[1]	11	10	14[1]	14	10[1]	10[1]	10[1]	11[1]	10[1,3]	9[1]	11[1,3]	10[3]	9[1,3]	14[1,3]
510.1	Dust (Fine Sand)	7[1]	7	11	7[1]	7	7	11[3]	11[3]	7	11	10	8	11	10[3]	7
511.1	Explosive Atmosphere	--	--	12	8[1]	8[1]	12[3]	--	--	13[3]	--	12[3]	13[3]	13	12[1,2]	9[1,2]
512.1	Leakage (Immersion)	6	6	6	6	6	6	6	6	6	6	6	7	6	6	6
513.2	Acceleration	--	--	--	--	--	11	12	12	12	12	11	12	12	11	8
514.2	Vibration	13	13	14	10	10	14	14	14	15	14	14	14	15	14	11
515.2	Acoustical Noise	--	--	--	--	--	15[1,4]	15[1,4]	15[1,4]	16	15	15	16[1]	16	15	15
516.2	Shock	12	12	13	9	9	13	13	13	14	13	13	15	14	13	10

TABLE I. Recommended Test sequence (continued)

Test Method	Group I (see notes 1, 2)					Group II (see notes 1, 3)									
	A	B	C	D	E	a	b	c	d	e	f	g	h	i	j
517.2 Space Simulation (Unmanned Test)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
518.1 Temperature-Humidity-Altitude	--	--	--	--	--	16[1]	16[1]	16[1]	17[1]	16[1]	16[1]	17[1]	17[1]	16[1]	16[1]
519.2 Gunfire, Vibration, Aircraft	--	--	--	--	--	17[1]	17[1]	17[1]	18[1]	17[1]	17[1]	18[1]	18[1]	17[1]	17[1]

Note 1. Test sequence is given in vertical column. A superscript adjacent to the sequence number is explained as follows:

1. Test with limited application.
2. Test recommended for missile in addition to those tests not marked with a superscript.
3. Test not generally applicable to airborne or ground launched vehicles.
4. Test not generally applicable to aircraft or helicopters.
5. Test not generally applicable to ground launched vehicles.

Note 2. Group I

A. General Base. (sheltered) and
B. General Base. (unsheltered)
All ground equipment not included in electronics and communications, or aircraft and missile support classes.

C. Aircraft and missile support. Equipment used outdoors on airfields and missile launching pads for servicing, maintenance support, checkout, etc. Electronic equipment not included.

D. Communications and electronics (sheltered) and
E. Communications and electronics (unsheltered)
Communication and electronic equipment of all types and equipment with electric circuits.

Note 3. Group II

Equipment installed in airplanes, helicopters, air launched and ground launched vehicles. See Test Method 517.2 for guidance in testing satellites and space vehicles.

a. Auxiliary power plants and power plant accessories (Primary power plants excluded.)

Note 3. Group II (continued)

b. Liquid systems. Liquid carrying or hydraulic actuated equipment.

c. Gas systems. Gas carrying or gas actuated equipment.

d. Electrical equipment. All electrical equipment but not electronic.

e. Mechanical equipment. Equipment having only mechanical operating parts.

f. Autopilots, gyros and guidance equipment, including accessories, but not electronics.

g. Instruments including indicators, electric meters, signal devices, etc., but not electronics.

h. Armament. Guns, Bombing and rocket equipment, but not electronic.

i. Photographic equipment and optical devices.

j. Electronic and communications equipment.

5. TEST METHODS

5.1 Individual methods for environmental testing follow.

6. NOTES

6.1 Worldwide climatic environmental conditions are enumerated in MIL-STD-210B, Climatic Extremes for Military Equipment. ASTM E491-73, Standard Recommended Practice for Solar Simulation for Thermal Balance Testing of Spacecraft lists specific solar simulation techniques.

6.2 International standardization agreement. Certain provisions of this standard are subject of international standardization agreement STANAG 3518 AE. When amendment, revision, or cancellation of this standard is proposed which affects or violates the international agreement concerned, the preparing activity will take appropriate reconciliation action through international standardization channels including departmental standardization offices, if required.

Custodians:
Army - EL
Navy - AS
Air Force - 11

Preparing activity:
Air Force - 11

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Army - MI, MU, ME, AV, GL, TE, MT, AT, CE
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Air Force - 10, 18, 19

International interest (see 6.1)

METHOD 500.1

LOW PRESSURE (ALTITUDE)

1. PURPOSE. The altitude test is conducted to determine the effects of reduced pressure on equipment. This method is applicable for the purpose of determining the ability of equipment to withstand reduced pressure encountered during shipment by air and for satisfactory operation under those pressure conditions found at high ground elevations.

1.1 General effects. Degrading effects may include leakage of gases or fluids from gasket-sealed enclosures and rupture of pressurized containers. Under low pressure conditions, low density materials may change their physical and chemical properties. Erratic operation or malfunction of equipment may result from arcing or corona. Greatly decreased efficiency of convection and conduction may occur as heat transfer mechanisms under low pressure conditions are encountered.

2. APPARATUS. Altitude chamber.

3. PROCEDURES

3.1 Procedure I

Step 1 - Prepare the test item in accordance with General Requirements, 3.2 and maintain standard ambient temperature during the entire test.

Step 2 - Decrease the chamber pressure to 429.1 mm of Hg (16.9 inches of Hg or 15,000 feet above sea level) at a rate not to exceed 2,000 fpm. Maintain this pressure for not less than 1 hour and then operate the test item where applicable and obtain results in accordance with General Requirements, 3.2. (If a sudden loss of pressure in the cargo compartment could cause failure of the test item which could damage the aircraft, the equipment shall also be tested to withstand an altitude of 40,000 feet, non-operating.)

Step 3 - With the test item not operating, return the chamber to standard ambient conditions at a rate not to exceed 2,000 fpm.

Step 4 - Operate and inspect the test item and obtain results in accordance with General Requirements, 3.2.

3.2 Procedure II. DISCONTINUED. (See Method 504.1, procedure I).

4. SUMMARY. The following details shall be as specified in the equipment specification:

a. Pretest data required

b. Failure criteria

c. Length of time required for operation and required measurements.

Step 9 - Return the test item, nonoperating, to standard ambient conditions and stabilize.

Step 10 - Operate and inspect the test item and obtain results in accordance with General Requirements, 3.2.

4. SUMMARY. The following details shall be as specified in the equipment specification:

a. Procedure number

b. Pretest data required

c. Failure criteria

d. Highest operating temperature at which the test item is designed to operate

e. Length of time required for operation and required measurements

f. Internal chamber temperature if other than 71°C (160°F)

g. Internal chamber temperature dwell time if other than 48 hours.

METHOD 501.1

HIGH TEMPERATURE

1. PURPOSE. The high temperature test is conducted to determine the resistance of equipment to elevated temperatures that may be encountered during service life either in storage (without protective packaging) or under service conditions.

1.1 General effects. In equipment, high temperature conditions may cause the permanent set of packings and gaskets. In items of complex construction, binding of parts may also result due to differential expansion of dissimilar materials. Rubber, plastic, and plywood may tend to discolor, crack, bulge, check, or craze. Closure and sealing strips may partially melt and adhere to contacting parts.

1.2 Procedure I is intended to approximate the exposure of equipment to a high temperature storage condition for a period of time prior to operation.

1.3 Procedure II is intended to approximate the cyclic high temperature stresses that equipment is exposed to during storage and operation.

2. APPARATUS. Temperature chamber.

3. PROCEDURES

3.1 Procedure I

Step 1 - Prepare the test item in accordance with General Requirements, 3.2.

Step 2 - Raise the internal chamber temperature to 71°C (160°F) or as specified in the equipment specification.

Step 3 - Maintain the internal chamber temperature for a period of 48 hours or as specified in the equipment specification while insuring the relative humidity is not in excess of 15 percent.

Step 4 - Adjust the internal chamber temperature to the highest operating temperature for which the test item is designed to operate and maintain until temperature stabilization of the test item is reached.

Step 5 - Operate the test item until the item is stabilized or as specified in the equipment specification, and obtain results in accordance with General Requirements, 3.2.4.

Step 6 - Return the test item, nonoperating to standard ambient condition and stabilize.

Step 7 - Operate and inspect test item and obtain results in accordance with General Requirements, 3.2.

NOTE: The rate of temperature change (steps 2, 4, and 6) may be the maximum attainable by the chamber, but shall not exceed 10°C (18°F) per minute.

3.2 Procedure II

Step 1 - Prepare the test item in accordance with General Requirements, 3.2.

Step 2 - Raise the internal chamber temperature to 49°C (120°F).

Step 3 - Maintain internal chamber temperature for 6 hours at 49°C (120°F).

Step 4 - Raise the internal chamber temperature to 71°C (160°F) within a time period of 1 hour and then maintain at that temperature for 4 additional hours.

Step 5 - Lower the internal chamber temperature to 49°C (120°F) within a time period of 1 hour.

Step 6 - Repeat steps 3, 4, and 5 two additional times (making a total of three 12-hour cycles).

Step 7 - Adjust the internal chamber temperature to the highest operating temperature under which the test item is designed to operate and maintain until temperature stabilization of the test item is reached.

Step 8 - Operate the test item until the item is stabilized or as specified in the equipment specification and obtain results in accordance with General Requirements, 3.2.

METHOD 502.1

LOW TEMPERATURE

1. PURPOSE. The low temperature test is conducted to determine the effects of low temperature on equipment during storage without protective packaging and service use.

1.1 General effects. Differential contraction of metal parts, loss of resiliency of packing and gaskets, and congealing of lubricants are a few of the difficulties associated with low temperature.

2. APPARATUS. Temperature chamber.

3. PROCEDURES

3.1 Procedure I

Step 1 - Prepare the test item in accordance with General Requirements, 3.2.

Step 2 - Lower the internal chamber temperature to the storage temperature -57°C (-70°F) or as specified in the equipment specification and maintain for a period of 24 hours after stabilization or for the period specified in the equipment specification.

Step 3 - Inspect the test item in accordance with General Requirements, 3.2.

Step 4 - Adjust the internal chamber temperature to the lowest temperature under which the test item is designed to operate as specified in the equipment specification and maintain until temperature stabilization of the test item is reached.

Step 5 - Operate the test item until the item is stabilized or for the time specified in the equipment specification and obtain results in accordance with General Requirements, 3.2.

Step 6 - Return the test item, nonoperating, to standard ambient conditions and stabilize.

Step 7 - Operate and inspect the test item and obtain the results in accordance with General Requirements, 3.2.

NOTE: The rate of temperature change (steps 2, 4, and 6) may be the maximum attainable by the chamber but shall not exceed 10°C (18°F) per minute.

4. SUMMARY. The following details shall be as specified in the equipment specification:

a. Pretest data required

b. Failure criteria

c. Storage temperature and duration if different from step 2

d. Lowest operating temperature

e. Chamber air velocity, where the heat transfer rate from the surface of the test item is important

f. Length of time required for operation and required measurements.

METHOD 503.1

TEMPERATURE SHOCK

1. PURPOSE. The temperature shock test is conducted to determine the effects on equipment of sudden changes in temperature of the surrounding atmosphere.

1.1 General effects. Adverse effects could occur in service due to rapid altitude changes during shipments and airdrops.

2. APPARATUS. A high temperature chamber and a low temperature chamber.

3. PROCEDURE

3.1 Procedure I

Step 1 - Prepare the test item in accordance with General Requirements 3.2 and raise the internal chamber temperature to 71°C (160°F). Maintain for a period of not less than 4 hours or until the test item stabilizes.

Step 2 - At the conclusion of this time period, the test item shall be transferred, within 5 minutes, to a cold chamber with an internal chamber temperature of -57°C (-70°F).

Step 3 - The test item shall be exposed to this temperature for a period of not less than 4 hours or until the test item stabilizes.

Step 4 - At the conclusion of this time period, the test item shall, within 5 minutes be returned to the high temperature chamber maintained at 71°C (160°F).

Step 5 - The test item shall be exposed to this temperature for a period of not less than 4 hours or until the test item stabilizes.

Step 6 - Repeat steps 2 through 5.

Step 7 - Repeat steps 2 and 3.

Step 8 - Return the test item to standard ambient conditions and stabilize.

Step 9 - Operate and inspect the test item and obtain results in accordance with General Requirements, 3.2.4.

NOTE: For step 2 and step 4, when authorized by the procuring activity, large or heavy test items shall be transferred from one chamber to the other in the minimum practical times.

4. SUMMARY. The following details shall be specified in the equipment specification:

a. Pretest data required

b. Failure criteria.

METHOD 504.1

TEMPERATURE-ALTITUDE

1. PURPOSE. The temperature-altitude test is conducted to determine the ability of equipment to operate satisfactorily under simultaneously applied varying conditions of low pressure and high/low temperature. The equipment category, as used in this method, is determined by the required altitude operating range and the required sea level continuous operating temperature delineated in table 504.1-I.

1.1 General effects. Deleterious effects to be anticipated include leakage of gases or fluids from sealed enclosures, rupture of pressurized containers, congealing of lubricants, cracking or rupture of materials due to contraction or expansion, short circuiting of electrical wiring and other damaging effects which might be expected from exposure to any of the above environments singly. In addition, equipment dependent on a convection type cooling system may be affected due to the reduction of efficiency of heat dissipation in less dense air.

2. APPARATUS. Temperature-altitude chamber and auxiliary thermal sensors with associated recording devices (see note (a)).

3. PROCEDURES

3.1 Procedure I. The test item shall be prepared in accordance with General Requirements, 3.2. In general, the testing schedule outlined in table 504.1-II shall be followed. However, each step in table 504.1-II represents a condition which the test item may encounter in service; therefore, each step may be applied independently of the others. For operating conditions other than those specified in table 504.1-I, the alternate temperature-altitude conditions in figures 504.1-1, 504.1-2, 504.1-3, or 504.1-4 shall be used. When changing chamber conditions from those required for one step to those required for any other step, in the sequence given in table 504.1-II or in any sequence, the rates of temperature and pressure changes may be the maximum attainable by the chamber, but these rates shall not exceed 1°C (1.8°F) per second for airborne equipment or 10°C (18°F) per minute for test equipment and 0.5 inch of mercury per second. Pressures for altitude tables are contained in U. S. Standard Atmosphere supplement, 1966.

TABLE 504.1-I. Equipment Categories for Temperature-Altitude Tests

EQUIPMENT CATEGORY	ALTITUDE RANGE (FT)	TEMPERATURE (°C)	EQUIPMENT MODE			
			OPERATING			NON-OPERATING
			CONTINUOUS	INTERMITTENT[1]	SHORT-TIME[2]	
1	Sea Level to 10,000	0 to 55	X	-	-	-
		-62 to 85	-	-	-	X[3]
2	Sea Level to 10,000	-40 to 55	X	-	-	-
		55 to 71	-	X	-	-
		-62 to 85	-	-	-	X[3]
3	Sea Level to 15,000	-40 to 55	X	-	-	-
		55 to 71	-	X	-	-
		-62 to 85	-	-	-	X
4	Sea Level to 30,000	-54 to 55	X	-	-	-
		55 to 71	-	X	-	-
		-62 to 85	-	-	-	X
5	Sea Level to 50,000	-54 to 55	X	-	-	-
		55 to 71	-	X	-	-
		-62 to 85	-	-	-	X
6	Sea Level to 70,000	-54 to 71	X	-	-	-
		71 to 95	-	X	-	-
		-62 to 95	-	-	-	X
7	Sea Level to 100,000 (95°C Continuous Sea Level Operation)	-54 to 95	X	-	-	-
		95 to 125	-	X	-	-
		125 to 150	-	-	X	-
		-62 to 125	-	-	-	X
8	Sea Level to 100,000 (125°C Continuous Sea Level Operation)	-54 to 125	X	-	-	-
		125 to 150	-	X	-	-
		150 to 260	-	-	X	-
		-62 to 150	-	-	-	X

X - Applicable equipment mode at specified temperature and altitude

Notes:

1. Thirty minutes of operation followed by a fifteen-minute de-energized period.
2. Ten minutes of operation followed by a fifteen-minute de-energized period.
3. Air transportation to 15,000 ft except where a sudden loss of pressure in the cargo compartment could cause failure of the test item which could damage the aircraft, the equipment shall also be tested to withstand an altitude of 40,000 feet, non-operating.

Step 1a - (Equipment Categories 1 & 2 only) With the test item de-energized, adjust the chamber temperature to that specified in step 1a of table 504.1-II. After the test item temperature has stabilized, the chamber pressure shall be adjusted to simulate the altitude specified in step 1a of table 504.1-II. Maintain these test conditions for at least the length of time specified in step 1a of table 504.1-II. At the conclusion of this time period the test item shall, to the extent practical, be visually inspected for the presence of deterioration which would impair future operation.

Step 1b - (All Equipment Categories) With the test item de-energized, adjust the chamber test conditions to those specified in step 1b of table 504.1-II. After the test item temperature has stabilized, maintain these test conditions for at least the length of time specified in step 1b of table 504.1-II. Where it is possible, without changing the test conditions, the test item shall be visually inspected for the presence of deterioration which would impair future operation.

Step 2 - With the test item de-energized, adjust the chamber test conditions to those specified in step 2 of table 504.1-II. These chamber test conditions shall be maintained throughout this step. After the test item temperature has stabilized, the test item shall be operated at the lowest specified input voltage (see note (b)). The test item shall operate satisfactorily immediately following the specified warmup time (see note (c)). The test item shall be de-energized and restabilized at the temperature specified in step 2 of table 504.1-II. The above operational sequence shall be repeated two additional times.

Step 3 - With the test item de-energized, adjust the chamber temperature to that specified in step 3 of table 504.1-II. The test item temperature shall be stabilized. The test item shall be energized at the highest specified input voltage (see note (d)) and the chamber pressure adjusted to simulate the altitude specified in step 3 of table 504.1-II. Upon reaching the specified chamber pressure and while maintaining the chamber temperature, the test item shall be checked for satisfactory operation and the results recorded.

Step 4 - With the test item de-energized, adjust the chamber test conditions to those specified in step 4 of table 504.1-II. After the test item temperature has stabilized, the chamber door shall be opened and frost permitted to form on the test item (see note (e)). The door shall remain open long enough for the frost to melt, but not long enough for the moisture to evaporate. The chamber door shall be closed and the test item operated at the highest specified input voltage (see note (d)) to ascertain satisfactory operation immediately following the specified warmup time. The test item shall be energized and de-energized at least three times.

Step 5 - Adjust the chamber test conditions to standard ambient conditions. After the test item temperature has stabilized; an operational and performance check of the test item shall be made and the results compared with the data obtained in General Requirements, 3.2.1, and evaluated using the failure criteria of General Requirements, 3.2.4.

Step 6 - With the test item de-energized, adjust the chamber test conditions to those specified in step 6 of table 504.1-II. The test item temperature shall be stabilized and then maintained for at least the length of time specified in step 6 of table 504.1-II. At the conclusion of this time period, where practicable, the test item shall be visually inspected for any deterioration.

Step 7 - With the test item de-energized, adjust the chamber test conditions to those specified in step 7 of table 504.1-II. After the test item temperature has stabilized and while maintaining the chamber temperature, operate the test item continuously at the highest specified input voltage (see note (d)) for the length of time specified in step 7 of table 504.1-II. Thermal sensor readings of the test item temperature shall be recorded every 30 minutes. At the end of the time period specified in step 7 of table 504.1-II, and while maintaining the test conditions, the test item shall be checked for satisfactory operation and the results recorded.

Step 8 - With the test item de-energized, adjust the chamber test conditions to those specified in step 8 of table 504.1-II and maintain until completion of the fourth operating time period. After the test item temperature has stabilized, the test item shall be operated at the highest specified input voltage (see note (d)) for four time periods each of the duration specified in step 8 of table 504.1-II. The first three time periods of operation shall be followed by a 15-minute period with the test item de-energized. The test item shall be checked for satisfactory operation during each operating time period and the results recorded. Thermal sensor readings of the test item temperature shall be recorded every 10 minutes of test item operation.

Step 9 - With the test item de-energized, adjust the chamber test conditions to those specified in step 9 of table 504.1-II and maintain until completion of the fourth operating time period. After the test item temperature has stabilized, the test item shall be operated at the highest specified input voltage (see note (d)) for four time periods each of the duration specified in step 9 of table 504.1-II. The first three periods of operation shall be followed by a 15-minute period with the test item de-energized. The test item shall be checked for satisfactory operation during each operating time period and the results recorded. Thermal sensor readings of the test item temperature shall be recorded at the beginning and end of each operating time period.

Step 10 - With the test item de-energized, adjust the chamber temperature to that specified in step 10 of table 504.1-II. The test item temperature shall be stabilized. The test item shall be operated at the highest specified input voltage (see note (d)) and the chamber pressure adjusted to simulate the altitude specified in step 10 of table 504.1-II. Maintain these test conditions for the length of time specified in step 10 of table 504.1-II. Thermal sensor readings of the test item temperature shall be recorded every 30 minutes. At the end of the time period specified in step 10 of table 504.1-II, and while maintaining the test conditions, the test item shall be checked for satisfactory operation and the results recorded.

Step 11 - With the test item de-energized, adjust the chamber temperature to that specified in step 11 of table 504.1-II (see note (f)), and maintain until completion of the fourth operating time period. The test item temperature shall be stabilized. The test item shall be energized at the highest specified input voltage (see note (d)) and the chamber pressure adjusted to simulate the altitude specified in step 11 of table 504.1-II. The test item shall be operated for four time periods each of the duration specified in step 11 of table 504.1-II. The first three time periods of operation shall be followed by a 15-minute period with the test item de-energized. The test item shall be checked for satisfactory operation during each operating time period and the results recorded. Thermal sensor readings of the test item temperature shall be recorded every 10 minutes of test item operation.

Step 12 - With the test item de-energized, adjust the chamber temperature to that specified in step 12 of table 504.1-II (see note (f)). The test item temperature shall be stabilized. The test item shall then be energized at the highest specified input voltage (see note (d)) and the chamber pressure adjusted to simulate the altitude specified in step 12 of table 504.1-II. Maintain these test conditions for the length of time specified in step 12 of table 504.1-II. Thermal sensor readings of the test item temperature shall be recorded every 30 minutes. At the end of the time period specified in step 12 or table 504.1-II, and while maintaining the test conditions, the test item shall be checked for satisfactory operation and the results recorded.

Step 13 - With the test item de-energized, adjust the chamber temperature to that specified in step 13 of table 504.1-II (see note (f)), and maintain until completion of the fourth operating time period. The test item temperature shall be stabilized. The test item shall be energized at the highest specified input voltage (see note (d)) and the chamber pressure adjusted to simulate the altitude specified in step 13 of table 504.1-II. The test item shall be operated for four time periods as specified in step 13 of table 504.1-II. The first three time periods of operation shall be followed by a 15-minute period with the test item de-energized. The test item shall be checked for satisfactory operation during each operating time period and the results recorded. Thermal sensor readings shall be recorded every 10 minutes of test item operation.

Step 14 - With the test item de-energized, adjust the chamber temperature to that specified in step 14 of table 504.1-II (see note (f)), and maintain until completion of the fourth operating time period. The test item temperature shall be stabilized. The test item shall be energized at the highest specified input voltage (see note (d)) and the chamber pressure adjusted to simulate the altitude specified in step 14 of table 504.1-II. The test item shall be operated four time periods each of the duration specified in step 14 of table 504.1-II, and shall be followed by a 15-minute period with the test item de-energized. The test item shall be checked for satisfactory operation during each operating time period and the results recorded. Thermal sensor readings of the test item temperature shall be recorded at the beginning and end of each operating time period.

Step 15 - Adjust the chamber test conditions to standard ambient conditions. After the test item temperature has stabilized, an operational and performance check of the test item shall be made and the results compared with the data obtained in General Requirements, 3.2.1, and evaluated using the criteria of General Requirements 3.2.4.

Notes:

a. The following guidelines are provided for consideration when determining location of thermal sensors used to monitor the test items:

   (1) One or more sensors in the ambient air within each major unit.

   (2) Contact temperature on the largest mass in each major unit.

   (3) Contact temperature on the part(s) where the highest surface temperature is expected.

   (4) Contact temperature on the part(s) whose temperature is likely to limit equipment performance.

b. For equipment other than electronic equipment, the input conditions shall be such as to produce the minimum internal physical stress.

c. All characteristics which are likely to be affected by low temperatures shall be checked first. Should the time required to check the test item exceed 15 minutes beyond the warmup time, the test item shall again be stabilized at the temperature specified for step 2 in table 504.1-II and the operational check continued.

d. For equipment other than electronic equipment, the input conditions shall be such as to produce the maximum internal physical stress.

e. When the chamber door is opened it is intended that frost will form; however, should the relative humidity of the air be such that frost will not form, an artificial means shall be used to provide the relative humidity necessary to have frost form.

f. Following those steps where a change in temperature at low pressure is required, the pressure may be increased to ambient before changing the temperature and then returned to the required pressure following temperature stabilization.

4. SUMMARY. The following details shall be as specified in the equipment specifications:

a. Pretest data required

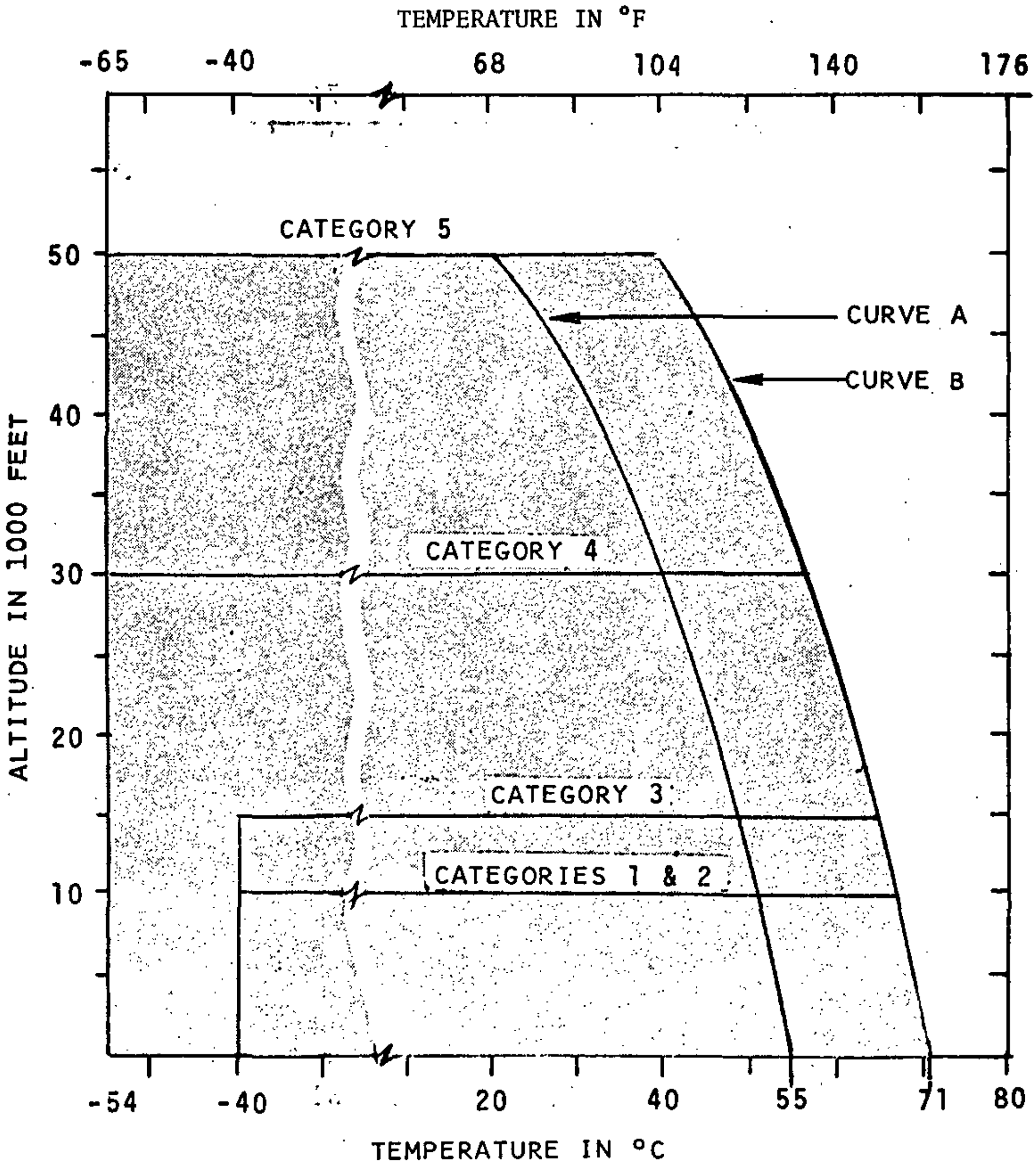
b. Pertinent equipment operation parameters limits (input voltage, etc.)

c. Failure criteria.

TABLE 504.1-II. Test Conditions for Temperature-Altitude Tests

CATEGORY	STEP	1a	1b	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Temp (°C) ALT (FT) TIME	25 40,000 1 HR	-62 SITE 2 HR	0 SITE ----	0 10,000 ---	OMIT	Standard Ambient Conditions	85 SITE 16 HR	55 SITE 4 HR	OMIT	OMIT	52 10,000 4 HR	OMIT	OMIT	OMIT	OMIT	Standard Ambient Conditions
2	TEMP (°C) ALT (FT) TIME	25 40,000 1 HR	-62 SITE 2 HR	-40 SITE ---	-40 10,000 ---	-10 SITE ---		85 SITE 16 HR	55 SITE 4 HR	71 SITE 20 MIN	OMIT	52 10,000 4 HR	68 10,000 20 MIN	OMIT	OMIT	OMIT	
3	TEMP (°C) ALT (FT) TIME	OMIT	-62 SITE 2 HR	-40 SITE ---	-40 15,000 ---	-10 SITE ---		85 SITE 16 HR	55 SITE 4 HR	71 SITE 20 MIN	OMIT	49 15,000 4 HR	65 15,000 20 MIN	OMIT	OMIT	OMIT	
4	TEMP (°C) ALT (FT) TIME	OMIT	-62 SITE 2 HR	-54 SITE ---	-54 30,000 ---	-10 SITE ---		85 SITE 16 HR	55 SITE 4 HR	71 SITE 30 MIN	OMIT	48 20,000 4 HR	64 20,000 30 MIN	40 30,000 4 HR	57 30,000 30 MIN	OMIT	
5	TEMP (°C) ALT (FT) TIME	OMIT	-62 SITE 2HR	-54 SITE ---	-54 50,000 ---	-10 SITE ---		85 SITE 16 HR	55 SITE 4 HR	71 SITE 30 MIN	OMIT	30 40,000 4 HR	47 40,000 30 MIN	20 50,000 4 HR	35 50,000 30 MIN	OMIT	
6	TEMP (°C) ALT (FT) TIME	OMIT	-62 SITE 2 HR	-54 SITE ---	-54 70,000 ---	-10 SITE ---		95 SITE 16 HR	71 SITE 4 HR	95 SITE 30 MIN	OMIT	36 50,000 4 HR	60 50,000 30 MIN	10 70,000 4 HR	35 70,000 30 MIN	OMIT	
7	TEMP (°C) ALT (FT) TIME	OMIT	-62 SITE 2 HR	-54 SITE ---	-54 80,000 ---	-10 SITE ---		125 SITE 16 HR	95 SITE 4 HR	125 SITE 30 MIN	150 SITE 10 MIN	60 50,000 4 HR	90 50,000 30 MIN	-10 100,000 4 HR	20 100,000 30 MIN	45 100,000 10 MIN	
8	TEMP (°C) ALT (FT) TIME	OMIT	-62 SITE 2 HR	-54 SITE ---	-54 80,000 ---	-15 SITE ---		150 SITE 16 HR	125 SITE 4 HR	150 SITE 30 MIN	260 SITE 10 MIN	90 50,000 4 HR	115 50,000 30 MIN	25 100,000 4 HR	50 100,000 30 MIN	155 100,000 10 MIN	

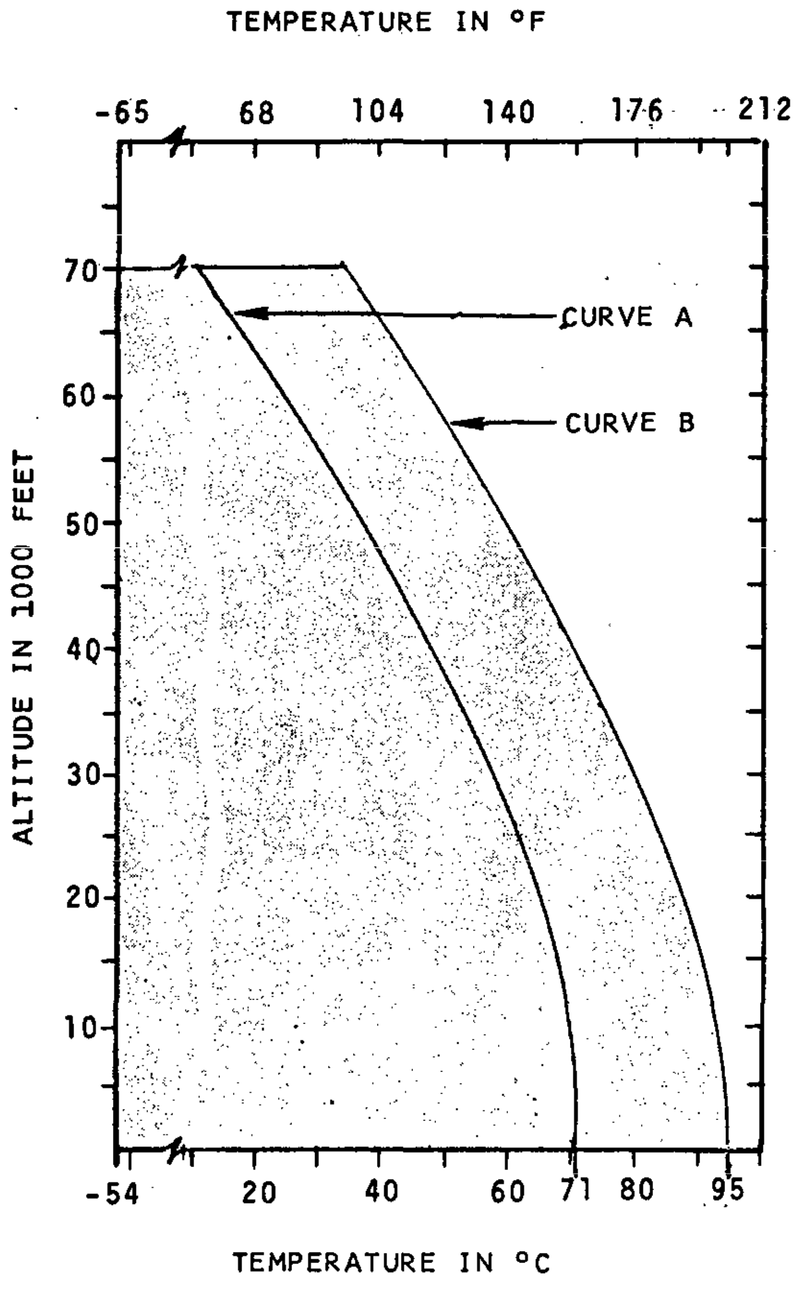
SITE - Altitude of test facility.



NOTES:

1. *Curve A - Design and Test Requirements for continuous operation.*
2. *Curve B - Design and Test Requirements for intermittent operation.*
3. *Operating requirements for Category 1 equipment are for continuous operation with temperature extremes of 0°C and 55°C.*

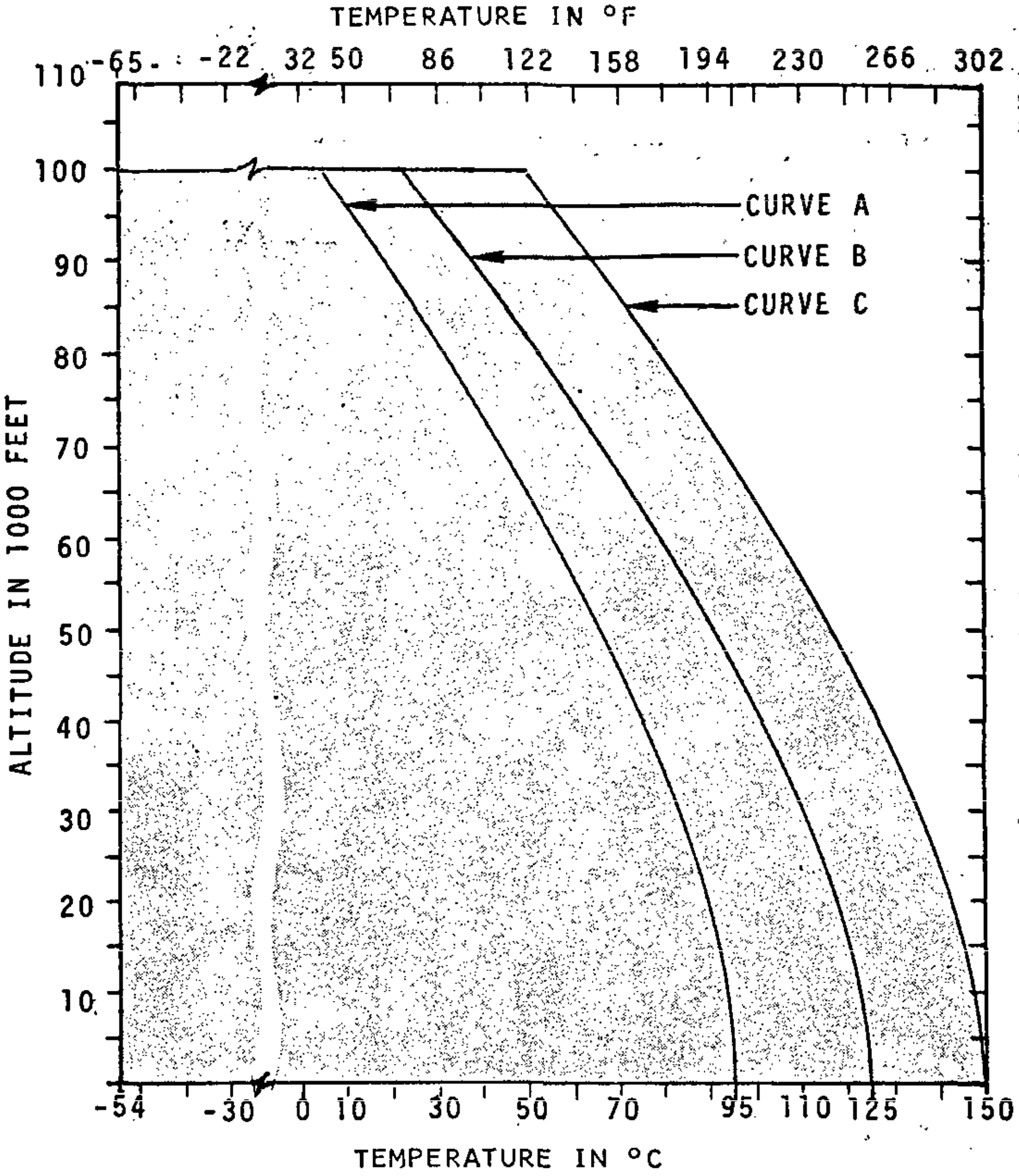
FIGURE 504.1-1 Temperature Versus Altitude Operational Requirements for Categories 1 through 5 Equipment.



NOTES:

1. *Curve A - Design and test requirements for continuous operation.*
2. *Curve B - Design and test requirements for intermittent operation.*

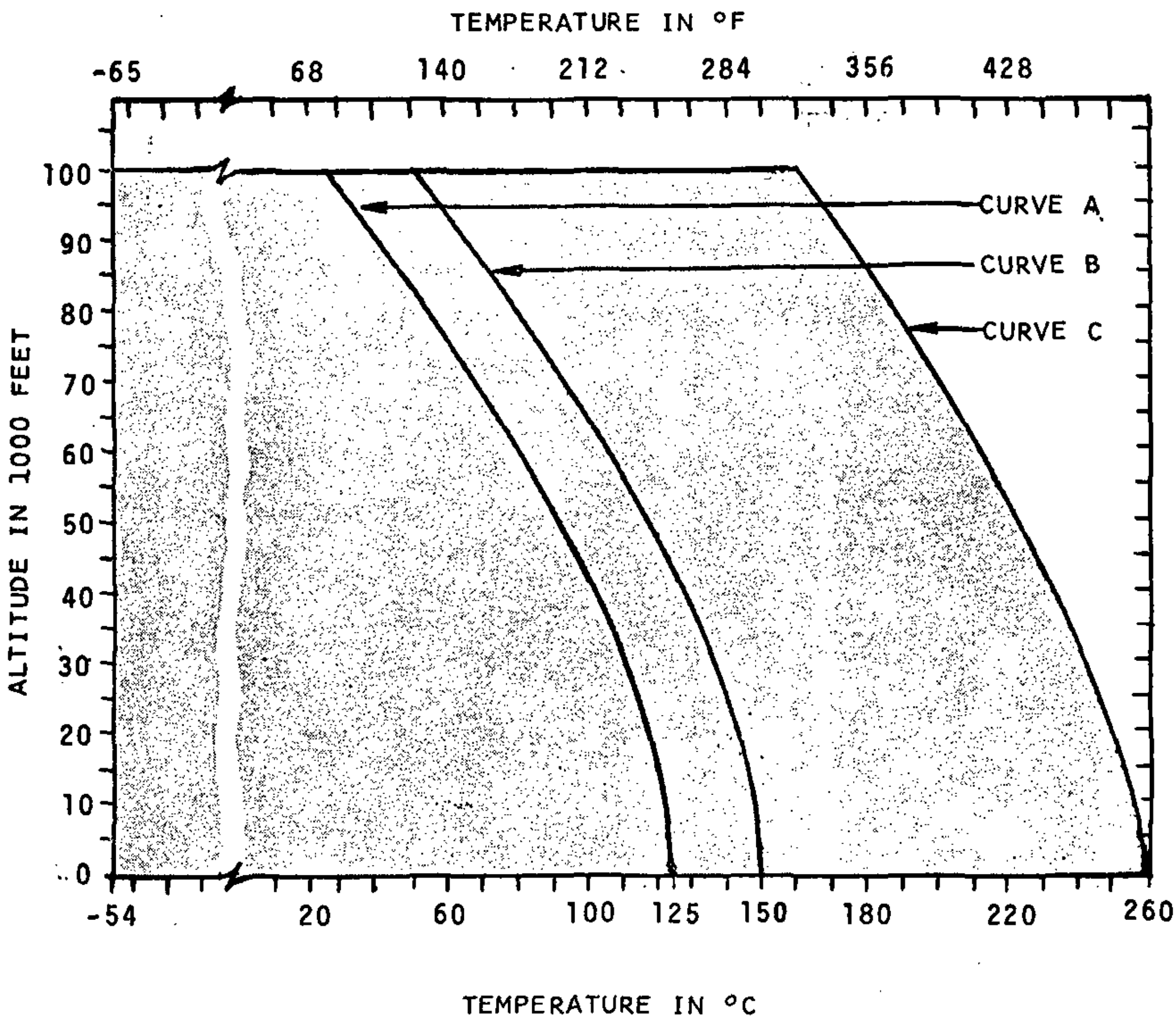
FIGURE 504.1-2 Temperature Versus Altitude Operational Requirements for Category 6 Equipment.



NOTES:

1. *Curve A - Design and test requirements for continuous operation of equipment designed to operate at 95°C at sea level.*
2. *Curve B - Design and test requirements for intermittent operation of equipment designed to operate continuously at 95°C at sea level.*
3. *Curve C - Design and test requirements for short time operation of equipment designed to operate continuously at 95°C at sea level.*

FIGURE 504.1-3 Temperature Versus Altitude Operational Requirements for Category 7 Equipment.



NOTES:

1. *Curve A - Design and test requirements for continuous operation of equipment designed to operate at 125°C at sea level.*
2. *Curve B - Design and test requirements for intermittent operation of equipment designed to operate continuously at 125°C at sea level.*
3. *Curve C - Design and test requirements for short time operation of equipment designed to operate continuously at 125°C at sea level.*

FIGURE 504.1-4 Temperature Versus Altitude Operational Requirements for Category 8 Equipment.

METHOD 505.1

SOLAR RADIATION (SUNSHINE)

1. PURPOSE. The sunshine test is conducted to determine the effect of solar radiation energy on equipment in the Earth's atmosphere. For the purpose of this test, only the terrestrial portion of the solar spectrum is considered. The limits and energy levels specified herein provide the simulated effects of natural sunshine. The ultraviolet portion simulates natural sunshine in a general way and is considered to be representative of irradiation in most geographical locations. The sunshine tests are applicable to equipment which may be exposed to solar radiation during service or unsheltered storage at the Earth's surface or in the lower atmosphere.

1.1 General effects. Heating effects may cause bending, differential expansion, bulging, cracking, crazing, softening and melting, overheating, binding, permanent set of gaskets, etc. Degradation from spectral energy input is manifested as fading of fabric colors, checking of paints and deterioration of natural rubber and plastics.

1.2 Procedure I. Accelerated steady state, solar radiation test; equipment nonoperating.

1.3 Procedure II. Accelerated cycling temperature and solar radiation test. This procedure is intended to simulate natural cycling temperature and solar radiation conditions. It is used either for evaluating heating effects on a real time basis, or for determining the temperature equipment reaches under the severest required conditions.

2. APPARATUS. Solar radiation chamber.

2.1 Chamber. The test chamber volume shall be a minimum of ten times that of the volume of the envelope volume of the test item. The chamber's simulated solar radiation source area shall be a minimum of 125 percent of the horizontal area projection of the test item.

2.2 Solar radiation source. For the purposes of this test, the following spectral distribution of solar radiation is acceptable: 50 to 72 watts/ft^2 of infrared (of wavelengths above 7,800 angstrom units), 4 to 7 watts/ft^2 of ultraviolet (of wavelengths below 3,800 angstrom units), and the balance visible. The radiation source shall be located at least 30 inches away from any outer surface of the test item. (Lamp vendor's spectral distribution curves may be used in establishing the spectral distribution within the above specified limits. U. S. Bureau of Standards traceability of this vendor data is waived).

2.2.1 Lamps. Tests which are conducted for degradation and deterioration of materials, as well as heat buildup within the test item, may use one of the following acceptable radiation sources:

a. Mercury vapor lamps (internal reflector type only)

b. Combination of incandescent spot lamps (including infrared filters) together with tubular type mercury vapor lamps with external reflectors

c. Combination of incandescent spot lamps (including infrared filters) together with mercury vapor lamps with internal reflectors

d. Carbon arc lamps with suitable reflectors

e. Mercury xenon arc lamps with suitable reflectors

f. Mercury vapor and lucolux lamps with suitable reflectors, or

g. Multivapor lamps with suitable reflectors.

This list is not intended to exclude new lamps available by advanced technology.

2.2.2 Tests which are conducted only for heat buildup within the test item may use infrared lamps of the incandescent type or other radiant heating source approved by the procuring activity.

2.3 Solar radiation measurement. Solar radiation intensity shall be measured with a pyranometer in accordance with General Requirements, 3.1.3.

3. PROCEDURES

3.1 Procedure I. Accelerated steady state, solar radiation test, equipment nonoperating. The test item shall be placed in the test chamber in accordance with General Requirements, 3.2.2, and exposed to radiant energy at the rate of 104 ±4 watts per square foot (355 ±14 BTU per square foot per hour) or as specified in the equipment specification. The period of the test shall be 48 hours (or longer if specified in the equipment specification) during which time the chamber temperature shall be maintained at 49 ±2°C (120°F). At the conclusion of the exposure period, and with the chamber temperature maintained as specified, the test item shall be operated and the results obtained in accordance with General Requirements, 3.2. The test item shall then be returned to room temperature, inspected, and results obtained in accordance with General Requirements, 3.2.

3.2 Procedure II. Accelerated cycling temperature and solar radiation test. The test item shall be prepared in accordance with General Requirements, 3.2. Raise the chamber air temperature to 32°C (90°F). The test item shall then be exposed to three continuous 24-hour cycles of controlled simulated solar radiation and dry bulb temperature as indicated in figure 505.1-1 or as specified in the equipment specification. Tolerances for control of radiation shall be ±5 watts/ft^2. Tolerances for air temperature control shall be ±2°C (±3.6°F). At the beginning and end of each test cycle, the chamber relative humidity (uncontrolled) shall be less than 40 percent. The air velocity in the chamber shall be maintained within 3 to 6 knots (300 to 600 ft/min). When specified in the equipment specification, at 1,500 hours of the third cycle (or at the approximate point of peak test item temperature), the test item shall be operated for 1 hour and results shall be obtained in accordance with General Requirements, 3.2. At the conclusion of the last exposure, the test item shall be removed from the chamber and operated and inspected and results obtained in accordance with General Requirements, 3.2. If the test item is operated during the test, it shall be returned to room ambient before the final operation; otherwise the final operation shall be performed as soon as the test item is removed from the chamber.

NOTE: The test item may or may not be operated throughout the test at the option of the equipment specification. When evaluation of heating effects is important, operation at least at peak temperature should be specified. For certain one-shot items (e.g., rockets) thermocouples affixed to critical portions of the test item should be used to determine time and value of peak temperature. The time of operation shall coincide with peak temperature.

4. SUMMARY. The following details shall be as specified in the equipment specification.

a. Procedure number

b. Pretest data required

c. Failure criteria

d. Number of cycles if other than three (Procedure II)

e. Temperature and solar radiation intensity, if other than given in procedure I or procedure II

f. Indicate the operation and inspection required of the test item or to be performed (if any) on the test item during the test cycles, including the start and duration of each indicated operation or inspection of the test item.

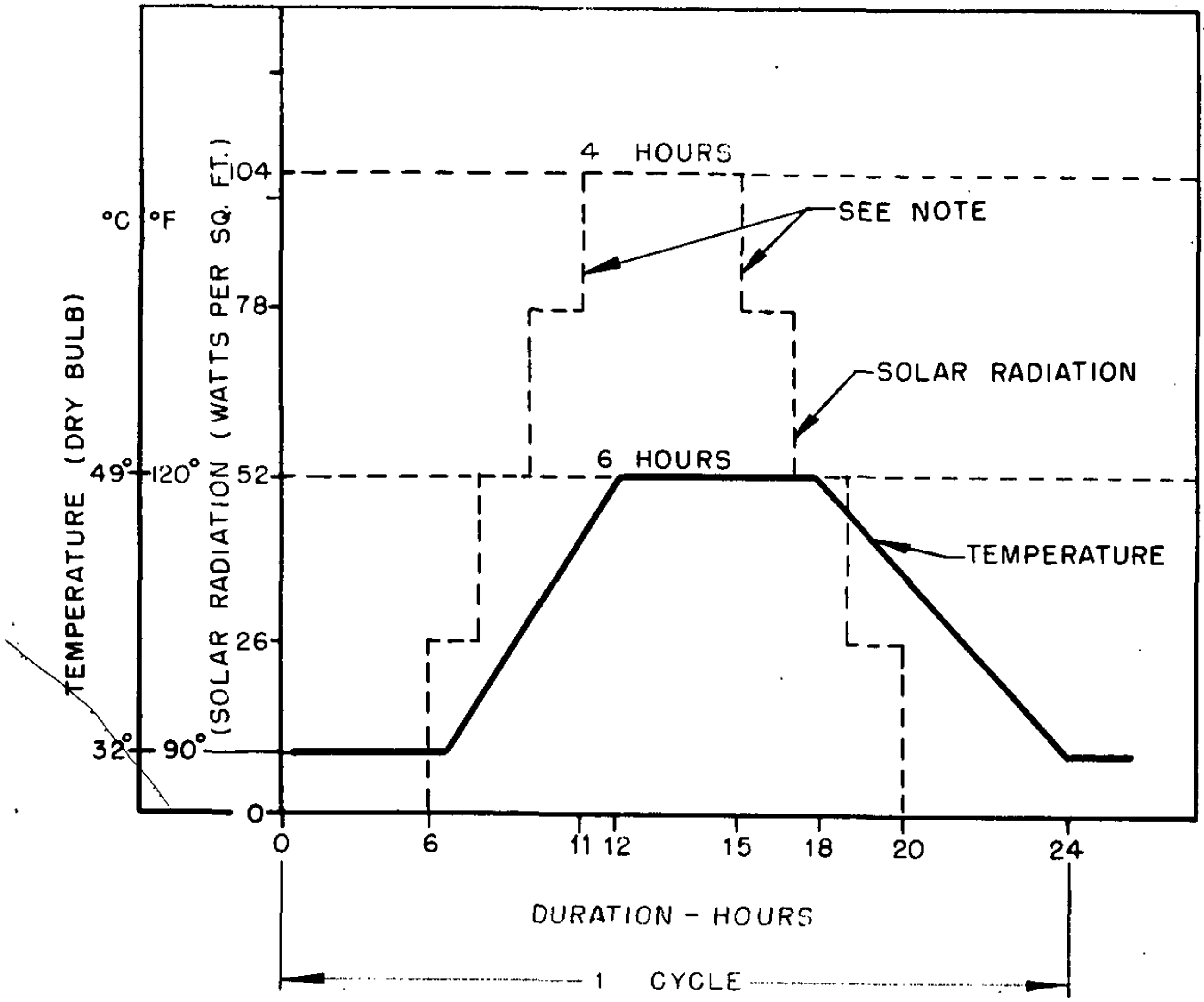


Figure 505.1-1. Accelerated Solar Radiation Cycle (Procedure II)

METHOD 506.1

RAIN

1. PURPOSE. The rain test is conducted to determine the effectiveness of protective covers or cases to shield equipment from rain. This test is applicable to equipment which may be exposed to rain under service conditions. Where a requirement exists for determining the effects of rain erosion on radomes, nose cones, etc., a rocket sled test facility or other such facility should be considered. Since any test procedure evolved would be contingent on requirements peculiar to the test item and the facility employed, a standardized test procedure for rain erosion is not included in this test method.

2. APPARATUS

2.1 Procedure I. Rain chamber with wind source.

2.2 Procedure II. Rain chamber.

2.3 Chamber. The rain chamber shall have the capability of producing falling rain and for procedure I a facility for producing wind blowing at the rates specified herein. The chamber temperature shall be uncontrolled, except as regulated by water introduced as rain, throughout the test period. The rain shall be produced by a water distribution device of such design that the water is emitted in the form of droplets having a diameter range between 0.5 and 4.5 millimeters. The temperature of the water shall be between 11° and 35°C (52° and 95°F). The water distribution shall be such that, with the wind source turned off, the rain is dispersed completely over the test item and an additional test area to accomplish the wind blown rain effects on the equipment. The wind source shall be so positioned with respect to the test item that it will cause the rain to beat directly, with variations up to 45° from the horizontal, and uniformly against one side of the test item. The wind source shall be capable of producing horizontal wind velocities up to 40 miles per hour. The wind velocity shall be measured at the position of the test item, prior to placement of the item in the chamber. No rust or corrosive contaminants shall be imposed on the test item by the test facility.

(A recommended method of measuring raindrop size is the flour pellet method as referenced in "The Relation of Raindrop Size to Intensity" by Laws and Parsons, Transactions of the American Geophysical Union, Part II, pps 452 to 459, -1943).

3. PROCEDURES

3.1 Procedure I (cycling). The procedure is intended for evaluating equipment used outdoors under blowing rain conditions. The test item shall be placed in the chamber in its normal operation position in accordance with General Requirements, 3.2. The test item shall be exposed to a simulated rain at a rate of 2 ±0.5 inches per hour for 10 minutes. The rate of rainfall shall then be raised to 5 ±1 inches per hour and held at this rate for 5 minutes. The rate shall then be reduced to 2 ±0.5 inches per hour for the next 15 minutes. Starting 5 minutes after the initiation of the rain, the wind source shall be turned on and adjusted to produce a horizontal wind velocity of 40 miles per hour (3,500 feet per minute). The wind source shall be maintained at this velocity for 15 minutes after which the wind source shall be turned off.

NOTE: If specified in the equipment specification, the test item shall be operated during the last 10 minutes of the 30-minute rain. Each of the sides of the test item that could be exposed to blown rain shall be subjected to the rain for a period of not less than 30 minutes, for a total test duration of not less than 2 hours. At the conclusion of the test period, the test item shall be removed from the test chamber, operated, inspected, and results obtained in accordance with General Requirements, 3.2. The protective cover or case shall, where possible, then be removed and the test item inspected for compliance with General Requirements, 3.2.

3.2 Procedure II, For simulation of steady-state rainfall.

Step 1 - Place the test item in the chamber in accordance with General Requirements, 3.2.2 and orient in such a manner as to allow impingement of the rain on the item normal (90°) to its horizontal plane.

Step 2 - Produce a simulated falling rain in the test chamber stabilized at a constant rate of 2 ±0.5 inches per hour.

Step 3 - Reorient the test item to an angle of 45° from the horizontal plane of step 1 and index the item around its center axis periodically to allow exposure to rainfall of all the significant surfaces of the test item.

Step 4 - Expose the test item to the simulated falling rain for a total time of not less than 2 hours, which shall represent the sum of equal exposure periods in the orientation modes of steps 1 and 3.

Step 5 - If specified in the equipment specification, execute performance checks on the test item during exposure to the rain as prescribed in General Requirements, 3.2.3.

Step 6 - At the conclusion of the rain exposure, remove the test item from the chamber, sponge or lightly wipe accumulated moisture from its exterior surfaces, open its case or protective covers, if possible, and visually inspect the test item for compliance with General Requirements, 3.2.6.

Step 7 - Upon completion of the step 6 visual inspection, perform operational checks on the test item and obtain results in accordance with General Requirements, 3.2.

4. SUMMARY. The following details shall be as specified in the equipment specification:

a. Procedure number

b. Pretest data required

c. Failure criteria

d. Whether equipment is to operate during rain and length of time required for operation and measurements.

METHOD 507.1

HUMIDITY

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

1.1 General effects. Corrosion is one of the principal effects of humidity. Hygroscopic materials are sensitive to moisture and may deteriorate rapidly under humid conditions. Absorption of moisture by many materials results in swelling, which destroys their functional utility and causes loss of physical strength and changes in other important mechanical properties. Insulating materials which absorb moisture may suffer degradation of their electrical and thermal properties. Cycling temperature and humidity may cause condensation of moisture inside of the equipment which could cause the equipment to malfunction due to electrical shorts or cause binding due to corrosion or fouling of lubricants between moving parts.

2. APPARATUS. Humidity-temperature chamber and associated equipment.

2.1 Chamber. The chamber and accessories shall be constructed and arranged in such a manner as to avoid condensate dripping on the test item. The chamber shall be trap-vented to the atmosphere to prevent the buildup of total pressure. Relative humidity shall be determined from the dry bulb-wet bulb thermometer comparison method or an equivalent method approved by the procuring activity. When readout charts are used, they shall be capable of being read with a resolution within 0.6°C (1°F). When the wet bulb control method is used, the wet bulb and tank shall be cleaned and a new wick installed at least every 30 days. The air velocity flowing across the wet bulb shall be not less than 900 feet per minute. Provisions shall be made for controlling the flow of air throughout the internal chamber test space where the velocity of air shall not exceed 150 feet per minute. Steam or distilled, demineralized, or deionized water having a pH value between 6.0 and 7.2 at 23°C (73°F) shall be used to obtain the specified humidity. No rust or corrosive contaminants shall be imposed on the test item by the test facility.

3. PROCEDURES

3.1 Procedure I. Airborne electronic equipment.

Step 1 - Prepare the test item in accordance with General Requirements, 3.2. Prior to starting the test, the internal chamber temperature shall be at standard ambient with uncontrolled humidity.

Step 2 - Gradually raise internal chamber temperature to 65°C (149°F) and the relative humidity to 95 +5 -3 percent over a period of 2 hours.

Step 3 - Maintain conditions of step 2 for not less than 6 hours.

Step 4 - Maintain 85 percent, or greater, relative humidity and reduce internal chamber temperature in 16 hours to 30°C (86°F).

Step 5 - Repeat steps 2, 3, and 4 for a total of 10 cycles (not less than 240 hours). Figure 507.1-1 is an outline of the humidity cycle for this procedure.

Step 6 - At the end of the tenth cycle, while still at 30°C (86°F) and 85 percent relative humidity, operate the test item and obtain results in accordance with General Requirements, 3.2.

Step 7 - Remove and inspect the test item and obtain results in accordance with General Requirements, 3.2.

3.2 Procedure II. Ground and airborne electronic equipment.

Step 1 - Prepare the test item in accordance with General Requirements, 3.2, except that initial measurements are taken in step 4.

Step 2 - Dry the test item at 54°C (129°F) for 24 hours.

Step 3 - Condition the test item at 23°C (73°F) and 50 ±10 percent relative humidity for 24 hours.

Step 4 - Take initial measurements in accordance with General Requirements, 3.2.1

NOTE: The test item may be readjusted or realigned, as necessary, to meet specification requirements. No further realignment or readjustment shall be permitted throughout the test period, other than with accessible controls employed for operation of the test item. No repair or replacement of parts shall be permitted. Equipment shall be operated only when specified test measurements are being performed.

Step 5 - Raise the internal chamber temperature to 30°C (86°F) and the relative humidity to 94 ±4 percent.

Step 6 - Subject the test item to five continuous 48-hour cycles in accordance with figure 507.1-2. Take measurements in accordance with General Requirements, 3.2.3 at the periods shown on figure 507.1-2, unless otherwise specified in the equipment specification. Prior to measurements, accumulated moisture may be removed by turning the test item upside down or shaking. Wiping is not permitted. (Certain operating procedures require an effective preconditioning of the test item environment prior to operation. When this occurs, the period of measurement shall be kept as short as possible.)

Step 7 - After completion of step 6 cycling, condition the test item for 24 hours at 23°C (73°F) and 50 ±10 percent relative humidity.

Step 8 - Operate the test item, adjusting for optimum performance only as permitted in step 4 note, and compare with data obtained in step 4.

Step 9 - Inspect the test item in accordance with General Requirements, 3.2.4 within an hour.

3.3 Procedure III. Ground and airborne sealed electronic equipment (other than hermetic sealed).

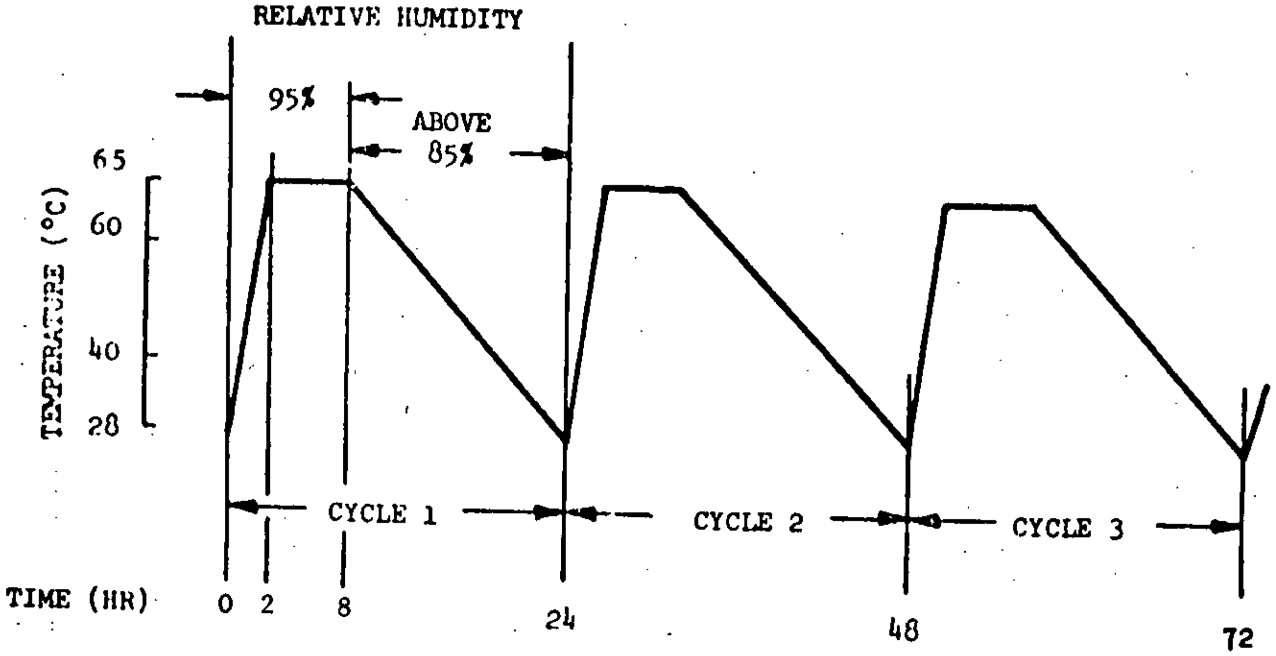
Step 1 - Prepare the test item in accordance with General Requirements, 3.2.

Step 2 - Dry the test item at 54°C (129°F) for 24 hours.

Step 3 - Condition the test item at 23°C (73°F) and 50 ±10 percent relative humidity for 24 hours.

Step 4 - Take initial measurements in accordance with General Requirements, 3.2.1.

NOTE: The test item may be realigned or readjusted as necessary to meet specification requirements. No further realignment or readjustment shall be



CONTINUE FOR A TOTAL OF 10 CYCLES (240 HR)

FIGURE 507.1-1. Humidity Cycle - Procedure I

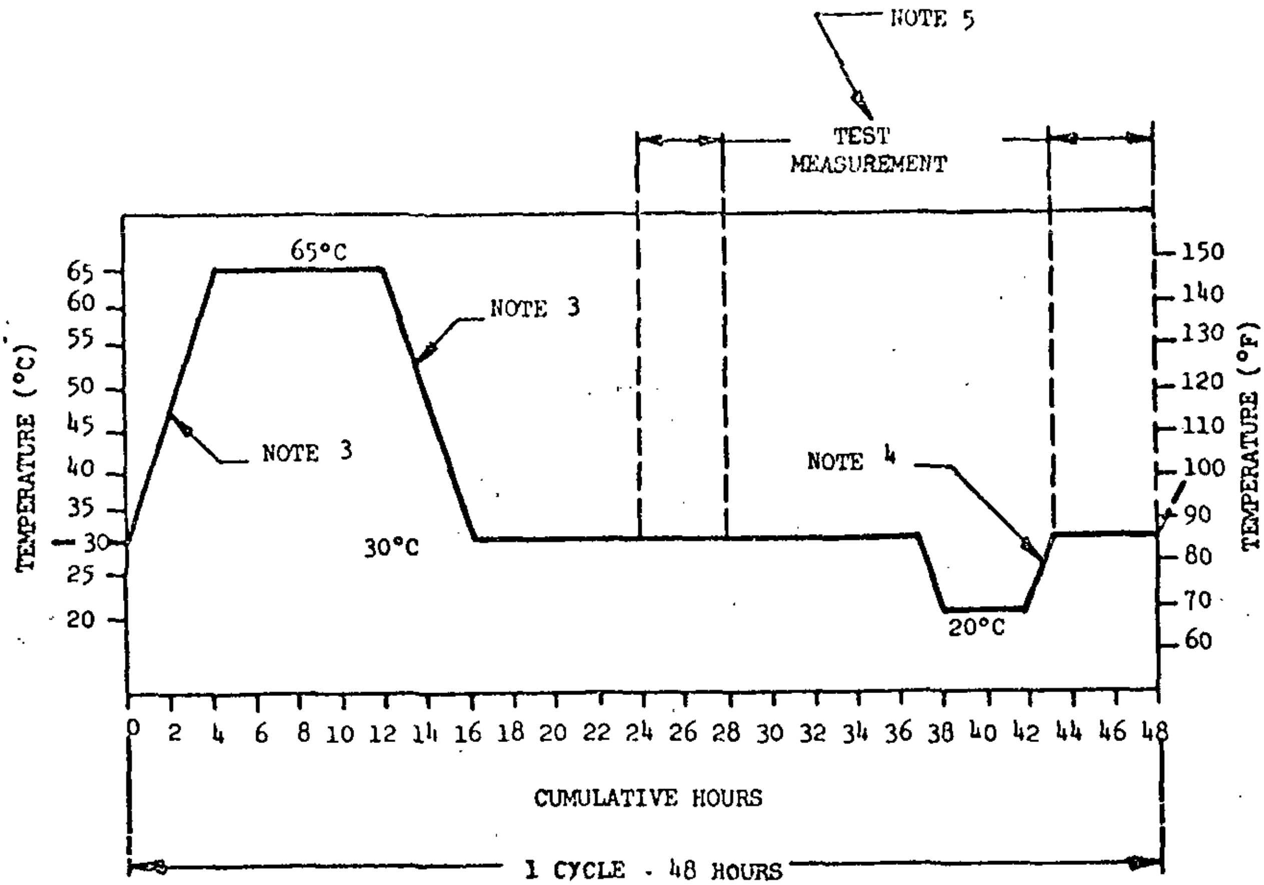


FIGURE 507.1-2. Humidity Cycle Procedures II and III

NOTES:

1. Tolerance during temperature change shall be not greater than 3°C (5°F).

2. Relative humidity shall be maintained at 94 ±4 percent at all times, except that during the descending temperature period, the relative humidity may be permitted to drop as low as 85 percent.

3. Rate of temperature change between 30° and 65°C (86° and 149°F) shall be not less than 8°C (14.4°F) per hour.

4. The temperature increase in this portion of the curve shall be not less than 10°C (18°F).

5. Test measurements shall be taken only at the period specified in the applicable equipment or system specification.

permitted throughout the test period other than with accessible controls employed for operation of the test item. No repair or replacement of parts shall be permitted. Equipment shall not be operated, except when specified test measurements are being performed.

Step 5 - Raise the internal chamber temperature to 30°C (86°F) and the relative humidity to 94 ±4 percent.

Step 6 - Subject the test item to five continuous 48-hour cycles in accordance with figure 507.1-2. The relative humidity shall be maintained at 94 ±4 percent at all times. Take measurements in accordance with General Requirements, 3.2.3 at the periods shown on figure 507.1-2 unless otherwise specified in the equipment specification. Prior to measurements, accumulated moisture may be removed by turning the test item upside down or shaking. Wiping is not permitted. (Certain operating procedures require an effective preconditioning of the test item environment prior to operation. When this occurs, the period of measurement shall be kept as short as possible.)

Step 7 - After completion of the step 6 cycling, open the test item and remove the chassis from its enclosure, in the test chamber.

Step 8 - Maintain the internal test chamber temperature at 30°C (86°F) with the relative humidity at 94 ±4 percent for 480 hours. During the last 5 hours of exposure, take measurements as specified in the equipment specification. Additional measurements may be made at the end of each 24-hour period, if so specified in the equipment specification. Prior to measurements, accumulated moisture may be removed by turning the test item upside down or shaking. Wiping is not permitted. For electronic equipment, if removal of the test chassis from its enclosure will, of itself, adversely affect the operation of the test item, the test item may be replaced in its enclosure for measurements.

Step 9 - After completion of the 480-hour test, condition the test item at 23°C (73°F) and 50 ±10 percent relative humidity for 24 hours.

Step 10 - Adjust the test item to optimum performance only as permitted in the step 4 note.

Step 11 - Operate and inspect the test item, and obtain results in accordance with General Requirements, 3.2, within 1 hour.

3.4 Procedure IV. Ground fire control and shipboard equipment.

Step 1 - Prepare the test item in accordance with General Requirements 3.2.

Step 2 - Dry the test item at a temperature of not less than 40°C (104°F) nor more than 50°C (122°F) for not less than 2 hours.

Step 3 - Condition the test item at 25° ±5°C (77° ±9°F) and 50 percent relative humidity for 24 hours.

Step 4 - Take initial measurements as specified in the equipment specification in accordance with General Requirements, 3.2.

NOTE: The test item may be readjusted or realigned as necessary to conform to the equipment specification requirements. No further realignment or readjustment shall be permitted throughout the test period other than with accessible controls, external to the test item, employed for operation of the test item. If repairs, replacement of parts, or adjustments other than by the accessible external controls are made at any time prior to completion of the measurements required at the end of the fifth cycle, all five of the 24-hour cycles shall be repeated. Repairs include any change to the test item that is not made by use of the accessible controls external to the test item. The test item shall only be operated when specified test measurements are being performed.

Step 5 - Subject the test item to five 24-hour cycles in accordance with figure 507.1-3. A 24-hour cycle consists of 16 hours at 60° ±5°C (140° ±9°F) and approximately 8 hours at 30° ±5°C (86° ±9°F) (includes transition times). The relative humidity shall be maintained at 95 percent, or greater, at both temperatures. Each transition time between 30° ±5°C (86° ±9°F) and 60° ±5°C (140° ±9°F) shall be not greater than 1-1/2 hours. The relative humidity during each transition need not be controlled. Approximately 2 hours after stabilization during the high temperature and low temperature portions of the first or second cycle, a sampling of the atmosphere in the chamber shall be made to determine that the conditions of temperature and relative humidity are uniform throughout the chamber.

Measurements as specified in the equipment specification shall be made during the second cycle at 60° ±5°C (140° ±9°F) immediately prior to decreasing to 30° ±5°C (86° ±9°F).

The test item shall be energized only a sufficient time to allow the required warmup and measurements specified in the equipment specification.

Step 6 - After completion of the fifth cycle with the test item in the chamber and the chamber at 30° ±5°C (86° ±9°F) and a relative humidity of not less than 95 percent, take measurements specified in the equipment specification (no repair, realignment, readjustment or replacement of parts shall be made, except as specified herein). Obtain results in accordance with General Requirements, 3.2.

Step 7 - Condition the test item at 25° ±5°C (77° ±9°F) and 50 ±5 percent relative humidity for not less than 12 hours nor more than 24 hours.

Step 8 - While at 25° ±5°C (77° ±9°F) and 50 percent relative humidity, take measurements as specified in the equipment specification.

Step 9 - Inspect test item to detect evidence of physical degradation (such as corrosion of metal parts, distortion of plastic parts, and insufficient lubrication of moving parts) in accordance with General Requirements, 3.2.

3.5 Procedure V. Ammunition and natural environment cycles.

Step 1 - Prepare the test item in accordance with General Requirements, 3.2, except that initial measurements are taken in step 5.

Step 2 - Dry the test item at 54°C (129°F) for 24 hours.

Step 3 - Condition the test item at 23°C (73°F) and 50° ±10 percent relative humidity for 24 hours.

Step 4 - Gradually raise the internal chamber temperature to 40.5°C (105°F) and 90 percent relative humidity in 2 hours.

Step 5 - Take initial measurements in accordance with General Requirements, 3.2.

NOTE: The test item may be readjusted or realigned as necessary to meet specification requirements. No further readjustment or realignment shall be permitted throughout the test period other than with accessible controls employed for operation of the test item. No repair or replacement of parts shall be permitted. Equipment shall be operated only when specified test measurements are being performed.

Step 6 - Maintain the internal chamber temperature at 40.5°C (105°F) and the relative humidity at 90 percent for 16 hours.

Step 7 - Gradually decrease the internal chamber temperature to 21°C (70°F) and increase the relative humidity to 95 percent in 2 hours.

Step 8 - Maintain the internal chamber temperature at 21°C (70°F) and the relative humidity at 95 percent for 4 hours.

Step 9 - Repeat steps 4, 6, 7, and 8 for a total of 20 cycles (480 hours). Take measurements as specified in the equipment specification. Prior to measurements, accumulated moisture may be removed by turning the test item upside down or shaking. Wiping is not permitted. Figure 507.1-4 is an outline of the humidity cycle for this procedure.

Step 10 - After completion of step 9 cycling, operate the test item adjusting for optimum performance only as permitted in step 5 note, and inspect the test item to obtain results in accordance with General Requirements, 3.2 within 1 hour.

4. SUMMARY. The following details shall be specified in the equipment specification:

a. Procedure number

b. Pretest data required

c. Failure criteria

d. Periods at which measurements are to be taken

e. Method for determining purity of water if a more precise method is desired. (An alternate to pH criteria is to perform a conductivity measurement. The maximum acceptable value would be that resistance which is equivalent to 3.5 parts per million total ionized solids.)

f. If test item must be exposed to extreme temperature prior to test (procedure I).

g. Number of cycles if other than 20 (procedure V, step 9).

h. Whether cycle is to be limited to first 24 hours (procedure II, step 6).

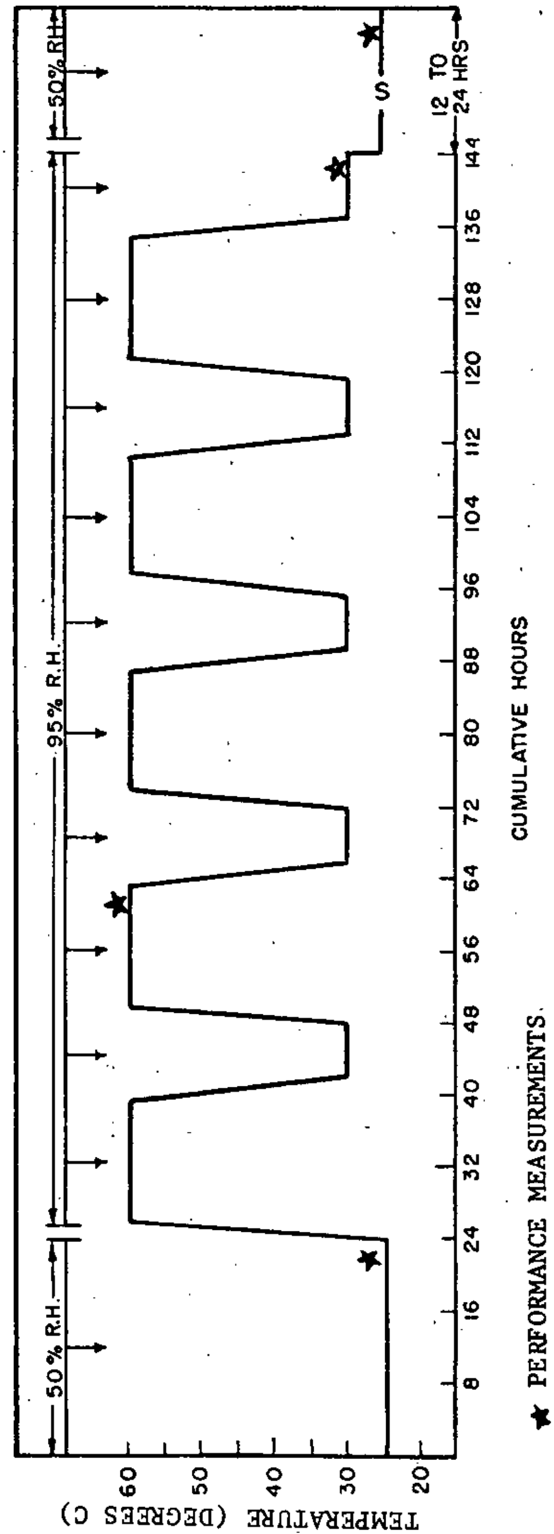


FIGURE 507.1-3. Humidity Cycle - Procedure IV

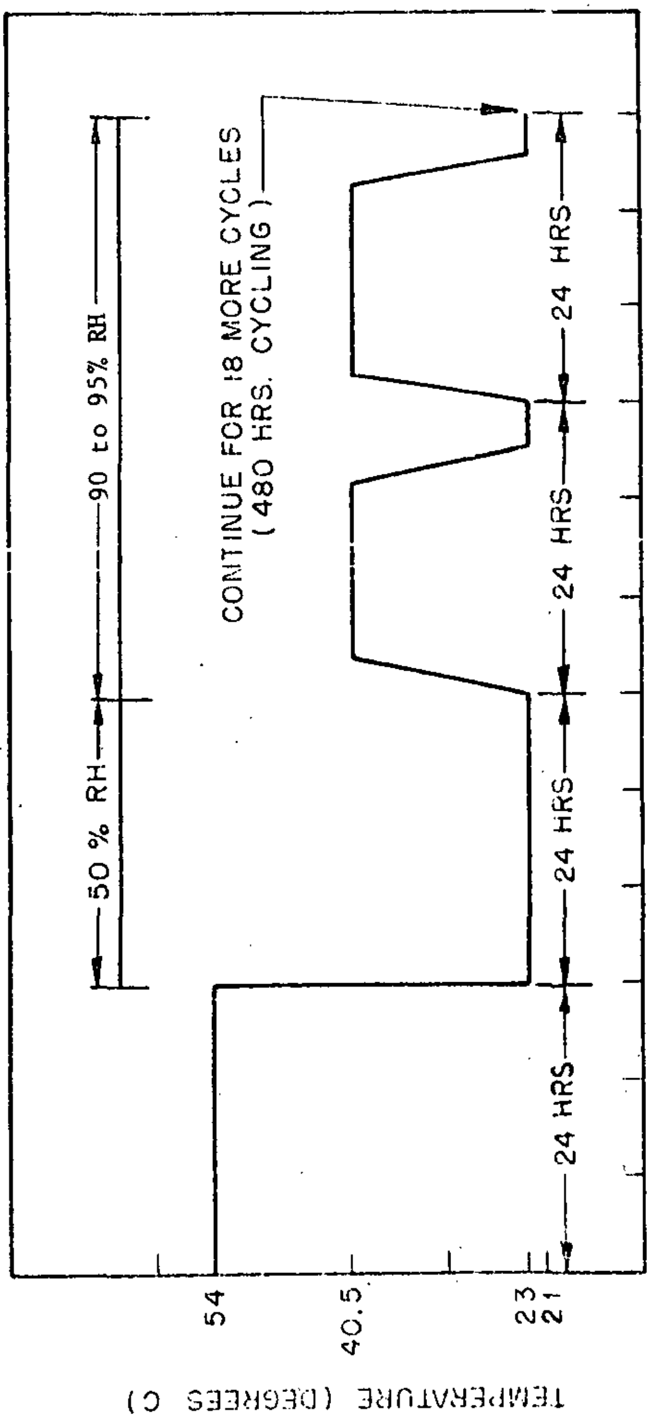


FIGURE 507.1-4. Humidity Cycle - Procedure V

METHOD 508.1

FUNGUS

1. PURPOSE. The fungus test is used to determine the resistance of equipment to fungi and to determine if such equipment is adversely affected by fungi under conditions favorable for their development, namely high humidity, warm atmosphere, and presence of inorganic salts.

1.1 General effects. Typical problems caused by fungi growing on equipment are:

a. Micro-organisms digest organic materials as a normal metabolic process thus degrading the substrate, reducing the surface tension, and increasing moisture penetration.

b. Enzymes and organic acids produced during metabolism diffuse out of the cells and onto the materials and cause metal corrosion, glass etching, hardening of grease, and other physical and chemical changes to the materials, such as insulation resistance and arcing.

c. The physical presence of micro-organisms produce living bridges across components which may result in electrical failures.

2. APPARATUS. The apparatus required to conduct this test consists of chambers or cabinets together with auxiliary instrumentation capable of maintaining the specified condition of temperature and humidity. Provisions shall be made to prevent condensation from dripping on the test item. There shall be free circulation of air around the test item and the contact area of fixtures supporting the test item shall be kept to a minimum.

When forced air is employed, the flow should not exceed 1 meter per second over the surface of the test specimen.

3. PROCEDURE

3.1 Procedure I

3.1.1 Preparation of mineral-salts solution. The solution shall contain the following:

Potassium dihydrogen
orthophosphate (KH_2PO_4) . . . . 0.7 g

Potassium monohydrogen
orthophosphate (K_2HPO_4) . . . . 0.7 g

Magnesium sulfate heptahydrate
($MgSO_4 \cdot 7H_2O$) . . . . 0.7 g

Ammonium nitrate (NH_4NO_3) . . . . 1.0 g

Sodium chloride (NaCl) . . . . 0.005 g

Ferrous sulfate heptahydrate
($FeSO_4 \cdot 7H_2O$) . . . . 0.002 g

Zinc sulfate heptahydrate
($ZnSO_4 \cdot 7H_2O$) . . . . 0.002 g

Manganous sulfate monohydrate
($MnSO_4 \cdot H_2O$) . . . . 0.001 g

Distilled water . . . . 1000 ml

Sterilize the mineral salts solution by autoclaving at 121°C (250°F) for 20 minutes. Adjust the pH of the solution by the addition of 0.01 normal solution of NaOH so that after sterilization the pH is between 6.0 and 6.5. Prepare sufficient salts solution for the required tests.

3.1.1.1 Purity of reagents. Reagent grade chemicals shall be used in all tests. Unless otherwise specified, it is intended that all reagents shall conform to the specification of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

3.1.1.2 Purity of water. Unless otherwise specified, references to water shall be understood to mean distilled water or water of equal purity.

3.1.2 Preparation of mixed spore suspension. The following test fungi shall be used:

Fungi	ATCC No. 1/	QM(NLABS) No. 2/
Aspergillus niger	9642	386
Aspergillus flavus	9643	380
Aspergillus versicolor	11730	432
Penicillium funiculosum	11797	474
Chaetomium globosum	6205	459

1/ American Type Culture Collection, 12301 Parklawn Drive, Rockville, Maryland 20852

2/ Pioneering Research Division, U.S. Army Natick Laboratories, Natick, Massachusetts 01760

Maintain cultures of these fungi separately on an appropriate medium such as potato dextrose agar. However, the culture of chaetomium globosum shall be cultured on strips of filter paper on the surface of mineral salts agar. (Mineral salts agar is identical to mineral salts solution described in 3.1.1, but contains in addition 15.0g of agar per liter). The stock cultures may be kept for not more than 4 months at 6° ±4°C (43° ±7°F) at which time subcultures shall be made and new stocks shall be selected from the subcultures. If genetic or physiological changes occur, obtain new cultures as specified above. Subcultures used for preparing new stock cultures or the spore suspension shall be incubated at 30°C (86°F) for 9 to 12 days or longer. Prepare a spore suspension of each of the five fungi by pouring into one subculture of each fungus a 10-ml portion of a sterile solution containing 0.05g per liter of a nontoxic wetting agent such as sodium dioctyl sulfosuccinate or sodium lauryl sulfate. Use a sterile platinum or nichrome inoculating wire to scrape gently the surface growth from the culture of the test organism. Pour the spore charge into a sterile 125-ml glass-stoppered Erlenmeyer flask containing 45 ml of sterile water and 50 to 75 solid glass beads, 5 mm in diameter. Shake the flask vigorously to liberate the spores from the fruiting bodies and to break the spore clumps. Filter the dispersed fungal spore suspension, through a 6 mm layer of glass wool contained in a glass funnel, into a sterile flask. This process should remove large mycelial fragments and clumps of agar which could interfere with the spraying process. Centrifuge the filtered spore suspension aseptically, and discard the supernatant liquid. Resuspend the residue in 50 ml of sterile water and centrifuge. Wash the spores obtained from each of the fungi in this manner three times. Dilute the final washed residue with sterile mineral-salts solution in such a manner that the resultant spore suspension shall contain 1,000,000 ±200,000 spores per ml as determined with a counting chamber. Repeat this operation for each organism used in the test and blend equal volumes of the resultant spore suspension to obtain the final mixed spore suspension. The spore suspension may be prepared fresh each day or may be held at 6° ±4°C (43° ±7°F) for not more than 7 days.

3.1.3 Viability of inoculum control. With each daily group of tests place each of three pieces of sterilized filter paper, 1-inch square, on hardened mineral-salts agar in separate Petri dishes. Inoculate these with the spore suspension by spraying the suspension from a sterilized atomizer 1/ until initiation of droplet coalesence. Incubate these at 30°C (86°F) at a relative humidity not less than 85 percent and examine them after 7 days of incubation. There shall be copious growth on all three of the filter paper control specimens. Absence of such growth requires repetition of the test.

1/ An atomizer capable of providing 15,000 ±3,000 spores per square centimeter.

3.1.4 Control items. In addition to the viability of inoculum control, known susceptible substrates shall be inoculated along with the test item to insure that proper conditions are present in the incubation chamber to promote fungus growth. The control items shall consist of cotton duct 8.25-ounce strips that are 1.25 inches wide, that have been dipped into a solution containing 10 percent glycerol, 0.1 percent potassium dihydrogen orthophosphate (KH_2PO_4), 0.1 percent ammonium nitrate (NH_4NO_3), 0.025 percent magnesium sulfate ($MgSO_4 \cdot 7H_2O$), and 0.05 percent yeast extract (pH 5.3), and from which the excess liquid has been removed. The strips should be hung to air dry before being inoculated and placed into the chamber.

3.1.5 Inoculation of test and control item

a. Mount the test control items on suitable fixtures or suspend from hangers. No cleaning of the test item shall be permitted for 72 hours prior to the beginning of the fungus test. Equipment handling prior to and during the fungus test shall be accomplished without contamination of the equipment.

b. Precondition the chamber and its contents at: 30°C (86°F) and 97 ±2 percent relative humidity for at least 4 hours.

c. Inoculate the test and control items with the mixed fungus spore suspension (3.1.2) by spraying it on and into the test and control items (if not hermetically sealed) in the form of a fine mist from a previously sterilized atomizer or nebulizer. In spraying the test and control items, care should be taken to spray all surfaces which are exposed during use or maintenance. If the surfaces are nonwetting, spray until initiation of droplet coalescence. Incubation is to be started immediately following the inoculation.

3.1.6 Incubation of test items

a. Incubate test items under cyclic temperature and humidity conditions to include 20 hours of relative humidity at 95 ±5 percent at an air temperature of 30° ±1°C (86° ±2°F) followed by 4 hours of 100 percent relative humidity at 25° ±1°C (77° ±2°F).

b. After 7 days, inspect the growth on the control items to be assured that the environmental conditions are suitable for growth. If inspection reveals that the environmental conditions are unsuitable for growth, the entire test shall be repeated.

c. If the control items show satisfactory fungus growth, continue the test for a period of 28 days from the time of inoculation or as specified in the equipment specification.

3.1.7 *Inspection*. At the end of the incubation period, the test item shall be removed from the test chamber and inspected in accordance with General Requirements, 3.2, except for hermetically sealed equipment, the equipment enclosure shall be opened and the interior examined for evidence of fungus growth or damage. The test item shall be operated when specified in the equipment specification and the results obtained in accordance with General Requirements, 3.2.

NOTE: Conductive solutions used as a spore media and growth accelerator may affect operational tests.

4. SUMMARY. The following details shall be as specified in the equipment specification:

a. Pretest data required

b. Failure criteria

c. Test period if other than 28 days (see 3.1.6 c)

d. Whether test item shall be operated (see 3.1.7).

METHOD 509.1

SALT FOG

1. PURPOSE. The salt fog test is conducted to determine the resistance of equipment to the effects of a salt atmosphere. The specified concentration of moisture and salt is greater than is found in service. The test is applicable to any equipment exposed to salt fog conditions in service.

1.1 Application. This test is valuable for determining the durability of coatings and finishes exposed to a corrosive salt atmosphere. For other applications, this test should be applied only after full recognition of its deficiencies and limitations which are as follows:

1.1.1 General effects

1.1.1.1 Deficiencies

a. The successful withstanding of this test does not guarantee that the test item will prove satisfactory under all corrosive conditions.

b. The salt fog used in this test does not truly duplicate the effects of a marine atmosphere.

c. It has not been demonstrated that a direct relationship exists between salt-fog corrosion and corrosion due to other media.

d. This test is generally unreliable for comparing the corrosion resistance of different materials or coating conditions, or for predicting their comparative service life. (Some idea of the service life of different samples of the same, or closely related metals, or of protective coating-base metal combinations exposed to marine or seacoast locations can be gained by this test provided the correlation of field service test data with laboratory tests that such a relationship does exist, as in the case of aluminum alloys, such correlation tests are also necessary to show the degree of acceleration, if any, produced by the laboratory test.)

1.1.1.2 Limitations

a. The salt fog test is acceptable for evaluating the uniformity (i.e., thickness and degree of porosity) of protective coatings, metallic and nonmetallic, of different lots of the same product, once some standard level of performance has been established. (When used to check the porosity of metallic coatings, the test is more dependable when applied to coatings which are cathodic rather than anodic toward the basic metal.)

b. This test can also be used to detect the presence of free iron contaminating the surface of another metal by inspection of the corrosion products.

2. APPARATUS. The apparatus used in the salt fog test shall include the following:

a. Exposure chamber with racks for supporting test items.

b. Salt solution reservoir with means for maintaining an adequate level of solution.

c. Means for atomizing salt solution, including suitable nozzles and compressed air supply.

d. Chamber heating means and control.

e. Means for humidifying the air at a temperature above the chamber temperature.

2.1 Chamber. The chamber and all accessories shall be made of material that will not affect the corrosiveness of the fog, e.g., glass, hard rubber, plastic, or kiln dried wood other than plywood. In addition, all parts which come in contact with test items shall be of materials that will not cause electrolytic corrosion. The chamber and accessories shall be constructed and arranged so that there is no direct impingement of the fog or dripping of the condensate on the test items, that the fog circulates freely about all test items to the same degree, and that no liquid which has come in contact with the test items returns to the salt-solution reservoir. The chamber shall be properly vented to prevent pressure buildup and allow uniform distribution of salt fog. The discharge end of the vent shall be protected from strong drafts which can create strong air currents in the test chamber.

2.2 Atomizers. The atomizers used shall be of such design and construction as to produce a finely divided, wet, dense fog. Atomizing nozzles shall be made of material that is nonreactive to the salt solution.

2.3 Air supply. The compressed air entering the atomizer shall be essentially free from all impurities, such as oil and dirt. Means shall be provided to humidify and warm the compressed air as required to meet the operating conditions. The air pressure shall be suitable to produce a finely divided dense fog with the atomizer or atomizers used. To insure against clogging the atomizers by salt deposition, the air should have a relative humidity of at least 85 percent at the point of release from the nozzle. A satisfactory method is to pass the air in very fine bubbles through a tower containing heated water which should be automatically maintained at a constant level. The temperature of the water should be at least 35°C (95°F). The permissible water temperature increases with increasing volume of air and with decreasing insulation of the chamber and the chamber's surroundings. However, the temperature should not exceed a value above which an excess of moisture is introduced into the chamber (for example 43°C (109°F) at an air pressure of 12 psi) or a value which makes it impossible to meet the requirements for operating temperature.

2.4 Preparation of salt solution. The salt used shall be sodium chloride containing on the dry basis not more than 0.1 percent sodium iodide and not more than 0.5 percent of total impurities. Unless otherwise specified, a 5 ±1 percent solution shall be prepared by dissolving five parts by weight of salt in 95 parts by weight of distilled or demineralized water. The solution shall be adjusted to and maintained at a specific gravity between the limits shown on figure 509.1-1 by utilizing the measured temperature and density of the salt solution. Sodium tetraborate (common borax) may be added to the salt solution in a ratio not to exceed 0.7 gms (1/4 level teaspoon) sodium tetraborate to 20 gallons of salt solution as a pH stabilization agent.

2.4.1 Adjustment of pH of the salt solution shall be so maintained that the solution atomized at 35°C (95°F) and collected by the method specified in 3.1.3 will be in the pH range of 6.5 to 7.2. Only diluted C.P. hydrochloric acid or C. P. sodium hydroxide shall be used to adjust the pH. The addition of sodium tetraborate as recommended in 2.4 will aid in maintaining a stable pH value. The pH measurement shall be made electrometrically, using a glass electrode with a saturated potassium chloride bridge, or by a colorimetric method, such as bromothymol blue, provided the results are equivalent to those obtained with the electrometric method. The pH shall be measured when preparing each new batch of solution and as specified in 3.1.4.

2.5 Filter. A filter fabricated of noncorrosive materials similar to that shown in figure 509.1-2 shall be provided in the supply line and immersed in the salt solution reservoir in a manner such as that illustrated in figure 509.1-3.

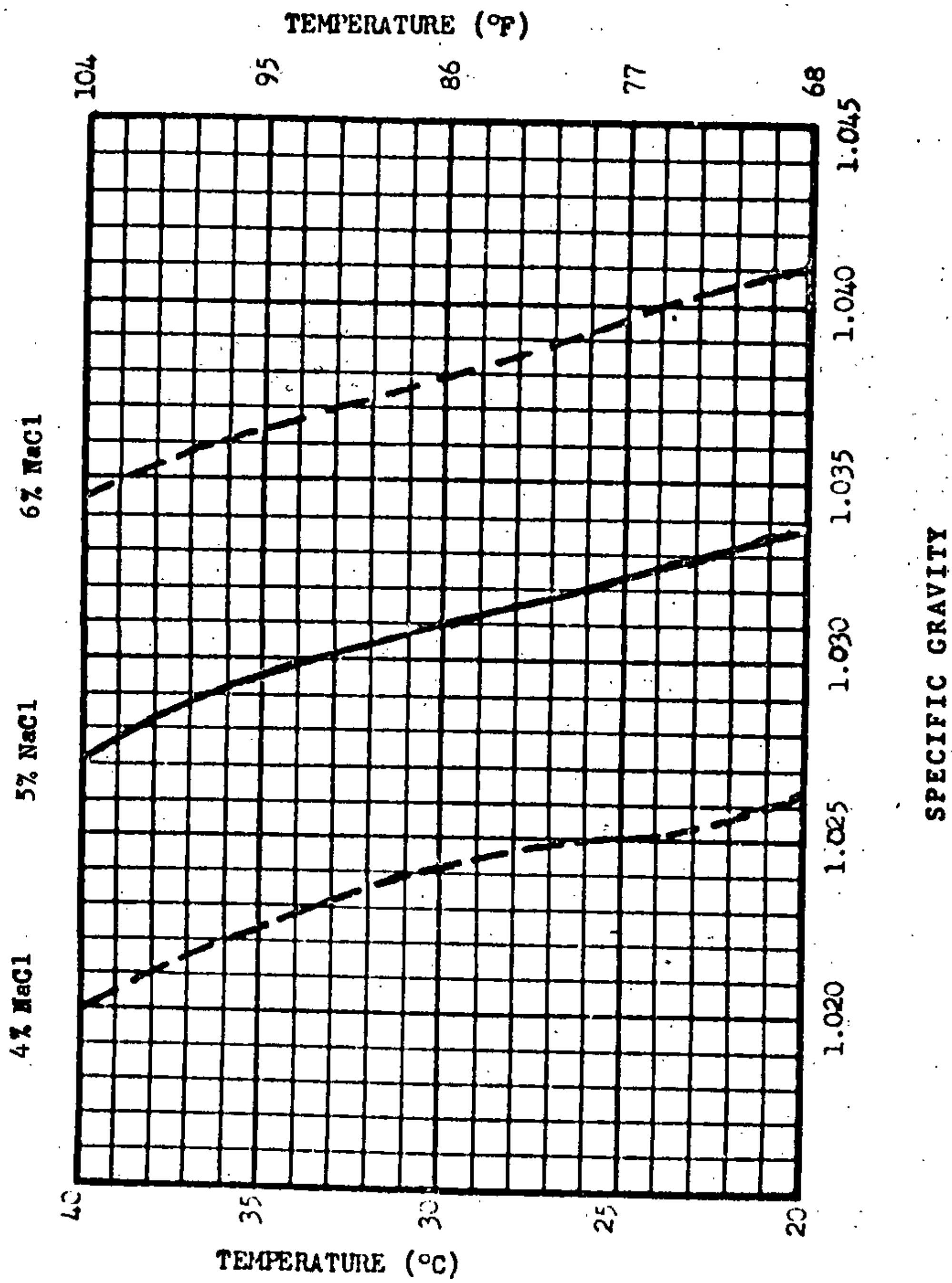


Figure 509.1-1 Variations of Specific Gravity of Salt (NaCl) Solution with Temperature

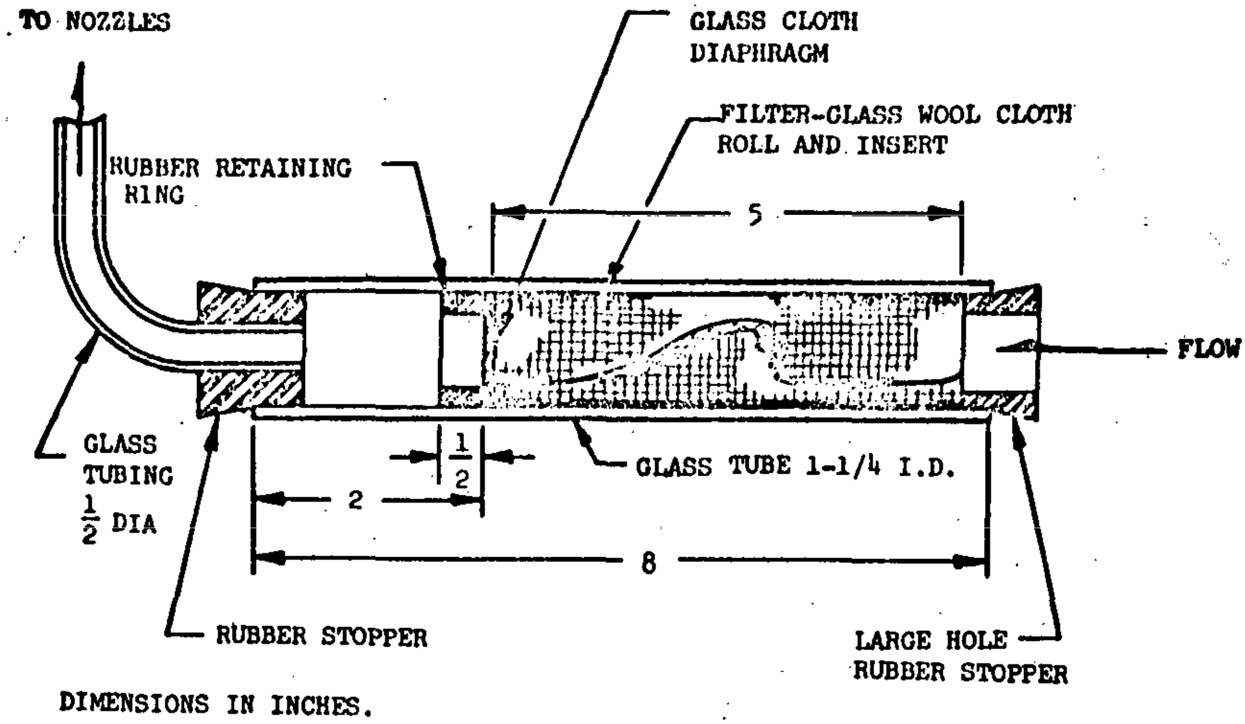


Figure 509.1-2 Salt Solution Filter

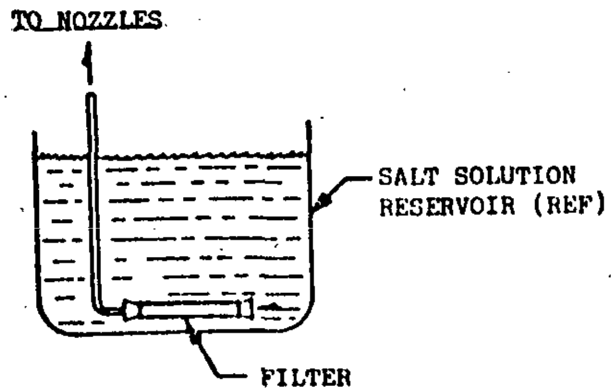


Figure 509.1-3 Location of Salt Solution Filter

3. PROCEDURE

3.1 Procedure I

3.1.1 Temperature. The test shall be conducted with a temperature in the exposure zone maintained at 35°C (95°F). Satisfactory methods for controlling the temperature accurately are by housing the apparatus in a properly controlled constant temperature room, by thoroughly insulating the apparatus and preheating the air to the proper temperature prior to atomization, or by jacketing the apparatus and controlling the temperature of the water or of the air used in the jacket. The use of immersion heaters within the chamber for the purpose of maintaining the temperature within the exposure zone is prohibited.

3.1.2 Atomization. Suitable atomization has been obtained in chambers having a volume of less than 12 cubic feet under the following conditions:

a. Nozzle pressure shall be as low as practicable to produce fog at the required rate.

b. Orifices between 0.02 and 0.03 inch in diameter.

c. Atomization of approximately 3 quarts of salt solution per 10 cubic feet of chamber volume per 24 hours.

When using large size chambers having a volume considerably in excess of 12 cubic feet, the conditions specified may require modification to meet the requirements for operating conditions.

3.1.3 Placement of salt fog collection receptacles. The salt fog conditions maintained in all parts of the exposure zone shall be such that a clean fog collecting receptacle placed at any point in the exposure zone will collect from 0.5 to 3 milliliters of solution per hour for each 80 square centimeters of horizontal collecting area (10 centimeters diameter) based on an average test of at least 16 hours. A minimum of two receptacles shall be used, one placed nearest to any nozzle and one farthest from all nozzles. Receptacles shall be placed so that they are not shielded by test items and so no drops of solution from test items or other sources will be collected.

3.1.4 Measurement of salt solution. The solution, collected in a manner specified in 3.1.3, shall have the sodium chloride content and pH specified in 2.4 when measured at a temperature of 35°C (95°F). The salt solution from all collection receptacles used can be combined to provide that quantity required for the measurements specified.

3.1.4.1 Measurement of sodium chloride content. The solution, maintained at the specified temperature, can be measured in a graduate of approximately 2.5 centimeters inside diameter. A small laboratory type hydrometer will be required for measurement within this volume.

3.1.4.2 Measurement of pH. The pH shall be measured as specified in 2.4.1.

3.1.4.3 Time of measurements. The measurement of both sodium chloride content and pH shall be made at the following specified times:

a. For salt fog chambers in continuous use, the measurements shall be made following each test.

b. For salt fog chambers that are used infrequently, a 24-hour test run shall be accomplished followed by the measurements. The test item shall not be exposed to this test run.

3.1.5 Preparation of test item. The test item shall be given a minimum of handling, particularly on the significant surfaces, and shall be prepared for test immediately before exposure. Unless otherwise specified, uncoated metallic or metallic coated devices shall be thoroughly cleaned of oil, dirt, and grease as necessary until the surface is free from water break. The cleaning methods shall not include the use of corrosive solvents nor solvents which deposit either corrosive or protective films, nor the use of abrasives other than a paste of pure magnesium oxide. Test items having an organic coating shall not be solvent cleaned. Those portions of test items which come in contact with the support and, unless otherwise specified in the case of coated devices or samples, cut edges and surfaces not required to be coated, shall be protected with a suitable coating of wax or similar substance impervious to moisture.

3.1.6 Performance of test. The test item shall be placed in the test chamber in accordance with General Requirements, 3.2.2, and exposed to the salt fog for a period of 48 hours or as specified in the equipment specification. At the end of the exposure period, unless otherwise specified, the test item shall be operated and the results compared with the data obtained in accordance with General Requirements, 3.2.1. The test item shall be inspected for corrosion in accordance with General Requirements 3.2.4. If necessary to aid in examination, a gentle wash in running water not warmer than 38°C (100°F) may be used. The test item shall then be stored in an ambient atmosphere for 48 hours or as specified in the equipment specification for drying. At the end of the drying period, when specified, the test item shall be again operated and the results compared with the data obtained in accordance with General Requirements, 3.2.1. The test item shall then be inspected in accordance with General Requirements, 3.2.4.

4. <u>SUMMARY.</u> The following details shall be specified in the equipment specification:

a. Pretest data required

b. Failure criteria

c. Applicable salt solution, if other than 5 percent

d. Salt fog exposure period if other than 48 hours (see 3.1.6)

e. Drying period if other than 48 hours (see 3.1.6)

f. Inspection and operation after 24 hours of salt fog exposure where buildup of salt deposits are critical to the proper operation of the test item

g. Specify if operation of electrical system is required (see 3.1.6).

METHOD 510.1

DUST (FINE SAND)

1. PURPOSE. The dust test is used to ascertain the ability of equipment to resist the effects of a dry dust (fine sand) laden atmosphere. This test simulates the effect of sharp edged dust (fine sand) particles, up to 150 microns in size, which may penetrate into cracks, crevices, bearings, and joints. This test is applicable to all mechanical, electrical, electronic, electrochemical, and electromechanical devices for which exposure to the effects of a dry dust (fine sand) laden atmosphere is anticipated. However, this method is not applicable to Southeast Asian dust conditions.

1.1 General effects. General effects resulting from the penetration of dust can cause a variety of damage such as fouling moving parts, making relays inoperative, forming electrically conductive bridges with resulting shorts and acting as a nucleus for the collection of water vapor, and hence a source of possible corrosion and malfunction of equipment.

1.2 Many items, such as rifles, vehicles, and helicopters, will encounter sand particles up to 1,000 microns, as opposed to the 149 micron maximum for 140-mesh silica flour sand tests, that would require a much coarser formulation than that covered by this method.

2. APPARATUS. The test facility shall consist of a chamber and accessories to control dust concentration, velocity, temperature, and humidity of dust laden air. In order to provide adequate circulation of the dust laden air, no more than 50 percent of the cross-sectional area (normal to air flow) and 30 percent of the volume of the chamber shall be occupied by the test item(s). The chamber shall be provided with a suitable means of maintaining and verifying the dust concentration in circulation. A minimum acceptable means for doing this is by use of a properly calibrated smoke meter and standard light source. The dust laden air shall be introduced into the test space in such a manner as to allow it to become approximately laminar in flow before it strikes the test item.

2.1 *Dust requirements*. The dust used in this test shall be a fine sand (97-99 percent by weight SiO_2) of angular structure, and shall have the following size distribution as determined by weight, using the U.S. Standard Sieve Series:

a. 100 percent of this dust shall pass through a 100-mesh screen

b. 98 ±2 percent of the dust shall pass through a 140-mesh screen

c. 90 ±2 percent of the dust shall pass through a 200-mesh screen

d. 75 ±2 percent of the dust shall pass through a 325-mesh screen.

NOTE: 140-mesh silica flour as produced by the Ottawa Silica Company, Ottawa, Illinois, or equal, is satisfactory for use in the performance of these tests.

3. PROCEDURE

3.1 Procedure I. Prepare the test item in accordance with General Requirements 3.2, positioning the test item as near the center of the chamber as practicable. If more than one item is being tested, there shall be a minimum clearance of 4 inches between surfaces of test items or any other material or object capable of furnishing protection. Also, no surface of the test item shall be closer than 4 inches from any wall of the test chamber. Orient the item so as to expose the most critical or vulnerable parts to the dust stream. The test item orientation may be changed during the test if so required by the equipment specification.

Step 1 - Set the chamber controls to maintain an internal chamber temperature of 23°C (73°F) and a relative humidity of less that 22 percent. Adjust the air velocity to 1,750 ±250 feet per minute. Adjust the dust feeder to control the dust concentration at 0.3 ±0.2 grams per cubic foot. With the test item nonoperating, maintain these conditions for 6 hours.

Step 2 - Stop the dust feed and reduce the air velocity to 300 ±200 feet per minute. Raise the internal chamber air temperature to 63°C (145°F). Hold these conditions 16 hours.

Step 3 - While holding chamber temperature at 63°C 145°F) adjust the air velocity to 1,750 ±250 fpm. Adjust the dust feeder to control the dust concentration at 0.3 ±0.2 gms per cubic foot. Unless otherwise specified, with the test item nonoperating, maintain these conditions for 6 hours.

Step 4 - Turn off all chamber controls and allow the test item to return to standard ambient conditions. Remove accumulated dust from the test item by brushing, wiping, or shaking, care being taken to avoid introduction of additional dust into the test item. Dust shall not be removed by either air blast or vacuum cleaning.

Step 5 - Operate and inspect the test item in accordance with General Requirements, 3.2.

Step 6 - Inspect the test item and obtain results as specified in General Requirements, 3.2.4. In the performance of this inspection, test items containing bearings, grease seals, lubricants, et cetera, shall be carefully examined for the presence of dust deposits.

4. SUMMARY. The following details shall be as specified in the equipment specification:

a. Pretest data required

b. Failure criteria

c. Change in orientation during test if required

d. Whether equipment is to operate during test and length of time required for operation and measurements (see steps 1 and 3)

e. Whether the second 6-hour test at 63°C (145°F) shall be performed immediately after reaching stabilization (see step 2)

f. Temperatures for steps 2 and 3, if different from 63°C (145°F).

METHOD 511.1

EXPLOSIVE ATMOSPHERE

1. PURPOSE. The explosive atmosphere test is conducted to determine the ability of equipment to operate in the presence of an explosive atmosphere without creating an explosion or to contain an explosion occurring inside the equipment. Since equipments operate in ever changing potentially explosive atmospheres, the equipments, when being laboratory tested, must operate in the presence of the optimum fuel-air mixture which requires the least amount of energy for ignition. The equipment igniting energy may be produced electrically, thermally, or chemically.

1.1 Procedure I. This procedure is intended for determining the explosion producing characteristics of equipment not hermetically sealed and not contained in cases designed to prevent flame and explosion propagation. Ground equipment used in or near vehicles shall also be tested in accordance with this procedure, except that the specified altitude survey need be conducted only to 15,000 feet.

1.2 Procedure II. This procedure is intended for determining the explosion and flame arresting characteristics of equipment cases designed for that purpose.

1.3 Procedure III. This procedure is intended for determining the explosion and flame arresting characteristics of equipment cases for shipboard application.

1.4 Procedure IV. This procedure is intended for determining the flame and explosion arresting characteristics of equipment containing hotspots in excess of 143°C (290°F).

2. APPARATUS. A chamber capable of providing and verifying the explosion-proof test conditions. MIL-C-9435 describes one type of chamber that may be used.

2.1 Fuel. Unless otherwise specified, the fuel used shall be gasoline, grade 100/130 conforming to MIL-G-5572 or a 1.05 stoichiometric mixture of propane (C_3H_8) and air within the following limits: propane 3.85 to 4.25 percent by volume and air 96.15 to 95.75 percent by volume.

2.1.1 Calculation of fuel-air-vapor ratio. As an illustration of the procedure for calculating the weight of 100/130 octane gasoline required to produce the desired 13-to-1 air-vapor ratio, the following sample problem is presented:

Required information:

a. Chamber air temperature during test: 27°C (81°F)

b. Fuel temperature: 24°C (75°F).

c. Specific gravity of fuel at 16°C (61°F): 0.704.

d. Test altitude: 20,000 feet (P = 6.75 lbs./in^2).

e. Air-vapor ratio (desired): 13-to-1.

Step 1 - Employing the following equation, calculate the apparent air-vapor ratio:

$$AAV = \frac{AV\ (desired)}{1.04\left(\frac{P}{14.696}\right) - 0.04} = \frac{13}{1.04\left(\frac{6.75}{14.696}\right) - 0.04} = 29.70$$

where:

AAV = Apparent air-vapor ratio

AV = Desired air-vapor ratio

P = Pressure equivalent of altitude, lbs./in^2

At or above 10,000 feet altitude, with chamber air temperature above 16°C (61°F) and at AV ratio of 5 or greater, air-vapor ratio = air-fuel ratio (AF) for 100/130 octane fuel. Since the conditions of the explosion test under consideration will always be well above these values, AV will equal AF in all cases.

Step 2 - Since AV = AF, use figure 511.1-I to determine weight of air (WA) and divide by AAV to obtain uncorrected weight of fuel required (W_{FU}).

$$W_{FU} = \frac{WA}{29.68} = \frac{3.455}{29.68} = 0.116 \text{ lbs, fuel weight (uncorrected).}$$

Figure 511.1-I pertains to a specific test chamber and shall not be used for all test facilities. It is utilized herein for illustration of the method of employment only. Each test chamber must have its own chamber volume chart.

Step 3 - Knowing fuel temperatures and specific gravity at 16°C (61°F) use figure 511.1-2 to determine specific gravity at given temperature.

Step 4 - Using figure 511.1-3, obtain correction factor K for the specific gravity determined during step 3. Apply factor to obtain weight of fuel corrected (W_{FC}).

$W_{FC} = KW_{FU} = 1.01 \times 0.116 = 0.117$ lbs, fuel weight (corrected).

The equipment used to vaporize the fuel for use in the explosion-proof test should be so designed that a small quantity of air and fuel vapor will be heated together to a temperature such that the fuel vapor will not condense as it is drawn from the vaporizer into the chamber.

3. PROCEDURES

3.1 Procedure I

3.1.1 Preparation for test

a. The test item shall be prepared in accordance with General Requirements, 3.2, and in such a manner that normal electrical operation is possible and mechanical controls may be operated through the pressure seals from the exterior of the chamber. External covers of the test item shall be removed or loosened to facilitate the penetration of the explosive mixture. Large test items may be tested one or more units at a time by extending electrical connections through the cable port to the balance of the associated equipment located externally.

b. The test item shall be operated to determine that it is functioning properly and to observe the location of any sparking or high temperature components which may constitute potential explosion hazards.

c. Mechanical loads on drive assemblies and servomechanical and electrical loads on switches and relays may be simulated when necessary if proper precaution is given to duplicating the normal load in respect to torque, voltage, current, inductive reactance, etc. In all instances, it shall be considered preferable to operate the test item as it normally functions in the system during service use.

3.1.2 Performance of test. Except as specified below, the test shall be conducted as follows at simulated test altitudes of sea level to 5,000 feet, 10,000 feet, 15,000 feet (15,000 feet maximum for ground equipment) 20,000 feet, 30,000 feet, 40,000 feet, and 50,000 feet above sea level.

Step 1 - The test chamber shall be sealed and the ambient temperature within shall be raised to 71° ±3°C (160° ±5°F), or to the maximum temperature to which the test item is designed to operate if lower than 71°C (160°F). The temperature of the test item and the chamber walls shall be permitted to rise to within 11°C (20°F) of that of the chamber ambient air, prior to introduction of the explosive mixture.

Step 2 - The internal test chamber pressure shall be reduced sufficiently to simulate an altitude approximately 10,000 feet above the desired test altitude. The weight of fuel necessary to produce an air-vapor ratio of 13-to-1 at the desired test altitude shall be determined from consideration of chamber volume, fuel temperature and specific gravity, chamber air and wall temperature, test altitude, etc. If the performance of this test will expose the equipment to an altitude in excess of its specified maximum operating or nonoperating altitude the next lower simulated test altitude shall be selected. The testing of ground equipment (equipment for operational use on the ground or aboard ship) shall be limited to an increase in the chamber altitude to 15,000 feet with the equipment nonoperating and the weight of fuel shall be admitted to the chamber while the altitude is being reduced to 10,000 feet (see 2.1.1). A time of 3 ±1 minutes shall be allowed for introduction and vaporization of the fuel. Air shall be admitted into the chamber until a simulated altitude of 5,000 feet above the test altitude is attained.

Step 3 - Operation of the test item shall at this time be commenced, all making and breaking electrical contacts being actuated. If high temperature components are present, a warmup time of 15 minutes shall be permitted. If no explosion results, air shall be admitted into the chamber so as to steadily reduce the altitude down past the desired test altitude to an elevation 5,000 feet below that altitude. If necessary, conduct tests to simulated sea level pressure by pressurizing chamber. Tests shall not be conducted below sea level. The operation of the test item shall be continuous throughout this period of altitude reduction and all making and breaking electrical contacts shall be operated as frequently as deemed practicable. Ground equipment shall be energized at 15,000 feet and the sources of igniting energy operated until the chamber altitude is reduced to sea level.

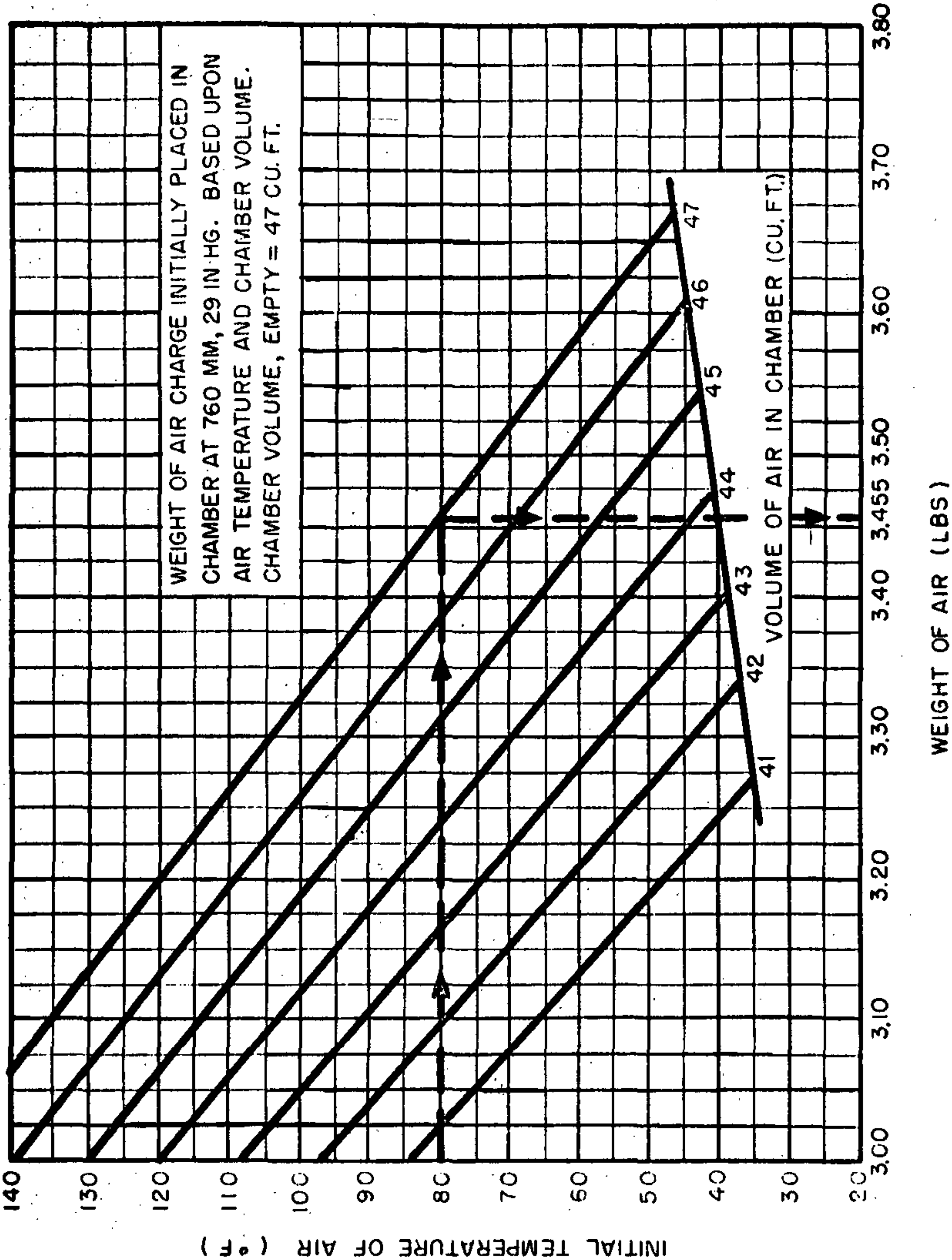


FIGURE 511.1-1. Weight of Air Charge vs. Temperature

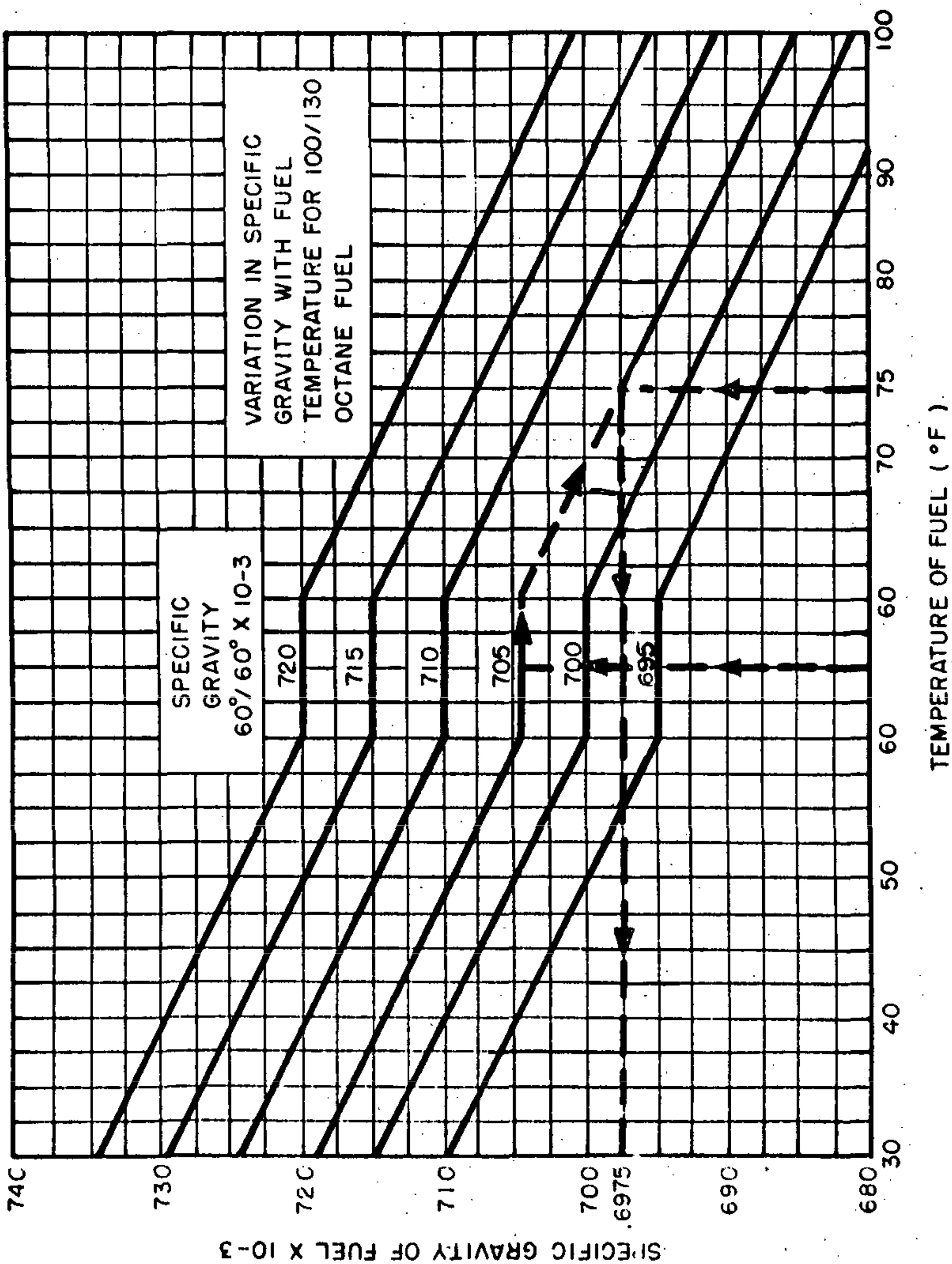


FIGURE 511.1-2. Specific Gravity vs Temperature

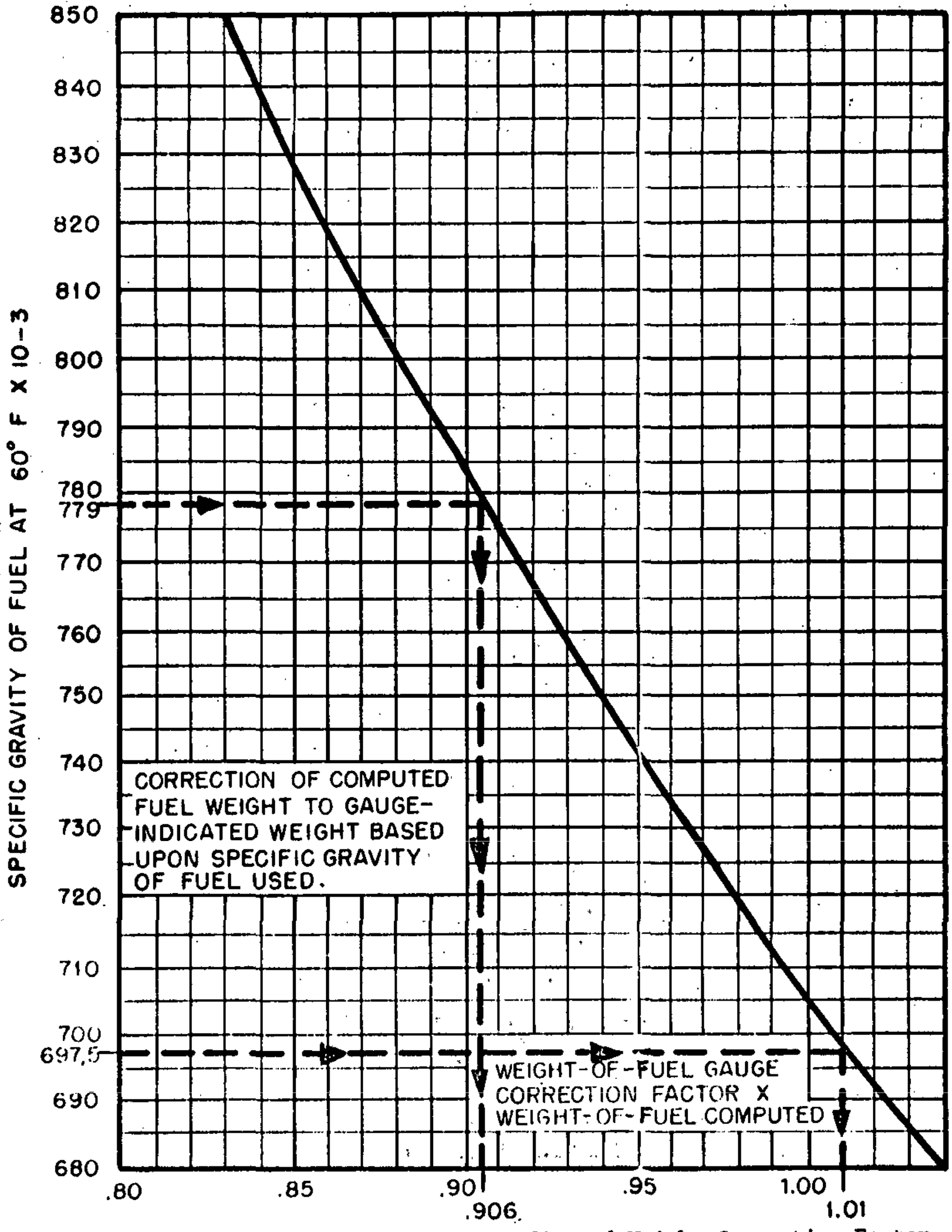


FIGURE 511.1-3. Fuel Weight to Gage Indicated Weight Correction Factor

Step 4 - If by the time the simulated altitude has been reduced to 5,000 feet below the test altitude (or sea level in the case of ground equipment), no explosion has occurred as a result of operation of the test item, the potential explosiveness of the air-vapor mixture shall be verified by igniting a sample of the mixture with a spark gap or glow plug. At pressure altitudes of 20,000 feet or higher, the attainment of ignition at any altitude shall be sufficient evidence that the mixture was ignitable even though ignition was not obtained at some other point in the vicinity of the test altitude. At any altitude below 20,000 feet, the mixture sample shall ignite immediately at the point within 3,000 feet of the test altitude. If the air-vapor mixture is not found to be explosive, the test shall be considered void and the entire procedure repeated.

3.1.3 Failure criteria. If the item causes explosion at any of the test altitudes, it shall be considered to have failed the test and no further trials need be attempted.

3.2 Procedure II

3.2.1 Preparation for test

a. Preparation of test case or enclosure. When necessary, the test case or enclosure shall be prepared for explosion-proof testing by drilling and tapping openings in the case or enclosure for inlet and outlet hose connections to the fuel vapor air mixture circulation system and for mounting a spark gap device. The case volume shall not be altered by more than ±5 percent by any modification to facilitate the introduction of explosive vapor.

b. Hose installation. When inserting a hose from a blower, adequate precaution shall be taken to prevent ignition of the ambient mixture by backfire or the release of pressure through the supply hose.

c. Spark gap device. A spark gap device for igniting the explosive mixture within the case or enclosure shall be provided. The case or enclosure may be drilled and tapped for the spark gap device or the spark gap device may be mounted internally.

d. The case or enclosure with either the test item or a model of the test item of the same volume and configuration in position within the case or enclosure shall be installed in the explosion chamber.

3.2.2 Performance of test. The test shall be accomplished three times at altitudes between sea level and 5,000 feet as follows:

Step 1 - The chamber shall be sealed and the internal pressure reduced sufficiently to simulate an altitude between ground level and 5,000 feet. The ambient chamber temperature shall be at least 25°C (77°F). An explosive mixture within the chamber shall be obtained by following the procedure set forth in procedure I.

Step 2 - The internal case ignition source shall be energized in order to cause an explosion within the case. The occurrence of an explosion within the case may be detected by use of a thermocouple inserted in the case and connected to a sensitive galvanometer outside the test chamber. If ignition of the mixture within the case does not occur immediately, the test shall be considered void and shall be repeated with a new explosive charge.

Step 3 - At least five internal case explosions shall be accomplished at the test altitude selected. If the case tested is small (not in excess of one-fiftieth of the test chamber volume) and if the reaction within the case upon ignition is of an explosive nature without continued burning of the mixture as it circulates into the case, more than one internal case explosion, but not more than five, may be produced without recharging the entire chamber. Ample time shall be allowed between internal case explosions for replacement of burnt gases with fresh explosive mixture, within the case. If the internal case explosions produced did not cause a main chamber explosion, the explosiveness of the fuel-air mixture in the main chamber shall be verified. If the air-vapor mixture in the main chamber is not found to be explosive, the test shall be considered void and the entire procedure repeated.

3.2.3 Failure criteria. If the internal case explosion causes a main chamber explosion, the test item shall be considered to have failed the test and no further trials need be attempted.

3.3 Procedure III

3.3.1 Preparation for test. The test enclosure and test item shall be prepared for test in accordance with 3.2.1 of procedure II.

3.3.2 Performance of test. The test shall be conducted at sea level or laboratory ambient as follows:

Step 1 - The test chamber shall be sealed. The ambient chamber temperature shall be at least 25°C (77°F). Sufficient fuel vapor and air shall be introduced and circulated throughout the test enclosure and test chamber to assure a uniform mixture. The interior of the test enclosure shall then be isolated from the chamber atmosphere.

Step 2 - The mixture in the enclosure shall be ignited and an explosion shall occur. The test shall be repeated twenty times unless a failure occurs. Ample time shall be allowed between internal enclosure explosions for replacement of burnt gases with fresh explosive mixture. If the internal enclosure explosions produced did not cause a main chamber explosion the explosiveness of the fuel vapor and air mixture in the test chamber shall be verified. If an explosion does not occur the test shall be considered void and the entire procedure repeated.

3.3.3 Failure criteria. The test item (sealed or unsealed as applicable) shall be considered as failing the test for the following:

a. Discharge of flame to the test chamber from the interior of the test enclosure.

b. Ignition of explosive mixture in the test chamber.

c. If the internal case explosion causes a main chamber explosion, the test item shall be considered to have failed the test and no further trials need be attempted.

d. After burning, immediately after the explosion within the test enclosure, caused by the ignition of explosive mixture entering the test enclosure as a result of cooling of the products of the original explosion.

e. Rupture or permanent distortion of the enclosure. Deformation of flat surfaces shall be checked and recorded.

3.4 Procedure IV

3.4.1 Preparation for test. The test item shall be placed in the test chamber in accordance with 3.1.1 of procedure I. The suspected components to be tested for thermal ignition shall be instrumented with thermocouples operating in a range of 65° to 260°C (150° to 500°F).

3.4.2 Performance of test. The test shall be conducted as follows:

Step 1 - The test chamber shall be sealed. The ambient chamber temperature shall be the highest operating temperature of the equipment. A time of 3 ±1 minutes shall be allowed for sufficient fuel vapor and air to be introduced and circulated throughout the test chamber.

Step 2 - The equipment shall be turned on and left in standby mode until thermal stabilization of the equipment has been attained. This period shall be not less than 5 minutes.

Step 3 - The equipment shall be operated in a normal cycle for a minimum of 5 minutes. The maximum temperatures attained at the suspected components shall be recorded. If a temperature in excess of 204°C (400°F) is attained, the operational cycle shall be extended to a minimum of 10 minutes. If an explosion occurs, the temperature attained at that time shall be recorded.

Step 4 - If an explosion does not occur, the potential explosiveness of the air-vapor mixture shall be verified by igniting a sample of the mixture within the chamber.

4. SUMMARY. The following details shall be as specified in the equipment specification:

a. Procedure number

b. Pretest data required

c. Failure criteria

d. Mechanical and electrical load (procedure 1, 3.1.1(c))

e. Chamber temperature condition, if lower than 71°C (160°F) (procedure I, step 1).

METHOD 512.1

LEAKAGE (IMMERSION)

1. PURPOSE. The purpose of this test is to determine the ability of the equipment to be immersed in water without leakage of the water into the enclosure.

1.1 General effects. Air seepage in the form of bubbles would be an indication of defective equipment or workmanship. Water seepage into the equipment could cause corrosion or fouling of lubricants between moving parts.

2. APPARATUS

2.1 Procedure I. Water container and accessories.

2.2 Procedure II. DISCONTINUED.

2.3 Procedure III. Altitude chamber, water container, and accessories.

2.4 Procedure IV. Altitude chamber and accessories.

3. PROCEDURES

3.1 Procedure I. (This is a test for gross leakage only.)

3.1.1 Preparation. Where applicable, open and close (or remove and replace) doors and covers three times immediately before tests.

3.1.2 Test conditions. The temperature of the water shall be 18° ±5°C (64° ±9°F) and the temperature of the test item shall be 45° ±3°C (113° ±5°F). The water container shall be of sufficient capacity so that the immersion of the test item will not raise the temperature of the water more than 3°C (5°F).

3.1.3 Performance of test. Immerse the test item (covers closed on field transported items) in the water so that the uppermost point of the test item is 36 ±5 inches below the surface of the water. The test item shall remain immersed for 120 ±5 minutes. Upon completion of the test period, remove the test item from the water and wipe the exterior surfaces of the test item dry. Open the test item and examine the interior and contents for evidence of leakage.

3.2 Procedure II. DISCONTINUED.

3.3 Procedure III. (This is a test for determining slight leakage as well as gross leakage. This procedure may also be used for equipment which is normally pressurized in use.)

3.3.1 Test conditions. The temperature of the liquid and test item shall be 23° ±10°C (73° ±18°F).

3.3.2 Performance of test. The test item shall be completely immersed in a suitable liquid such as water so that the uppermost part of the test item is 2 ±1 inches below the surface of the liquid. The absolute pressure of the air above the liquid shall be reduced to 1, 19, or 25 inches of mercury (absolute) or other values as specified in the equipment specification, and maintained for 1 minute, or until air bubbles substantially cease to be given off by the liquid, whichever is the longer time. The absolute pressure above the liquid shall then be increased to 2.5, 20 or 26 inches of mercury, respectively, and maintained for 60 minutes.

3.3.3 Failure criteria. Bubbles coming from within the equipment shall be considered a leakage; however, bubbles which result from trapped air on the various exterior surfaces of the test item shall not be considered a leak.

3.4 Procedure IV. (For equipment which is normally pressurized.)

3.4.1 Test conditions. The temperature of the liquid, pressurizing gas, and the test item shall be 23 ±10°C (73° ±18°F). The gas used for pressuring (e.g., air, nitrogen, or helium) shall be clean and dry with a dewpoint of at least -32°C (-25°F).

3.4.2 Performance of test. The equipment shall be completely immersed in a suitable liquid such as water so that the uppermost part of the test item is 2 ±1 inches below the surface of the liquid. The equipment shall be internally pressurized from a minimum to 125 percent of the maximum operating pressure, as specified in the equipment specification and maintained for a minimum of 60 minutes at each pressure.

3.4.3 Failure criteria. Bubbles coming from within the equipment shall be considered a leakage; however, bubbles which result from trapped air on the various exterior surfaces of the test item shall not be considered a leak.

NOTE: In lieu of procedures III or IV, a helium or halogen leak detector (equal or superior in sensitivity to these immersion test methods) may be used upon approval of the procuring activity.

4. SUMMARY. The following details shall be specified in the equipment specification:

a. Procedure number

b. Pretest data required

c. Failure criteria

d. Operational requirements, if specified.

e. Condition (transit or operational) of equipment (see 3.1.3, 3.3.2, 3.4.2)

f. Liquids used (Procedures III and IV)

g. Pressure, liquid height, and time if other than as specified herein

h. Air pressure (Procedure III).

METHOD 513.2

ACCELERATION

1. PURPOSE. The acceleration test is performed to determine if equipment is constructed to withstand expected steady state stresses and to insure that performance degradations or malfunctions will not be produced by the simulated service acceleration environment. Procedure I is the structural test and procedure II is the operational test.

2. APPARATUS. Either of two facilities may be utilized for acceleration tests: a centrifuge, or a track and rocket sled facility. A centrifuge of adequate size is recommended for all structural and most operational tests because of the convenience and ease of control. However, the performance of space oriented equipment, such as gyros, space control platforms, etc, are difficult to test on a centrifuge, even when a counter-rotating fixture is employed. A rocket sled run is advantageous where strictly linear acceleration is required.

3. PROCEDURES. The test item shall be subjected to both the structural and the operational test, unless otherwise specified.

3.1 Mounting of test item. Direction of forward acceleration is always considered to be the direction of the vehicle acceleration and equipment shall be oriented accordingly, using its normal mounting means. For centrifuges, the location of the test item (with reference to the G level established for the test) shall normally be determined by a measurement from the rotational center of the centrifuge to the geometric center of the test item. Should any point of the test item nearest the center of the centrifuge experience less than 90 percent of the specified G level, the test item shall be moved outward on a radius of the centrifuge or the speed of rotation shall be increased until not less than 90 percent of the specified G level is obtained.

Caution: If the furthest end of the test item experiences more than 110 percent of the desired G level at the geometric center (while the nearest end experiences 90 percent or under), then the test item may be tested using a lower speed and a larger radius centrifuge arm. For large test specimens exceptions should be made to allow for maximum gradient based on the existing availability of large centrifuges in commercial or Government test facilities.

3.1.1 Test item orientation (centrifuge). When a centrifuge is used to attain the required acceleration levels, the test item shall be oriented as follows:

Fore: Front or forward end of test item shall face toward center of centrifuge.

Aft: Reverse item 180 degrees from the fore position.

Up: Top of specimen shall face toward center of centrifuge.

Down: Reverse item 180 degrees from the up position.

Lateral: Each side (right, left) in turn shall face toward center of centrifuge.

3.2 Test level determination. The G level to be applied to the test item is contingent on two factors: The direction of forward acceleration level A of the vehicle, and the orientation of the test item within the vehicle.

Where: A = The highest possible known or unknown forward acceleration of a vehicle in which equipment is to be mounted. A shall never be less than one g, where g is acceleration due to gravity.

Instructions for selection of test levels for procedure I from table 513.2-I, and for procedure II from table 513.2-II are as follows:

Forward accel. of vehicle	Orientation of test item in vehicle	Test level
Known	Known	Substitute known acceleration A in forward acceleration column of appropriate vehicle category, and use given multiplying factors to attain test level for indicated directions.
Known	Unknown	Substitute known acceleration A in forward acceleration column of appropriate category, and use largest given multiplying factor to attain test level for all directions.
Unknown	Known	Select most probable level from those given in forward acceleration column of appropriate category, and use given multiplying factors to test level for required direction.

Table 513.2-I. G Levels for Structural Test (Procedure I)

Vehicle Category	Forward Acceleration A (g) 1/	Test Level 4/				
		Direction of Vehicle Acceleration (see figure 513.2-1)				
		Fore	Aft	Up	Down	Lateral (two directions)
Aircraft 3/	2.0	1.5xA	4.5xA	6.75xA	2.25xA	3.0xA
Helicopters	2.0	1.5xA	1.5xA	5.25xA	2.25xA	3.0xA
Manned aero-space vehicles	6.0 to 12.0 2/	1.5xA	0.5xA	2.25xA	0.75xA	1.0xA
Aircraft carried stores	In accordance with MIL-A-8591					
Ground launched missiles	6.0 to 30.0 2/	1.5xA	0.5xA	1.0xA	1.0xA	1.0xA

1/ Levels in this column shall be used when forward acceleration is unknown. When the forward acceleration of the vehicle is known, that level shall be used for A.

2/ When forward acceleration is not known, the high limits shown shall be specified.

3/ Forward acceleration for carrier based aircraft shall be 4g.

4/ Add pitch and roll accelerations as applicable.

Table 513.2-II. G Levels for Operational Test (Procedure II)

Vehicle Categoty	Forward Acceleration A (g) 1/	Test Level 4/				
		Direction of Vehicle Acceleration (see figure 513.2-1)				
		Fore	Aft	Up	Down	Lateral (two directions)
Aircraft 3/	2.0	1.0xA	3.0xA	4.5xA	1.5xA	2.0xA
Helicopter	2.0	1.0xA	1.0xA	3.5xA	1.5xA	2.0xA
Manned aero-space vehicles	6.0 to 12.0 2/	1.0xA	0.33xA	1.5xA	0.5xA	0.66xA
Air carried stores	In accordance with MIL-A-8591					
Ground launched missiles	6.0 to 30.0 2/	1.0xA	0.33xA	0.66xA		0.66xA

1/ Levels in this column shall be used when forward acceleration is unknown. When the forward acceleration of the vehicle is known, that level shall be used for A.

2/ When forward acceleration is not known, the high limits shown shall be specified.

3/ Forward acceleration for carrier based aircraft shall be 4g.

4/ Add pitch and roll accelerations as applicable.

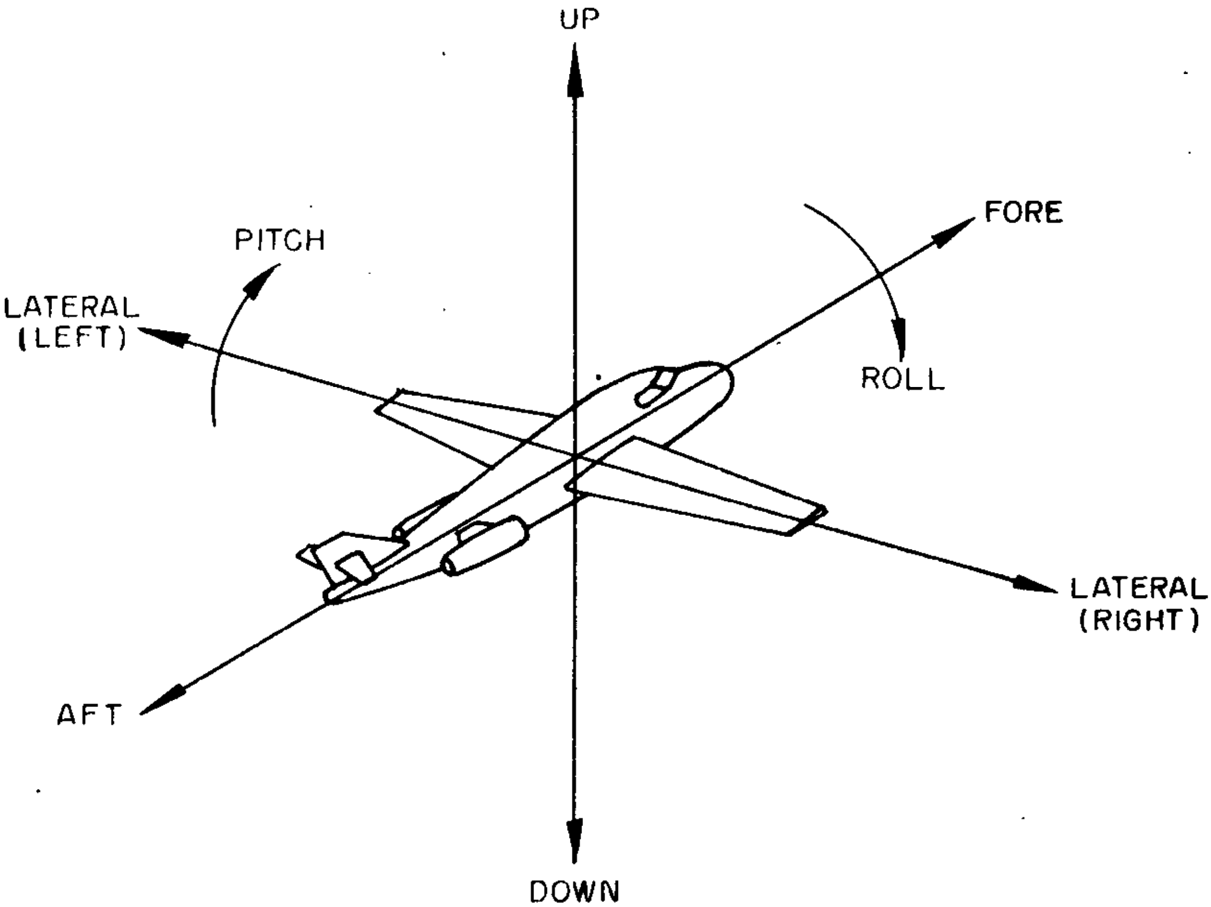


FIGURE 513.2-1. Direction of Vehicle Acceleration

Unknown	Unknown	Select most probable level from those given in forward acceleration column of appropriate category, and use largest given multiplying factor to attain test level for all directions.

3.2.1 The test levels for table 513.2-I and table 513.2-II are based on accelerations at the C.G. (center of gravity) of the vehicle. For fighter aircraft, these G levels must be increased for equipment locations away from the C.G. to account for maneuver loads, including the effects of roll and pitch motions.

a. For the up and down directions, the increase shall be as follows for wing locations:

$\Delta G_r = \frac{d(\alpha_r)}{g}$, where ΔG_r = Additional acceleration due to roll

d = lateral distance from C.G. in feet

α_r = maximum roll acceleration, radians/sec^2 (Use α_r = 15 unless otherwise known)

g = 32.17 ft/sec^2

Add the ΔG_r value obtained above to the table 513.2-II acceleration value for the operational test acceleration level. For the structural test level, multiply the new operational test value by 1.5 if this provides a value larger than table 513.2-I.

b. For lateral directions, the G level shall be determined as follows for wing locations:

$G_{cr} = \frac{d\omega^2}{g}$, where G_{cr} = centrifugal acceleration due to roll

ω = maximum roll velocity, radians/sec (Use ω = 5 unless otherwise known)

d = lateral distance from C.G. in feet

g = 32.17 ft/sec^2

Use the G_{cr} level obtained above for the operational test acceleration level when the computed value is larger than that in table 513.2-II. For the structural test level, multiply the new operational test value by 1.5 if this provides a value larger than table 513.2-I.

c. For the up and down directions, the increase shall be as follows for fuselage locations:

$$\Delta G_p = \frac{d\alpha_p}{g}, \text{ where } \Delta G_p = \text{Additional acceleration due to pitch}$$

d = fore and aft distance from C.G.

α_p = maximum pitch acceleration in radians/sec^2. (use $\alpha_p = 5$ unless otherwise known)

g = 32.17 ft/sec^2

Add the ΔG_p value obtained above to the table 513.2-II acceleration value for the operational test acceleration level. For the structural test level, multiply the new operational test value by 1.5.

d. For the fore and aft directions, the G level shall be determined as follows for fuselage locations:

$$G_{cp} = \frac{d(\omega)^2}{g}, \text{ where } G_{cp} = \text{centrifugal acceleration due to pitch}$$

ω = maximum pitch velocity, radians/sec (use ω = 2.5 unless otherwise known)

d = fore or aft distance from C.G.

g = 32.17 ft/sec^2

Use the G_{cp} level computed above for the operational test acceleration level when the computed value is larger than that in table 513.2-II. For the structural test level, multiply the new operational test value by 1.5.

3.3 Procedure I structural test. The test item shall be installed on the acceleration apparatus in accordance with General Requirements, 3.2.2, by its normal mounting means. The G level shall be determined in accordance with 3.2, and shall be applied while the test item is nonoperating.

3.3.1 Performance of test. The G level determined for the test shall be applied along at least three mutually perpendicular axes in two opposite directions along each axis. The test time duration in each direction shall be at least 1 minute following centrifuge stabilization. On centrifuges, a test time of 1 minute is usually sufficient to determine structural soundness (proper operation); however, the test time may be increased. Test times for other apparatus will probably be shorter, depending upon the type of apparatus. At the conclusion of the test, the test item shall be operated and inspected and results obtained in accordance with General Requirements, 3.2.

3.4 Procedure II operational test. The test item shall be installed on the accelerated apparatus in accordance with General Requirements, 3.2.2, by its normal mounting means. The G level shall be determined in accordance with 3.2, and shall be applied while the test item is operating. The test item shall then be inspected as specified in General Requirements, 3.2.

3.4.1 Performance of test. The G level determined for the test shall be applied along at least three mutually perpendicular axes in two opposite directions along each axis. The test time duration in each direction shall be at least 1 minute following centrifuge stabilization. A test time of 1 minute is usually sufficient to determine proper operation, however, the test time may be increased. The test item shall be operated before, during, and at the conclusion of each test and results obtained in accordance with General Requirements, 3.2.

4. SUMMARY. The following details shall be as specified in the equipment specification or test plan:

a. Procedure number if both procedures are not required (see 3)

b. Pretest data required

c. Failure criteria

d. Test level and test time (see 3.3 and 3.4)

e. Length of time required for operation and required measurements.

METHOD 514.2

VIBRATION

1. PURPOSE. The vibration test is performed to determine if equipment is constructed to withstand expected dynamic vibrational stresses and to insure that performance degradations or malfunctions will not be produced by the service vibration environment. Tests specified herein are established for equipment which may be used in a variety of military applications.

2. APPARATUS. Vibration equipment with required instrumentation.

3. GENERAL. The vibration test tables and figures provide a convenient means of summarizing test procedures to be specified in the equipment specification or test plan according to various military applications. Each table title refers to the applicable category of the equipment to be tested. Guidance for selecting a test is as follows:

a. Determine equipment category (or categories) in accordance with 3.1.

b. Proceed to the designated table(s) and figure(s) corresponding to the applicable equipment category. Select a test based on the table instructions, procedure, and figure designated.

3.1 Equipment category. For purposes of this test method, equipment is categorized according to the vehicle in which it will be installed or transported as follows:

Category	Description	Procedure	Table	Figure
a	Equipment installed in airplanes and helicopters. An equipment intended for both aircraft and helicopters should be qualified for each installation in turn.	--	514.1-I (discontinued)	514.1-1 (discontinued)
b.1	Equipment installed in propellor airplanes and equipment mounted directly to engines including jet engines.	I	514.2-II	514.2-2
b.2	Equipment installed in jet airplanes except for jet engine mounted equipment.	IA	514.2-IIA	514.2-2A

c	Equipment installed in helicopters	I	514.2-III	514.2-3
d.1	Equipment installed in external stores carried on airplanes	IIA	514.2-IV	514.2-4
d.2	Assembled external stores carried on airplanes	IIB	514.2-IV	514.2-4A
d.3	Assembled externally carried stores for helicopters	IIC	514.2-IVA	514.2-4B, 4C, 4D, 4E, 4F
e	Equipment installed in ground launched missiles	V, VI or VII as applicable	514.2-V	514.2-5
f	Equipment installed in ground vehicles	VIII	514.2-VI	514.2-6
g	Equipment transported as cargo	X, XI	514.2-VII	514.2-7
h	Ground equipment, excluding category f. (For transportation see category g.)	--	--	--
i	Shipboard and amphibious equipment or when a ship is the common carrier (see 4.6.13)	--	--	--

3.2 Applicable tests. For any given equipment category, all tests listed beside the selected procedure for the applicable equipment mounting configuration in the tables shall be performed unless otherwise specified. For example, referring to table 514.2-V section A, for testing equipment category e when procedure VI is selected, there are three parts with different test levels indicated by the test curves. Tests indicated by (X) in all three parts shall be performed to evaluate equipment with isolators.

3.3 Selection of test curves. A curve shall be selected from the tables and figures or by making a detailed analysis of the expected vibration environment within the particular vehicle involved. A primary consideration is the equipment location with respect to predominant vibration sources such as high intensity noise of jet and rocket exhausts, aerodynamic excitation including atmospheric wind and turbulence, and unbalance of rotating parts. Additional factors to be considered shall include attenuation or amplification and filtering by structural members. Guidance for selecting vibration curves with respect to equipment location or application is given in the tables. Applicable test curves for each equipment category are shown on the figures.

3.4 Procedure selection. The equipment specification or test plan shall identify which tests are to be imposed on the equipment by specifying the applicable procedure, table, figure, and test curve.

3.4.1 Example. Select the test conditions for equipment to be used in the following application:

Category: Equipment installed in a propellor airplane

Equipment location: Forward half of fuselage

Equipment mounting: On vibration isolated panel

Referring to table 514.2-II, the above identification specifies the following test conditions:

Procedure I

Part 1 (curve C)

Part 2 (curve B)

Part 1 specifies a resonance search, resonance dwell and sinusoidal vibration cycling to the level of curve C from figure 514.2-2 within the time schedule specified for part 1 on table 514.2-II. Next, with vibration isolators removed in accordance with note 2, part 2 is performed the same as part 1 but to the test level or curve B from figure 514.2-2 within the time schedule specified for part 2 from table 514.2-II.

4. PROCEDURES. The basis for selecting a test procedure for a particular equipment category shall be according to 3. The vibration environment, specified by the curve selected from applicable tables in accordance with 3, shall be applied to each of the three mutually perpendicular axes of the test item. (For assembled external stores, see procedure IIB.) The entire sequence of tests may be accomplished for any one axis before changing to the next axis. The transverse motion at the input monitoring point(s) shall be minimized, and should be limited to 100 percent of the input motion except that reaction machines shall be balanced to reduce transverse motion ±10 percent.

4.1 Test item operation. Unless otherwise specified, the test item shall be operated during application of vibration (resonance search, resonance dwell, cycling, and random vibration) so that functional effects caused by these tests may be evaluated. Procedure IA, IIA and IIB provide for a functional vibration test and an endurance vibration test. The test item shall meet performance requirements as specified in the detail equipment specification and General Requirements, 3.2 while the functional vibration test levels are being applied. When a test item performance test is required during vibration and the time required for the performance test is greater than the duration of the vibration test, the performance test may be abbreviated accordingly. The test item shall be operated and inspected and the results shall be obtained in accordance with General Requirements, 3.2

4.2 Mounting techniques. The test item shall be attached by its normal mounting means, either directly to the vibration exciter or transition table, or by means of a rigid fixture capable of transmitting the vibration conditions specified herein. Precautions shall be taken in the establishment of mechanical interfaces to minimize the introduction of extraneous responses in the test setup. The test load shall be distributed as uniformly as possible on the vibration exciter table in order to minimize effects of unbalanced loads. The input control sensing device(s) shall be rigidly attached to the vibration table, or fixture if used, as near as possible to the attachment point(s) of the test item. Additional vibration sensors shall be located in or on the test item to determine resonant frequencies and amplification factors. Locations to be selected should include main structure, printed circuit boards, large components, and modules, where practicable. The sensor sizes and weights shall be limited so that their effect on the dynamic responses being measured is minimal. For sinusoidal vibration, when necessary for obtaining uniform results, a tracking filter should be used in the vibration exciter control feedback loop prior to the servo input.

4.3 Combined temperature-vibration test. Tests shall be performed under room ambient conditions unless a high or low temperature vibration test is specified, in which case the temperature extremes and time duration also shall be as specified in the equipment specification.

4.5 Common test techniques

4.5.1 Sinusoidal vibration tests. The vibration shall be applied along each of three mutually perpendicular axes of the test item. The vibratory acceleration levels or double amplitudes of the specified test curve shall be maintained at the test item mounting points. When necessary for obtaining uniform results, a tracking filter should be used in the exciter control feedback loop prior to the servo input. When specified, for sinusoidal resonance search, resonance dwell, and cycling tests of items weighing more than 80 pounds mounted in airplanes, and missiles, the vibratory accelerations shall be reduced 1g for each 20-pound increment over 80 pounds. Acceleration derating shall apply only to the highest test level of the selected curve, but in no case shall the derated test level be less than 50 percent of the selected curve (see note 1 of the applicable table). When the input vibration is measured at more than one control point, the control signal shall be the average of all the accelerometers unless otherwise specified. For massive test items, fixtures and large force exciters, it is recommended that the input control level be an average of at least three or more inputs.

4.5.1.1 Resonance search. Resonant frequencies of the equipment shall be determined by varying the frequency of applied vibration slowly through the specified range at reduced test levels but with sufficient amplitude to excite the item. Sinusoidal resonance search may be performed using the test level and cycling time specified for sinusoidal cycling test, provided the resonance search time is included in the required cycling test time of 4.5.1.3.

4.5.1.2 Resonance dwell. The test item shall be vibrated along each axis at the most severe resonant frequencies determined in 4.5.1.1. Test levels, frequency ranges, and test times shall be in accordance with the applicable conditions from the tables and figures for each equipment category. If more than four significant resonant frequencies are found for any one axis, the four most severe resonant frequencies shall be chosen for the dwell test. If a change in the resonant frequency occurs during the test, its time of occurrence shall be recorded and immediately the frequency shall be adjusted to maintain the peak resonance condition. The final resonant frequency shall be recorded.

4.5.1.3 Cycling. The test item shall be vibrated along each axis in accordance with the applicable test levels, frequency range, and times from the applicable tables and figures. The frequency of applied vibration shall be swept over the specified range logarithmically in accordance with figure 514.2-10. The specified sweep time is that of an ascending plus a descending sweep and is twice the ascending sweep time shown on figure 514.2-10 for the specified range.

4.5.2 Random vibration test. The test item shall be subjected to random vibration along each of three mutually perpendicular axes according to the specified curve. Test times shall be according to the applicable schedule from the tables. The instantaneous random vibration acceleration peaks may be limited to three times the rms acceleration level. The power spectral density of the test control signal shall not deviate from the specified requirements by more than +100,-30 percent (+3, -1.5 dB) below 500 Hz and +100, -50 percent (±3 dB) between 500 Hz and 2,000 Hz except that deviations as large as +300, -75 percent (±6 dB) shall be allowed over a cumulative bandwidth of 100 Hz maximum, between 500 and 2,000 Hz.

Tolerance levels in terms of dB are defined as:

$$dB = 10 \log_{10} \frac{W_1}{W_0}$$

Where W_1 = measured acceleration power spectral density in G^2/Hz units. The term W_0 defines the specified level in G^2/Hz units. Confirmation of these tolerances shall be made by use of an analysis system providing statistical accuracies corresponding to a bandwidth-time constant product, BT = 50, minimum. Specific analyzer characteristics shall be as specified below or equivalent, subject to the BT = 50, minimum limitation.

a. On-line, contiguous filter, equalization/analysis system having a bandwidth as follows:

B = 25 Hz, maximum between 20 and 200 Hz

B = 50 Hz, maximum between 200 and 1,000 Hz

B = 100 Hz, maximum between 1,000 and 2,000 Hz

b. Swept frequency analysis systems characterized as follows:

(1) Constant bandwidth analyzer.

(a) Filter bandwidth as follows:

B = 25 Hz, maximum between 20 to 200 Hz

B = 50 Hz, maximum between 200 to 1,000 Hz

B = 100 Hz, maximum between 1,000 to 2,000 Hz

(b) Analyzer averaging time = T = 2 RC = 1 second, minimum, where T = True averaging time and RC = analyzer time constant

(c) Analysis sweep rate (linear) = $R = \frac{B}{4RC}$ or $\frac{B^2}{8}$ (Hz/second) maximum, whichever is smaller.

(2) Constant percentage bandwidth analyzer

(a) Filter bandwidth = pf_c = one-tenth of center frequency maximum, ($0.1f_c$) where p = percentage and f_c = analyzer center frequency

(b) Analyzer averaging time = $T = \frac{50}{pf_c}$, minimum

(c) Analysis sweep rate (logarithmic) = $R = \frac{pf_c}{4RC}$ or $\frac{(pf_c)^2}{8}$

(Hz/second), maximum, whichever is smaller.

c. Digital power spectral density analysis system employing quantization techniques providing accuracies corresponding to the above approach.

Accelerometer(s) employed for test level control shall be mounted in accordance with 4.2. Where more than one accelerometer is employed for test level control, the power average of the several accelerometer signals shall be used as the test level signal control.

4.6 Procedures

4.6.1 Procedure I. Equipment installed in airplanes or helicopters. (Category b.1 or c.)

4.6.1.1 Part 1. For category b.1 equipment, proceed the same as in 4.5.1.1, 4.5.1.2, and 4.5.1.3. The test levels and time durations shall be as specified in table 514.2-II and figure 514.2-2. For category c equipment, proceed the same as in 4.5.1.3 only. The test levels and time schedules shall be as specified in table 514.2-III and figure 514.2-3.

4.6.1.2 Part 2. For category b.1 equipment, test items normally provided with vibration isolators shall be vibrated in accordance with 4.5.1.1, 4.5.1.2, and 4.5.1.3 with the vibration isolators removed but including any other required holding devices. The test levels and time durations shall be as specified in table 514.2-II and figure 514.2-2. For category c equipment, proceed the same as in 4.5.1.3 only with the vibration isolators removed but including any other holding devices. The test levels and time schedules shall be as specified in table 514.2-III and figure 514.2-3.

4.6.2 Procedure IA. Random vibration test for equipment installed in jet airplanes. (Not for turboprop aircraft or jet powered helicopters.) The random vibration environment which occurs at equipment locations in jet aircraft stems from four principal sources:

a. Turbulent aerodynamic airflow along external surfaces of the aircraft structure.

b. Jet engine noise impinging on aircraft structure.

c. Gun blast pressure impinging on aircraft structure from high speed repetitive firing of installed guns.

d. General aircraft motions caused by such factors as runway roughness, landing, and gusts.

The tests outlined in this procedure consider all of these environments and require design to the most severe of these. These tests are preferred for use with equipment in jet aircraft in lieu of the sinusoidal tests of procedure I, table 514.2-II, figure 514.2-2, except for jet engine mounted equipment. For equipment mounted directly to aircraft jet engines, use procedure I. To determine an equipment specific random vibration test, compute functional and endurance test levels for aerodynamic induced and for jet engine induced vibration from table 514.2-IIA and figure 514.2-2A. Use the more severe of the two functional levels as the equipment's functional test, and the more severe of the two endurance levels (on an equal time, T, basis) for the equipment's endurance test.

4.6.2.1 Performance of test. The individual equipment test item shall be subjected to broadband random vibration excitation. The power spectral density tolerances of applied vibration shall be according to 4.5.2. The test item shall be attached to the vibration exciter according to 4.2. Equipment hard mounted in service shall be hard mounted to the test fixture. Equipment isolated in service shall use service isolators when mounted on the test fixture. If service isolators cannot be made available during the qualification test, isolators shall be provided with characteristics such that the isolator/equipment resonant frequencies shall be between 20 Hz and 45 Hz with resonant amplification ratio between 3 and 5. Vibration shall be applied sequentially along each of the three orthogonal axes of the test item. Two test levels are required, a functional level and an endurance level. For each axis, one half of the functional test shall be conducted first, then the endurance test, followed by the second half of the functional test. The equipment shall perform according to the equipment specification operating requirements in accordance with General Requirements, 3.2 during the functional testing. The acceleration power spectral density (G^2/Hz) of applied vibration, as measured on the test fixture at mounting points of the test item, shall be according to table 514.2-IIA and figure 514.2-2A. The functional and endurance test time durations and other test conditions shall be determined from the test level equations and other parameter values from table 514.2-IIA.

4.6.2.2 Equipment with isolators. Equipment designed for operational installation on vibration isolators shall also be subjected to a minimum rigidity endurance test with the isolators removed. This test shall be conducted according to part 2, procedure 1, table 514.2-II, and curve AR of figure 514.2-2. At the conclusion of this test the equipment shall provide specified performance, in accordance with General Requirements, 3.2.

4.6.2.3 References

a. Dreher, J.F., "Aircraft Equipment Random Vibration Test Criteria Based on Vibrations Induced by Turbulent Airflow Across Aircraft External Surfaces," Shock and Vibration Bulletin No. 43 (part 3, pp 127-139), NRL, Wash., DC, June 1973.

b. Wafford, J.H., and Dreher, J.F., "Aircraft Equipment Random Vibration Test Criteria Based on Vibration Induced by Jet and Fan Engine Exhaust Noise," Shock and Vibration Bulletin No. 43 (part 3, pp 141-151), NRL, Wash., DC, June 1973.

c. Earls, D.L., "Technical Progress on New Vibration and Acoustic Tests," for proposed MIL-STD-810C entitled, Environmental Test Methods, Journal of Environmental Sciences, pp 22-32, July/August 1973.

4.6.3 Procedure II. This procedure includes tests for three applications:

a. Individual equipment items designed for installation in external stores carried on airplanes

b. Assembled external stores carried on airplanes

c. Assembled external stores carried on helicopters

These tests apply to such stores as air launched missiles, bombs, dispensers, instrument pods and rocket launchers (see equipment categories d.1, d.2 and d.3 as applicable).

4.6.3.1 Procedure IIA. Equipment installed in external stores carried on airplanes.

4.6.3.1.1 Test conditions. The individual equipment test item (designed for installation in an external store) shall be subjected to broadband random vibration excitation. The power spectral density tolerances of applied vibration shall be according to 4.5.2. The test item shall be attached to the vibration exciter according to 4.2. Vibration shall be applied sequentially along each of the three orthogonal axes of the test item.

4.6.3.1.2 Captive flight. Two test levels are required, a functional level and an endurance level. For each axis, one-half of the functional test shall be conducted first, then the endurance test, followed by the second-half of the functional test. The equipment shall perform according to the equipment specification operating requirements in accordance with General Requirements, 3.2 during the functional testing. The acceleration power spectral density (G^2/Hz) of applied vibration, as measured on the test fixture at mounting points of the test item, shall be according to table 514.2-IV and figure 514.2-4 except as noted below. The functional and endurance test time durations and other test conditions shall be determined from the test level requirements and other parameter values from table 514.2-IV. If the computed functional and endurance (T=1) test levels (W_2) are less than 0.04 G^2/Hz, use $W_2 = 0.04\ G^2/Hz$ and T = 1 for the endurance test.

4.6.3.1.3 Free flight functional test. For stores that are deployed by separation from the aircraft (free flight) such as bombs and missiles, a free flight functional test shall be conducted in addition to the captive flight tests of 4.6.3.1.2. The equipment shall perform according to the equipment specification operating requirements in accordance with General Requirements, 3.2 during the functional testing. 4.6.3.1.1, 4.6.3.1.2, table 514.2-IV, and figure 514.2-4 shall be used to determine the test procedures, levels and frequency spectra for the free flight test except as noted below. In this case, factors A_1, A_2, and (N/3T) shall be set equal to one. The value of q shall be the maximum value attainable during free flight. The duration of this functional test, per axis, shall equal the maximum free flight time expected at maximum q, but not less than 30 seconds. In the event that all free flight functional checks are made during the captive functional test and the captive functional test levels are larger than or equal to those derived here (4.6.3.1.3), no free flight functional test is required.

NOTE: Items marked DISCONTINUED refer to items of the superseded issue of MIL-STD-810 including notices thereto.

4.6.3.1.4 References

a. Dreher, J. F., Lakin, E. D., Tolle, E. A., "Vibracoustic Environment and Test Criteria for Aircraft Stores During Captive Flight," Shock and Vibration Bulletin No. 39, Supplement, (pp 15-40), NRL, Wash., DC, April 1969.

b. Dreher, J. F., "Effects of Vibration and Acoustical Noise on Aircraft/Stores Compatibility," Proc. Aircraft Store Compatibility Symp., Vol. 6, pp 245-272, Eglin AFB, Florida, November 1969.

c. Piersol, A. G., "Vibration and Acoustic Test Criteria for Captive Flight of Externally Carried Aircraft Stores," AFFDL-TR-71-158, Wright-Patterson AFB, Ohio, December 1971.

d. Burkhard, A., "Captive Flight Acoustic Test Criteria for Aircraft Stores," Shock and Vibration Bulletin No. 43, Part 3 (pp 113-126), NRL, Wash., DC., June 1973.

4.6.3.2 Procedure IIB. Assembled externally carried airplane stores

4.6.3.2.1 Purpose. This vibration test is performed to determine that the assembled store as a system is constructed to withstand and perform in the expected dynamic environment. The nature of this test is to simulate the lower frequency vibratory environment of the store by application of vibratory energy at discreet points. To insure that the vibratory test levels reflect the inflight vibratory levels, the selection of the test points and vibration input levels are determined by the response of the store. Procedure II of Method 515.2, acoustic testing for assembled externally carried aircraft stores, shall also be conducted to simulate the higher frequency distributed aerodynamically induced vibratory environment. Acoustic testing is not required if the minimum value of f_o of 4.6.3.2.3 is greater than 1,200 Hz. Procedure IIA of this method shall be used when individual equipment items such as fuzes, electronic equipment, etc., need to be tested separately from the whole store.

4.6.3.2.2 Accelerometer placement. Accelerometers to monitor the vibratory response of the store shall be mounted on two relatively hard points or rings within the store: one in the nose section and one in the aft section. For stores such as bombs with nonintegral tail cones, the aft section mounting point shall be in the aft most section of the main body of the store. At each mounting point or ring, two accelerometers shall be mounted - one in the vertical and one in the lateral plane. (Longitudinal direction is along the axis of the store. The vertical direction shall be considered as perpendicular to the longitudinal axis and contained in a plane passing through the mounting lugs.)

4.6.3.2.3 Test levels. The test frequency spectrum for each store mounted monitoring accelerometer shall be determined from figure 514.2-4A and the values of table 514.2-IV. Generally, the test spectrum for the forward accelerometers will be different from that of the aft accelerometers. Test levels for both a functional and endurance test shall be determined. The value of f_o used in figure 514.2-4A for this test shall be defined as follows:

$f_o = (t/R^2) \times 10^5 + 100$ Hz for stores with circular or elliptical cross-sections

f_o = 500 Hz for all other cross-sections

t = local store average skin thickness where radius, R, is measured--inches

R = one-half the average of major and minor external diameters (inches) of the elliptical cross-section (for a cylindrical section use local average radius; for conical section use smallest f_o calculated using geometry within 1 foot of accelerometer mounting point)

NOTE: If calculated $f_o \leq$ 1,200 Hz, use 2,000 Hz
Acceptable range for t/R^2 = .001 $\leq$ t/R2 $\leq$ .02
If calculated values fall outside these limits, use these limit values.

4.6.3.2.4 Test setup. The store shall be mounted and tested with its longitudinal axis horizontal and positioned so that its mounting lugs are on top of the store using 4.6.3.2.4a or, as an alternate, 4.6.3.2.4b, depending on the facilities available.

a. Mounting method. The store shall be suspended from a structural frame by means of its normal mounting lugs using hooks and sway braces which simulate the operational mounting apparatus. The test setup shall be such that the rigid body modes (translation and rotation) of vibration for the store/frame/suspension system are between 5-20 Hz. Vibration shall be applied to the store by means of a rod or other suitable mounting device running from a vibration shaker to a relatively hard structurally supported point on the surface of the store.

b. Alternate mounting method. The store shall be hard mounted directly to the shaker, using its normal mounting lugs and a suitable fixture. The stiffness of the mounting fixture shall be such that its induced resonant frequencies are as high as possible but none are below one-third of any f_o frequency.

4.6.3.2.5 Determination of resonance response peaks. Vibration shall be applied at an input level sufficient to excite vibratory responses within the store. The frequencies at which significant resonance response peaks occur shall be identified for each store mounted accelerometer using no greater than a 10 percent constant percentage bandwidth analysis. A resonance response peak shall have at least a 6 dB amplification of input level to be considered significant. This shall be done for both vertically and laterally applied vibration.

4.6.3.2.6 Captive flight test. The following procedure shall be performed so that both the lateral and vertical directions are tested to their respective test levels. Separate testing for each direction shall be required unless one test is able to excite both directions simultaneously to their respective test levels. Two test levels are required, a functional level and an endurance level. For each axis, one-half of the functional test shall be conducted first then the endurance test followed by second half of functional test. The equipment shall perform according to the equipment specification operating requirements during functional testing.

4.6.3.2.6.1 Part 1. Random vibration shall be applied to the store using an input spectrum shape of the store mounted forward accelerometer, but at an input level 6 dB down from the calculated response level of the forward accelerometer. The input random vibration level shall then be peaked or notched in those portions of the frequency range where significant resonance response peaks were identified in 4.6.3.2.5. The peaking and notching of the input spectrum shall be such that the significant resonance response peaks of each store mounted accelerometer in the direction of applied vibration shall be equal to or greater than their respective test levels calculated in 4.6.3.2.3 and figure 514.2-4A. When using the test setup of 4.6.3.2.4a, different attachment locations for the shaker to the store may be tried to determine an optimum point so that both ends of the store are simultaneously tested to their respective test levels.

4.6.3.2.6.2 Part 2. The response of the accelerometers in the direction perpendicular to the store mounted accelerometers which were used to establish the test spectrum shall be compared to their levels specified in 4.6.3.2.3. For each frequency where the response of a (the) perpendicular accelerometer(s) is above their specified levels the following procedure may be used.

4.6.3.2.6.3 Part 3. Calculate at each of these frequencies a ratio of specified to observed levels for each accelerometer which was in the direction of vibration and those perpendicular accelerometer(s) which have excessive levels. These ratios shall be averaged so that an average value is determined for each frequency. The input vibration spectrum shall be adjusted so that at each of these frequencies their respective average value shall be equal to unity. The duration of the functional and endurance test is given in table 514.2-IV and the test levels for each test are determined in 4.6.3.2.3.

4.6.3.2.7 Free flight functional test. For stores that are deployed by separation from the aircraft (free flight) such as bombs and missiles, a free flight functional test shall be conducted in addition to the captive flight tests of 4.6.3.2.6. The equipment shall perform according to the equipment specification operating requirements as specified in General Requirements, 3.2 during the functional testing. Use 4.6.3.2.6, table 514.2-IV, and figure 514.2-4A to determine the test procedures, levels and frequency spectra for the free flight test except as noted below.

In this case, factors A_1, A_2, and (N/3T) shall be set equal to one. The value of q shall be the maximum value attainable during free flight. The duration of this functional test, per axis, shall equal the maximum free flight time expected at maximum vibration level, but not less than 30 seconds. In the event that all free flight functional checks are made during the captive functional test and the captive functional test levels are larger than or equal to those derived here (4.6.3.2.7), no free flight functional test is required.

4.6.3.2.8 References

a. Dreher, J. F.; Lakin, E. D.; Tolle, E. A.; "Vibracoustic Environment and Test Criteria for Aircraft Stores During Captive Flight," Shock and Vibration Bulletin No. 39, Supplement (pp 15-40), NRL, Wash., DC, April 1969.

b. Dreher, J. F., "Effects of Vibration and Acoustical Noise on Aircraft/Stores Compatibility," Proc. Aircraft Store Compatibility Symp., Vol. 6, pp 245-272, Eglin AFB, Florida, November 1969.

c. Piersol, A. G., "Vibration and Acoustic Test Criteria for Captive Flight of Externally Carried Aircraft Stores," AFFDL-TR-71-158 Wright-Patterson AFB, Ohio, December 1971.

4.6.3.3 Procedure IIC, assembled externally carried stores for helicopters

4.6.3.3.1 Purpose. To determine that externally carried stores attached to the wings and pylons of helicopters (with a main rotor speed of 324 rpm, two blades, such as UH-1B, UH-1C, AH-1G, etc) are capable of withstanding expected dynamic vibrational stresses normally induced by the helicopter during flight conditions and to qualify the equipment for service life. If the equipment normally operates while being carried by the helicopter, then the equipment is expected to operate satisfactorily during the vibration test. For helicopters other than the above, use values of frequencies and g levels applicable to the helicopter on which that item is to be mounted.

NOTE: This procedure is only applicable to the operating phase of the equipment and does not include the common carrier transportation phase.

4.6.3.3.2 Test fixture. A rigid test fixture shall be designed for attaching the test item to the vibration exciter in all three axes with the mounting lugs in the up position. The test item shall be attached to the fixture by its normal mounting means (e.g., suspension lugs for 2.75-inch FFAR launchers). The vibration levels shall be controlled from an accelerometer mounted at or near the attachment point on the test item.

4.6.3.3.3 Cycling test. The test item shall be subjected to vibration cycling in each of three orthogonal axes. The frequency of applied vibration shall be cycled at a logarithmic rate between the frequency limits and at the vibratory acceleration levels as shown on figure 514.2-4B. The cycling period and rate shall be determined from table 514.2-IVA.

4.6.3.3.4 Dwell test. The test item shall be subjected to vibration dwell in each of three orthogonal axes. The dwell test shall be conducted at the four frequencies and at the vibratory acceleration levels as shown on figures 514.2-4D, 514.2-4E, 514.2-4F for the particular weight of the test item. (The minimum acceleration level shall be 0.5g for all dwell tests.) The dwell period at each frequency shall be determined from curve A of figure 514.2-4C.

NOTE: For test items such as rocket launchers, which are flown to the target area loaded and come back empty, it is recommended that one-half of the cycling test be applied to a loaded launcher and the other half be applied to an empty launcher.

4.6.4 Procedure III (Former 4.8 DISCONTINUED). (See equipment categories d.1 and d.2.)

4.6.5 Procedure IV (Former 4.9 DISCONTINUED). (See equipment categories d.1 and d.2.)

4.6.6 Procedure V. Equipment installed in ground launched missiles (without vibration isolators, equipment category e.)

4.6.6.1 Part 1. Proceed the same as in 4.5.1.3. The test level shall be according to one specified curve P through U from table 514.2-V and figure 514.2-5. Test time schedules shall be as listed for part 1 of procedure V as specified in table 514.2-V.

4.6.6.2 Part 2. Proceed the same as in 4.5.2. The test level shall be according to one specified in curve AE through AP from table 514.2-V and figure 514.2-5. Test time schedules shall be as listed for part 2 of procedure V as specified in table 514.2-V.

4.6.7 Procedure VI. Equipment installed in ground launched missiles (with vibration isolators, equipment category e.)

4.6.7.1 Part 1. Test items normally provided with vibration isolators shall be vibrated with the isolators in place as in 4.5.1.3. Test levels shall be according to one specified curve P through U from figure 514.2-5. Test time schedules shall be as listed for part 1 of procedure VI as specified in table 514.2-V.

4.6.7.2 Part 2. Test items normally provided with vibration isolators shall be vibrated in accordance with 4.5.1.3 with the vibration isolators removed but including any other required holding devices. Test levels shall be according to curve N from figure 514.2-5. Test time schedules shall be as listed for part 2 of procedure VI as specified in table 514.2-V.

4.6.7.3 Part 3. With vibration isolators in place, proceed the same as in 4.5.2. Test levels shall be according to one specified curve AE through AP from figure 514.2-5. Test time schedules shall be as listed for part 3 of procedure VI as specified in table 514.2-V.

4.6.8 Procedure VII (Former 4.12). Equipment installed in ground launched missiles. (Isolated equipment, tested without isolators, equipment category e.)

4.6.8.1 Part 1. Proceed the same as in 4.5.1.3. Test levels shall be according to curve N from figure 514.2-5. Test time schedules shall be as listed for part 1 of procedure VII as specified in table 514.2-V.

4.6.8.2 Part 2. Proceed the same as in 4.5.2. Test levels shall be according to curve AE from figure 514.2-5. Test time schedules shall be as specified for part 2 of procedure VII as specified in table 514.2-V.

4.6.9 Procedure VIII (Former 4.13). Equipment installed in ground vehicles (equipment category f). Proceed the same as in 4.5.1.3. Test levels shall be according to one specified curve V, W, or Y from figure 514.2-6. Test time schedules shall be as specified in procedure VIII as specified in table 514.2-VI. When test item resonances below 5 Hz are measured or expected the test curves shall be extended to 2 Hz and the sweep time shall be 18 minutes (2-500-2 Hz); 15 minutes (2-200-2 Hz).

4.6.10 Procedure IX (Former 4.14)

4.6.10.1 Part 1 (Former 4.14.1) DISCONTINUED

4.6.10.2 Part 2, bounce, vehicular

4.6.10.2.1 Apparatus. A package tester capable of 1 inch (double amplitude) displacement and of suitable capacity for testing military equipment.

4.6.10.2.2 Test conditions

a. Cover the test bed of the package tester with a panel of 1/2-inch plywood, with the grain parallel to the drive chain. Secure the plywood with six-penny nails, with top of heads flush with, or slightly below the surface. Space nails at 6-inch intervals around all four edges. If the distance between either pair of fences is greater than 24 inches, the plywood shall also be nailed at 3-inch intervals in a 6-inch square at the center of the test area.

b. Using suitable wooden fences, constrain the vehicular, or simulated, adapter plate to a horizontal motion of not more than 2 inches in any lateral direction.

4.6.10.2.3 Performance of test

Step 1 - Prepare the test item in accordance with General Requirements, 3.2, securing the test item to the vehicular, or simulated, adapter plate and placing on the package tester with the constraints outlined in 4.6.10.2.2. If the test item weighs over 200 pounds, simulated adapter plate approved by the procuring agency shall be used.

Step 2 - Attach an accelerometer as close as possible to the point of test item attachment to record the shock transmitted to the test item.

Step 3 - Adjust the package tester, shafts in phase and table operating in a vertical linear mode, to a speed such that the average value of the random acceleration peaks shall be 7.5 ±2.5g's. Measure this input with an accurate measuring or recording system at the output of a band pass filter. The filter band pass shall be 0.2 to 100 Hz and the attenuation slope shall be 12 to 18 dB per octave at the 3-dB down point. Due to the random nature of the input, pulses greater than 10g's can be expected to occur, however, if they are infrequent, they need not be used in calculating the average. Perform the test for a total of 3 hours. At the end of each 3/4-hour period, rotate the adapter plate and test item 90 degrees each time in the same direction.

Step 4 - At the end of the 3-hour period, operate and inspect the test item in accordance with General Requirements, 3.2. Then inspect the test item as specified in General Requirements, 3.2.

4.6.11 Procedure X (Former 4.15). Equipment transported as secured cargo. Proceed the same as in 4.5.1.3 with the unpackaged test item secured to the vibrator table. The test level and time schedules shall be in accordance with figure 514.2-7 and table 514.2-VII. The test item will not be operated during vibration.

4.6.12 Procedure XI (Former 4.16). Equipment transported as loose cargo.

4.6.12.1 Part 1 (Former 4.16.1) DISCONTINUED

4.6.12.2 Part 2, bounce, loose cargo

4.6.12.2.1 Purpose. To determine that the equipment, as prepared for field use, shall be capable of withstanding the vibrations normally induced during combat transportation as loose cargo. Equipment in this class is normally transported in a transit case, combination case, or special container from which it is removed just prior to use, e.g., ammunition or missiles.

4.6.12.2.2 Apparatus. A package tester capable of 1 inch (double amplitude) displacement and of suitable capacity for testing military equipment.

4.6.12.2.3 Test conditions. The test bed of the package tester shall be covered with a panel of 1/2-inch plywood, with the grain parallel to the drive chain. The plywood shall be secured with six-penny nails, with top of heads flush with or slightly below the surface. Nails shall be spaced at 6-inch intervals around all four edges. If the distance between either pair of fences is greater than 24 inches, the plywood shall also be nailed at 3-inch intervals in a 6-inch square at the center of the test area. Using suitable wooden fences, constrain the test item to a horizontal motion of not more than 2 inches in a direction parallel to the axes of the axes of the shafts, a distance more than sufficient to insure the test item will not rebound from fence to fence. For large items, care should be taken to avoid potential air-cushioning effects which may exist between the surface of the package tester and the test item.

4.6.12.2.4 Performance of test. The test item, as secured in its transit case, or combination case, or as otherwise prepared for field transportation, shall be placed on the package tester within the constraints outlined above. The test item will not be operated during vibration. The package tester shall be operated in the synchronous mode with the shafts in phase. (In this mode any point on the bed of the package tester will move in a circular path in a vertical plane perpendicular to the axes of the shafts.) The package tester shall be operated at 1-inch double amplitude and 284 rpm ±2 rpm for a total of 3 hours. At the end of each 1/2-hour period, turn the test item to rest on a different face, so that at the end of the 3-hour period the test item will have rested on each of its six faces (top, bottom, sides, and ends). At the end of the 3-hour period, the test item shall be operated and inspected and results obtained in accordance with General Requirements, 3.2. The package tester shall be operated in the vertical linear mode (straight up and down in the vertical plane) instead of in the synchronous mode when one of the following conditions occurs:

a. Bouncing of the test item is very severe and presents a hazard to personnel.

METHOD 508.2

FUNGUS

Section I

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I.2 PURPOSE. The purpose of the fungus chamber test is to assess the extent to which the test item will support fungal growth and how the fungal growth may affect performance or use of the test item.

I.3 ENVIRONMENTAL EFFECTS. Fungal growth impairs the functioning or use of equipment by changing the physical properties of the equipment.

I.3.1 *Damage mechanisms*. The damage mechanisms are as follows:

a. Direct attack on materials. Non-resistant materials are susceptible to direct attack as the fungi break the material down and use it as food. This results in deterioration affecting the physical properties of the material. Examples of non-resistant materials are:

(1) Natural materials - (Products of natural origin are most susceptible to this attack) -

(a) Cellulosic materials (e.g. wood, paper, natural fiber textiles and cordage).

(b) Animal and vegetable based adhesives.

(c) Grease, oils and many hydrocarbons.

(d) Leather.

(2) Synthetic materials -

(a) PVC formulations (e.g. those plasticized with fatty acid esters).

(b) Certain polyurethanes (e.g. polyesters and some polyethers).

(c) Plastics, which contain organic fillers of laminating materials.

(d) Paints and varnishes which contain susceptible constituents.

b. Indirect attack on materials. Damage to fungus resistant materials results from indirect attack when:

(1) fungal growth on surface deposits of dust, grease, perspiration and other contaminants which find their way onto equipment during manufacture or accumulate during service can cause damage to the underlying material even though that material may be resistant to direct attack.

(2) metabolic waste products (i.e. organic acids), excreted by fungi, cause corrosion of metals, etching of glass or staining or degrading of plastics and other materials.

(3) the products of fungal growth on adjacent materials, which are susceptible to direct attack, come in contact with the resistant materials.

I.3.2 Physical interference. Physical interference can occur as follows:

a. Electrical or electronic systems. Damage to electrical or electronic systems may result from either direct or indirect attack. Fungal growth can form undesirable electrical conducting paths across insulating materials or may adversely affect the electrical characteristics of critically adjusted electronic circuits.

b. Optical systems. Damage to optical systems results primarily from indirect attack. The fungal growth can adversely affect light transmission through the optical system; block delicate moving parts; and change non-wetting surfaces to wetting surfaces with resulting loss in performance.

I.3.3 Health and aesthetic factors. Fungus growth on equipment can cause physiological problems, (e.g. allergies) or be so aesthetically unpleasant that the users will be reluctant to use the equipment.

I.4 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS. Since microbial deterioration is a function of temperature and humidity and is an inseparable condition of hot-humid tropics and the midlatitudes, it must be considered in the design of all standard general purpose materiel.[1] Method 508.2 (Fungus) consequently is used when an item is to be tested to determine if fungus growth will occur and if so, how it will affect the use of the item.

[1]From AR 70-38, Research, Development, Test and Evaluation of Material for Extreme Climatic Conditions, Chapter 2, Climatic Criteria.

a. Options. The options are limited to extending the test duration and performing a functional test prior to and following the fungus test.

b. The related test conditions involve primarily:

(1) Test time (28 to 84 days).

(2) Test configuration - whether the test item shall be exposed in other than an unsealed condition.

I.4.1 Choice of test phases

a. The operational purpose of the test item. From the requirements, determine the functions to be performed by the equipment and any limiting conditions, (e.g. storage, human factors aspects, whether it is a large volume/low cost/ expendable item, etc.).

b. Required test data. The primary questions that may be addressed after the fungus test are:

(1) Will fungus grow on the item?

(2) How rapidly will it grow on the test item?

(3) How does the fungus growth affect the test item?

(4) To what extent will the fungus affect the mission of the item?

(5) Can the test item be stored effectively in a field environment?

(6) Is the test item safe for use following fungal growth?

(7) Are there simple reversal processes, e.g. wiping off fungal growth?

c. Selection of test phases. Three test phases are included within Method 508.2 (pre-test, chamber and performance). Based on the test requirements document, determine which phases are applicable.

(1) Phase I (pre-test) - Phase I is conducted in all cases to provide baseline data.

(2) Phase II (chamber) - Phase II is the basic fungus test and is conducted in all cases.

(3) Phase III (performance) - Phase III is used to determine compliance with the performance requirements of the test item following the fungus chamber test.

I.4.2 Choice of related test conditions. Recognizing that at least two of the test phases must be conducted, the primary decisions must be made concerning test duration and test item configuration.

a. Test duration. A test duration of 28 days is considered to be the minimum test period. Since indirect effects and physical interference are not likely to occur in the relatively short time frame of the fungus test, extension of the exposure period to 84 days should be considered if a greater degree of certainty (lesser risk) concerning the existence of fungal growth or determining the effect of fungal growth is required.

b. Test item configuration. The test item configuration is an important factor. Even though equipment is to be protected by a container, the container could leak and entrap moisture. As a minimum, the tester should consider the following testing configurations:

(1) In usual shipping/storage container or transit case.

(2) Under realistic storage and use conditions.

(3) With restraints (such as with openings that are normally covered, or commercial equipment not designed for military use).

c. Additional guidelines. Review the equipment specifications and requirements documents. Apply any additional guidelines as necessary.

I.5 SPECIAL CONSIDERATIONS

I.5.1 Failure analysis

a. Any fungi on the test item must be analyzed to determine if the growth is on the test item materials(s) or on contaminants.

b. Any fungal growth on the test item material(s) (whether from the inoculum or other sources) must be evaluated by qualified personnel for:

(1) The extent of growth on the component(s) supporting same. Table 508.2-1 can be used as a guide for this evaluation.

(2) The immediate effect that the growth has on the physical characteristics of the test item.

(3) The long range effect that the growth could have on the test item.

(4) The specific material(s) (nutrient) supporting the growth.

c. Fungal growth must not be disturbed during the operational checkout.

d. Human factors effects must be evaluated.

I.5.2 Test interruption. This policy is designed to provide a standard methodology for selecting a course of action in the event of an unscheduled interruption in a test. Any deviation from this policy shall be explained in the test report. Every case of an interrupted test shall be examined individually using the logical decision process provided in this document. The fungus test, unlike other environmental tests, involves living organisms. If the test is interrupted, the fact that live organisms are involved must be considered.

a. If the interruption occurs early in the test, the test should be restarted from the beginning with a new test item or a cleaned item (see II.3.3.1a).

b. If the interruption occurs late in the test cycle, examine the item for evidence of fungal growth. If the test item is biosusceptible, there is no need for a retest. If there is no evidence of fungal growth or if the interruption occurred early follow the guidance as shown below.

(1) Lowered temperature. A lowering of the test chamber temperature generally will retard fungus growth. If there is no evidence of mycological deterioration and the relative humidity has been maintained as in I.5.1b(3), re-establish test conditions and continue the test from the point that the temperature fell below the prescribed tolerances.

(2) Elevated temperature. Elevated temperatures may have a drastic effect on fungus growth. Any rise in temperature above 31°C (88°F) for a period of 4 hours or more shall result in complete re-initiation of the test. Any more moderate risk in temperature without evidence of mycological deterioration, and maintaining of the relative humidity as in I.5.1b(3), re-establish test conditions and continue the test as if no interruption had occurred.

(3) Lowered humidity. Any drop in humidity levels below 90 percent, for a period of 4 hours or more shall result in complete re-initiation of the test. If a more moderate drop in relative humidity occurs that does not result in fungal deterioration, re-establish test conditions and continue the test as if no interruption had occurred.

When re-initiating a test although it is preferable to use a new test item, the same test item may be used if cleaned as specified in II.3.1a. New cotton control strips shall be placed in the test chamber and both the test item and controls will be reinoculated with the test fungi.

I.5.3 <u>Miscellaneous</u>

a. The fungus test is designed to economically obtain data on the biosusceptibility of materiel. It should not be used for testing of basic materials since a variety of other test procedures, including soil burial, pure culture, mixed culture and plate testing are available.

b. Method 508 is designed to provide optimal climatic conditions and all of the basic inorganic minerals needed for growth of the fungal species used in the test. The group of fungal species was chosen for its ability to attack a wide variety of materials commonly used in construction of military equipment.

c. The test temperature and humidity cycle selected for this test involves a 5° Celsius drop in temperature to allow moist air to enter the test item (breathing effect) and condense onto or in the internal components, thus representing a natural environment diurnal cycle.

d. The presence of moisture is essential for spore germination and subsequent growth. Generally, germination and growth will commence when the relative humidity of the ambient air exceeds 70 percent. Development will become progressively more rapid as the humidity rises above this value, reaching a maximum in the 90-100 percent relative humidity range.

e. The specified temperature range 24-31°C (75-88°F) is most conducive for fungal growth known to cause damage to equipment.

f. Control items specified in phase II are designed to:

(1) Verify the viability of the fungal spores used in the inoculum.

(2) Establish the suitability of the chamber environment conducive for fungal growth.

g. Testing of equipment for resistance to fungal growth is a specialized technique requiring both appropriate technical knowledge and access to proper fungus cultures and test equipment. Such testing must be preformed at laboratories specially equipped for the work by trained personnel.

I.6 REFERENCES

TABLE 508.2-1 Microbial test evaluation scheme.

Amount of Growth	Percent of Area of Component Covered	Grade	Organic Substrates
None	0	0	Substrate is devoid of microbial growth.
Trace	1-10	1	Sparse or very restricted microbial growth and reproduction. Substrate utilization minor or inhibited. Little or no chemical, physical, or structural change detectable.
Slight	11-30	2	Intermittent infestations or loosely spread microbial colonies on substrate surface and moderate reproduction.
Moderate	31-70	3	Substantial amount of microbial growth and reproduction. Substrate exhibiting chemical, physical or structural change.
Severe	71-100	4	Massive microbial growth or reproduction. Substrate decomposed or rapidly deteriorating.

METHOD 508.2

FUNGUS

Section II

II.1 APPARATUS. The required apparatus consists of chambers or cabinets, together with auxiliary instrumentation capable of maintaining and monitoring the specific conditions of temperature and humidity and complies with 3.3.1, General Requirements.

II.2 PREPARATION FOR TEST

a. The chamber and accessories shall be constructed and arranged in such a manner as to avoid condensate dripping on the test item.

b. The chamber shall be vented to the atmosphere to prevent the build up of total pressure.

c. Relative humidity shall be determined from the dry bulb - wet bulb temperature comparison method or an equivalent method approved by the procuring activity.

(1) When the wet bulb control method is used, the wet bulb assembly shall be cleaned and a new wick installed for each test.

(2) The air velocity across the wet bulb shall not be less than 4.6 meters per second (900 feet per minute).

(3) The wet and dry bulb sensors shall not be installed in the discharge side of any local fan or blower used to create the requirements of II.2.c(2).

d. Provisions shall be made for controlling the flow of air throughout the internal test chamber space so that the air velocity shall be between 1 and 2 meters per second (197-394 ft/min).

e. Free circulation of air around the test item shall be maintained, and the contact area of fixtures supporting the test item shall be kept to a minimum (see 3.3, General Requirements, Test Facilities and Apparatus).

f. Continuous recordings of test section temperature and relative humidity conditions shall be taken.

g. Readout charts shall be capable of being read with a resolution within 0.6°C (1°F).

h. The desired humidity shall be generated by using steam, or distilled, demineralized or dionized water having a pH value between 6.0 and 7.2 at 23°C (73°F).

(1) Live steam shall not be injected directly into the test section working space where it may have an adverse affect on the test item and microbial activity.

(2) Rust or corrosive contaminants shall not be imposed on the test item by the test facility.

i. Unless otherwise specified:

(1) All reagents shall conform to the specification of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.

(2) References to water shall be understood to mean distilled water or water of equal purity.

j. If the test is interrupted, follow the procedure of I.5.1.

II.3 PROCEDURES. The following test phases are provided for application in combinations as required. Prior to initiating any testing, determine:

a. The test duration(s) (I.4.2a).

b. The test item configuration(s) (I.4.2b).

II.3.1 Phase I. Pre-test checkout - All items require a pre-test checkout to provide baseline data. Conduct the checkout as follows:

Step 1. Prepare the test item in accordance with 3.2.2 General Requirements, and required test item configuration (II.3b).

Step 2. Conduct a complete visual examination of the test item with special attention to discolored areas, imperfections, or the existence of any other conditions that could be conducive to fungus growth.

Step 3. Document the results of step 2.

Step 4. Conduct an operational checkout in accordance with the approved test plan if operation is specified by requirements document during or following the fungus test.

Step 5. Record results for compliance with 3.2.2, General Requirements.

Step 6. Proceed to phase II.

II.3.2 Phase II. Chamber test.

II.3.2.1 Test preparation.

II.3.2.1.1 Preparation of mineral salts solution.

a. Using clean apparatus, prepare the mineral salts solution to contain the following:

Potassium dihydrogen orthophosphate (KH_2PO_4) 0.7g

Potassium monohydrogen orthophosphate (K_2HPO_4) 0.7g

Magnesium sulphate heptahydrate ($MgSO_4.7 H_2O$) 0.7g

Ammonium nitrate (NH_4NO_3) 1.0g

Sodium chloride (NaCl). 0.005g

Ferrous sulfate heptahydrate ($FeSO_4.7 H_2O$) 0.002g

Zinc sulfate heptahydrate ($ZnSO_4.7 H_2O$) 0.002g

Manganous sulfate monohydrate ($MnSO_4. H_2O$). 0.001g

Distilled water 1000ml

b. Measure the pH of the mineral salts solution. If not between 6.0 and 6.5, discard and prepare a proper solution.

II.3.2.1.2 Preparation of mixed spore suspension. NOTE: PRECAUTIONS: Although the fungi specified for this test are not normally considered to present a serious hazard to humans, certain people may develop allergies or other reactions. It is therefore recommended that standard operation procedures (SOPs) for safety be employed. It is also recommended that the tests be conducted by personnel trained in microbiological techniques.

a. Using asceptic techniques, prepare the spore suspension containing the following test fungi:

FUNGI	FUNGUS SOURCE IDENTIFICATION NO. USDA*	ATCC**
Aspergillus niger	QM 386	ATCC 9642
Aspergillus flavus	QM 380	ATCC 9643
Aspergillus versicolor	QM 432	ATCC 11730
Penicillium funiculosum	QM 474	ATCC 11797
Chaetomium globosum	QM 459	ATCC 6205

*U. S. Department of Agriculture (SEA/FR)
Northern Regional Research Center
ARS Culture Collection
1815 N. University Street
Peoria, Illinois 60604

(The fungi may be distributed in a lyophilized state, or on agar slants).

**American Type Culture Collection
12301 Parklawn Drive
Rockville, Maryland 20852

b. Maintain pure cultures of these fungi separately on an appropriate medium such as potato dextrose agar except that chaetomium globosum shall be cultured on strips of filter paper overlayed on the surface of mineral salts agar.

c. Prepare mineral salts agar by dissolving 15.0g agar in a liter of the mineral salts solution described in II.3.2.1.1. Note: Do not keep the stock cultures for more than 4 months at $6^{\circ} \pm 4^{\circ}C$ ($43^{\circ} \pm 7^{\circ}F$); after that time, prepare subcultures and use them for the new stocks.

d. Verify the purity of fungus cultures prior to the test.

e. Incubate subcultures used for preparing new stock cultures or the spore suspension at $30^{\circ} \pm 1.4^{\circ}C$ ($86^{\circ} \pm 2.5^{\circ}F$) for 14 to 21 days.

f. Prepare a spore suspension of each of the five fungi by pouring into one subculture of each fungus 10 ml of an aqueous solution containing 0.05g per liter of a nontoxic wetting agent such as sodium dioctyl sulfosuccinate or sodium lauryl sulfate.

g. Use a rounded glass rod to gently scrape the surface growth from the culture of the test organism.

h. Pour the spore charge into a 125 ml capped Erlenmeyer flask containing 45 ml of water and 50 to 75 solid glass beads, 5 mm in diameter.

i. Shake the flask vigorously to liberate the spores from the fruiting bodies and to break the spore clumps.

j. Filter the dispersed fungal spore suspension into a flask through a 6 mm layer of glass wool contained in a glass funnel. Note: This process should remove large mycelial fragments and clumps of agar.

k. Centrifuge the filtered spore suspension and discard the supernatant liquid.

l. Resuspend the residue in 50 ml of water and centrifuge. Wash the spores obtained from each of the fungi in this manner three times.

m. Dilute the final washed residue with mineral-salts solution in such a manner that the resultant spore suspension shall contain 1,000,000 ± 200,000 spores per ml as determined with a counting chamber.

n. Repeat this operation for each organism used in the test.

o. Perform a viability check for each organism in accordance with II.3.2.1.3a.

p. Blend equal volumes of the resultant spore suspension to obtain the final mixed spore suspension. Note: The spore suspension may be prepared fresh. If not freshly prepared, it should be held at $6^\circ \pm 4^\circ C$ ($43^\circ \pm 7^\circ F$) for not more than 7 days.

II.3.2.1.3 Control items. Two types of control tests are required. Using procedure of II.3.3.1.3a verify the viability of the spore suspension and its preparation. Using the procedure of II.3.2.1.3b verify the suitability of the chamber environment.

a. Viability of spore suspension.

(1) Prior to preparing the composite spore suspension inoculate sterile potato dextrose agar plates with 0.2 to 0.3 milliliters of the spore suspension of each of the individual fungal species using separate potato dextrose agar plates for each species.

(2) Distribute the inoculum over the entire surface of the plate.

(3) Incubate the inoculated potato dextrose agar plate at 24° to $31^\circ C$ (75° to $88^\circ F$) for 7 to 10 days.

(4) After the incubation period, check the fungal growth. Note: The absence of copious growth of any of the test organisms over the entire surface in each container will invalidate the results of any tests using these spores.

b. Test chamber environment.

(1) Inoculate a known susceptible substrate along with the test item to insure that proper conditions are present in the incubation chamber to promote fungal growth. Note: The controlled substrate shall consist of cotton fabric strips conforming to MIL-T-43566A Tape, Textile, Cotton, General Purpose, Natural or in Colors, Type 1a, Class 2, bleached, white flat construction.

(2) Prepare the following solution:

(a) 10.0 grams glycerol

(b) 0.1 potassium dihydrogen orthophosphate (KH_2PO_4)

(c) 0.1g ammonium nitrate (NH_4NO_3)

(d) 0.025g magnesium sulfate ($MgSO_4.7\ H_2$)

(e) 0.05g yeast extract

(f) Distilled water to a total volume of 100 ml

(g) HC1 or NaOH to adjust the final solution pH to 5.3.

(3) Dip the cotton strips into the above solution. After dipping, remove the excess liquid from the strips and hang them to dry before placing them in the chamber and inoculating them.

(4) Within the chamber, place the strips vertically in close proximity to and bracketing the test item so that the test strips and test items experience the same test environment. The length of the strips shall be at least the height of the test item.

II.3.3 Phase III. Test performance

II.3.3.1 Preparation for incubation

a. Assure that the condition of the test items subjected to testing is similar to that as delivered by the manufacturer or customer for use, or as otherwise specified. Any cleaning of the test item shall be accomplished at least 72 hours prior to the beginning of the fungus test.

b. Install the test item in the chamber or cabinet on suitable fixtures or suspended from hangers.

c. Hold the test item in the operating chamber for at least 4 hours immediately prior to inoculation.

d. Inoculate the test item and cotton fabric chamber control items (II.3.2.1.3b(1) with the mixed fungal spore suspension (II.3.2.1.2) by spraying it on the control and on and into the test item(s) (if not hermetically sealed)[1] in the form of a fine mist from an atomizer or nebulizer. Note: In spraying the test and control items with composite spore suspension care should be taken to cover all external and internal surfaces which are exposed during use or maintenance. If the surfaces are nonwetting, spray until initiation of droplet coalescence.

e. Replace covers of the test items loosely.

f. Start incubation immediately following the inoculation.

II.3.3.2 Incubation of the test item.

a. Incubate the test item(s) under a daily cycle of temperature and humidity conditions consisting of 20 hours of a relative humidity of 95 ± 5 percent at an air temperature of 30° ± 1°C (86° ± 2°F) followed by a 4-hour period in which conditions of 95^{+5}_{-0} percent relative humidity at 25° ± 1°C (77° ± 2°F) are maintained for at least 2 hours. Up to a total of 2 hours of the 4-hour period will be used for the transition(s) of temperature and relative humidity. Temperature and humidity conditions during the transition periods must be as follows: temperature 24° to 31°C (75° to 88°F) and relative humidity above 90 percent.

b. Repeat the 24-hour daily cycle for the test duration.

c. After 7 days, inspect the growth on the control cotton strips to assure that the environmental conditions in the chamber are suitable for growth.

---

[1]Personnel with appropriate knowledge of the test item should be available to aid in exposing its interior surfaces for inoculation.

For this assurance, at least 90 percent of the part of the surface area of each test strip located at the level of the test item should be covered by fungi when inspected visually. If not, repeat the entire test with the required adjustments of the chamber to produce conditions suitable for growth. Leave the control strips in the chamber for the duration of the test; note their condition at this time and record it with the test item data as described in II.3.1, step 3.

d. If the cotton strips show satisfactory fungus growth after 7 days, continue the test for the required period of days from the time of inoculation (I.4.2a). If there is a decrease in fungal growth on the cotton strips at the end of the test as compared to the 7-day results, the test is invalid.

II.3.3.3 Inspection. At the end of the incubation period, inspect the test item immediately. If possible, inspect the item within the chamber. If the inspection is conducted outside of the chamber and not completed in 8 hours, return the test item to the test chamber or similar humid environment for a minimum of 12 hours. Except for hermetically sealed equipment, open the equipment enclosure and examine both the interior and exterior of the test item. Record results of the inspection to include that information of II.4 as applicable. Note: Data shall be used for comparison with that obtained in II.3.1.

II.3.4 Phase III. Operation/usage (to be conducted only if required).

II.3.4.1 If operation is required (e.g. electrical equipment), conduct the operation in the period as specified in II.3.3.3. Data shall be recorded for comparison with the baseline data obtained in II.3.1, step 3. Personnel with appropriate knowledge should be available to aid in exposing interior surfaces of the item for inspection and making operational and use decisions.

II.4 INFORMATION TO BE RECORDED

a. Presence or evidence of fungal growth.

b. Location of fungus.

c. Narrative description of growth, including colors, area covered, growth patterns, density of growth, and thickness of growth.

d. Test period.

e. Effect of fungus on performance or use.

(1) As received from chamber

(2) After use maintenance.

f. Test conditions.

g. Condition of test item at time of test.

h. All deviations from specified test conditions.

i. Whether directly from manufacturer.

j. Test item history (prior tests).

k. Physiological or aesthetic considerations.

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b. Forward and rear oscillations cannot be reduced. When operated in the vertical linear mode, wooden fences shall be placed on all four sides of the test item to constrain its motion to not more than 2 inches in either direction.

4.6.13 Procedure XII. For shipboard and amphibious equipment or when a ship is the common carrier, the vibration test shall be in accordance with type I of MIL-STD-167.

4.6.14 Procedure XIII. Transportation vibration test for system, van or shelter assemblage.

4.6.14.1 Part 1. DISCONTINUED

4.6.14.2 Part 2, bounce, system shelter assemblage

4.6.14.2.1 Purpose. To insure that the system shelter assemblage shall be capable of withstanding the vibrations normally induced during transportation. The system shelter assemblage may consist of equipment mounted in a truck or trailer, or equipment mounted in a shelter which is then mounted on a truck or trailer.

4.6.14.2.2 Performance of test. The tire pressure of the van or shelter transport vehicle shall be adjusted for tactical (off-road) cross-country service. The system shelter assemblage shall be driven five times over sections of the Munson Test Course at the Aberdeen Proving Ground, Aberdeen, Maryland, or approved equal, in the following order and at the specified speeds:

Coarse washboard (6-inch waves spaced 72 inches apart)	5 mph
Belgian block	20 mph
Radial washboard (2-inch to 4-inch waves)	15 mph
Two-inch washboard	10 mph
Three-inch spaced bump	20 mph

5. SUMMARY. The following details shall be as specified in the equipment specification or test plan:

a. Equipment category, applicable table, procedure, figure, and test curve (see 3).

b. Pretest data required (General Requirements, 3.2).

c. Failure criteria

d. Weight of test item when acceleration derating of selected curve is required (see 4.5.1 and table 514.2-IIA, note 6).

e. Temperature extremes and temperature test time durations (see 4.3).

f. Total vehicle mileage for category f equipment (see table 514.2-VI).

g. Necessary parameters for calculating test levels for equipment categories 6.2, d.1 and d.2.

Table 514.2-II. Test Procedure and Time Schedule Chart for Equipment Installed in Propeller Airplanes - Equipment Category b.1

A. Procedure Selection and Time Schedule Chart

Equipment mounting configuration	Procedure number	Procedure part number	Applicable tests (see 4 for test procedures)			Test time schedule (per axis)				Fig. 514.2-2
			Resonance search (4.5.1.1)	Resonance dwell (4.5.1.2)	Sinusoidal cycling (4.5.1.3)	Dwell time at each resonance (4.5.1.2)	Sinusoidal cycling time	Sweep time 5-500-5 Hz	Sweep time 5-2000-5 Hz	Curve 1/
Without vibration isolators	1	1	X	X	X	30 min	3 hrs less dwell time	15 min	20 min	C, D, E, F G, H, J, or L
With vibration isolators 2/	1	1	X	X	X	30 min	3 hrs less dwell time	15 min	20 min	C, D, E, F, G, J, H, or L
		2	X	X	X	10 min	30 min	15 min	20 min	B, AR
Normally with vibration isolators but tested without isolators	1	2	X	X	X	30 min	3 hrs less dwell time	15 min	20 min	B, AR

1/ For sinusoidal vibration resonance tests and cycling tests of item mounted in airplanes and weighing more than 80 pounds, the vibratory accelerations shall be reduced by 1g for each 20-pound increment of weight over 80 pounds. Acceleration derating shall apply only to the highest test level of the selected test curve, however, the vibratory acceleration shall in no case be less than 50 percent of the specified curve level.

2/ Test items of equipment normally provided with vibration isolators first shall be tested with the isolators in place (part 1). The isolators then shall be removed, and test item rigidly mounted and subjected to the test level indicated (part 2).

B. Curve Selection Chart for Category b.1 Equipment

Selection criteria	Fig. 514.2-2 Curve (for freq. to 500 Hz)	Fig. 514.2-2 Curve (for freq. to 2000 Hz for jet engines)
Equipment installed on vibration isolated panels or racks when the panel or rack is not available for test or when the equipment is tested with isolators removed as specified by the applicable procedure.	B	AR
Equipment in forward half of fuselage or equipment in wing areas of airplanes with engines at rear of fuselage.	C	J
Equipment in rear half of fuselage or equipment in wing areas of airplanes with wing or front mounted engines or other equipment of engine locations not specifically mentioned for other curves.	D	H
Equipment located in the engine compartments or engine pylons of airplanes.	E	G
Equipment mounted directly on airplane engines.	F	L

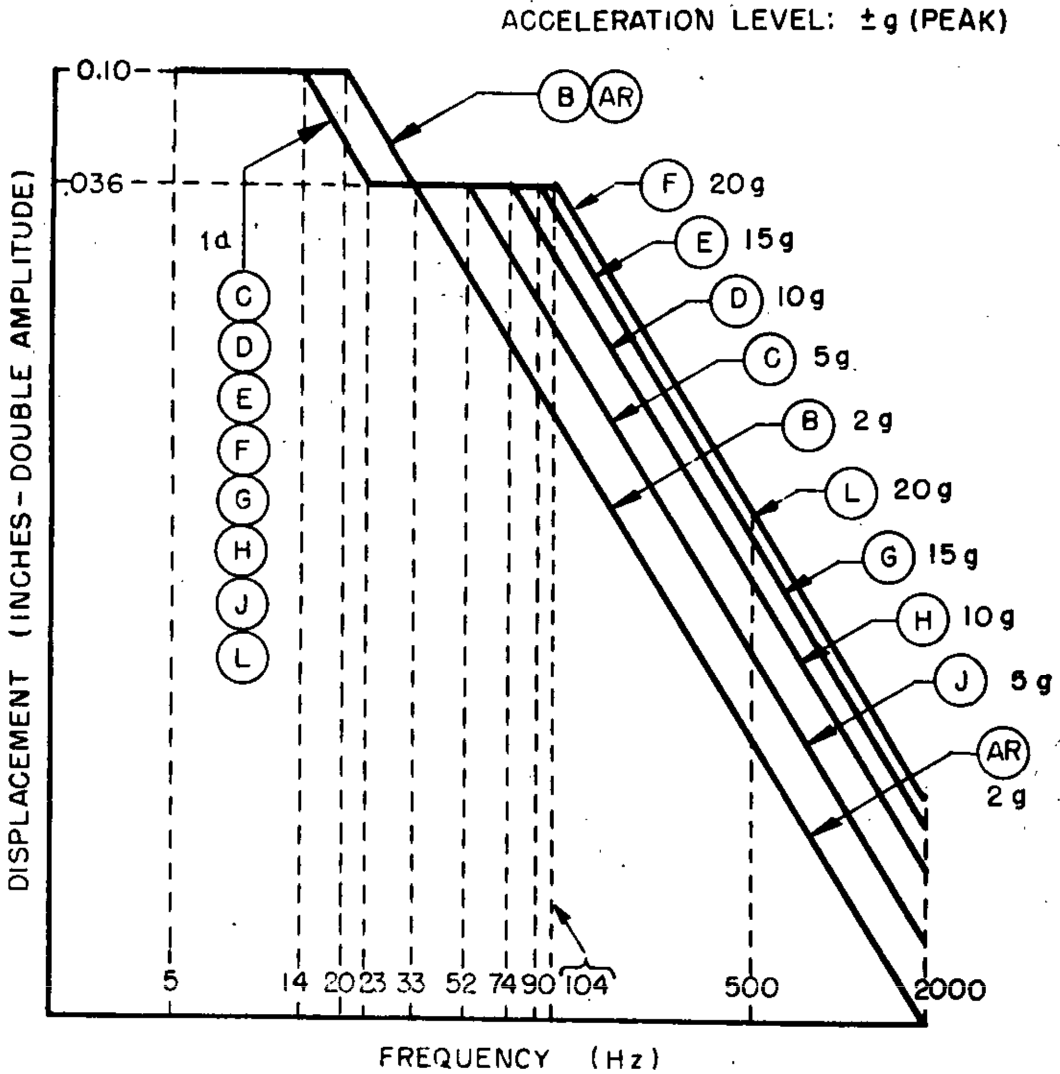
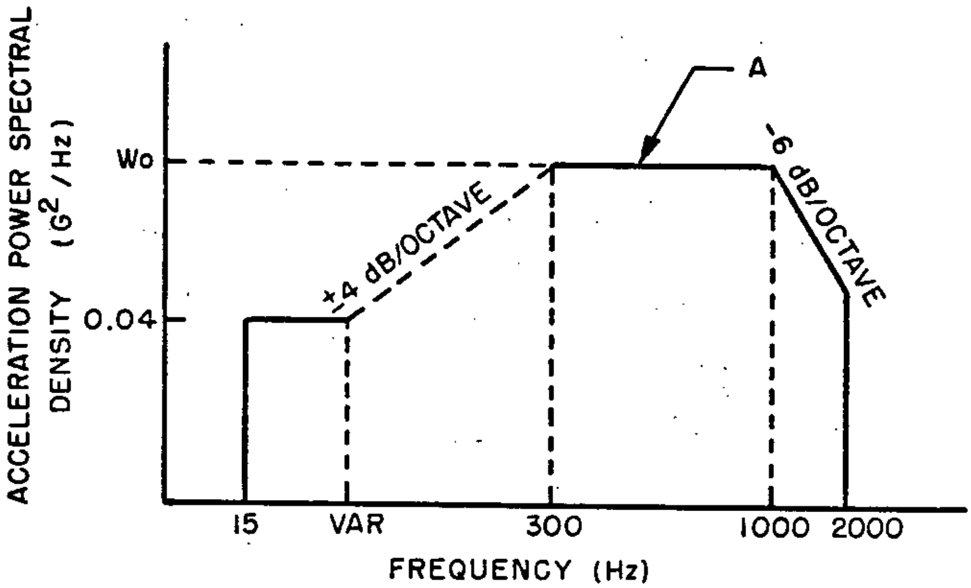


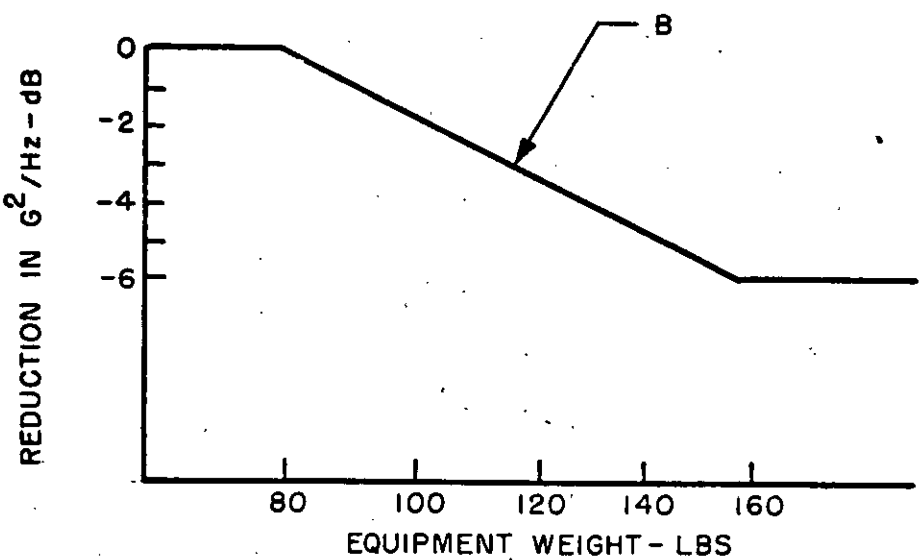
Figure 514.2-2. Vibration Test Curves for Equipment Installed in Airplanes, Excluding Helicopters, Equipment Category b.1.

Table 514.2-IIA. Random Vibration Test Criteria for Jet Aircraft Equipment, Category b.2

Criteria	Notes
Aerodynamic induced vibration (curve A, figure 514.2-2A) Functional test level 1/, 9/ $W_o = K(q)^2$ Endurance test level 2/, 3/, 6/ $W_o = K(q)^2\ (N/3T)^{1/4}$	1. Functional test time shall be 1 hour per axis. 2. Use W_o = 0.04 g^2/hz if calculated endurance test level values are less than 0.04 g2/hz, T = 1.
Jet engine noise induced vibration (curve A, figure 514.2-2A) Functional test level 1/, 4/, 6/, 7/, 8/ $W_o = (0.48\ \cos^2\theta/R)[D_c(V_c/1850)^3 + D_f(V_f/1850)^3]$ Endurance test level 2/, 3/, 4/, 6/, 7/, 8/ $W_o = (0.48\ \cos^2\theta/R)[D_c(V_c/1850)^3 + D_f(V_f/1850)^3]\ (N/10T)^{1/4}$	3. If one hour (T = 1) endurance test level is ≤ functional test level, no endurance test is required except according to Note 2.
Gunblast induced vibration (see method 519)	4. If aircraft has more than one engine, W_o shall be the sum of the individually computed values for each engine.
Definitions	
K = 2.7 x 10^{-8} for cockpit equipment and equipment attached to structure in compartments adjacent to external surfaces that are smooth, free from discontinuities. K = 14 x 10^{-8} for equipment attached to structure in compartments adjacent to or immediately aft of external surfaces having discontinuities (cavities, chins, blade antennas, speed brakes, etc.) and equipments in wings, pylons, stabilizers, and fuselage aft of trailing edge wing root. q = 1200 psf or maximum aircraft q, whichever is less. N = maximum number of anticipated service missions for equipment or carrying aircraft ($N \geq 3$). T = test time per axis, hours ($T \geq 1$). D_c = engine core exhaust diameter, feet (for engines without fans, use maximum exhaust diameter). D_f = engine fan exhaust diameter, feet. R = minimum distance between center of engine aft exhaust plane and the center of gravity of installed equipment, feet. V_c = engine core exhaust velocity, feet per sec (for engines without fans, use maximum exhaust velocity without afterburner). V_f = engine fan exhaust velocity, feet per sec. θ = angle between R line and engine exhaust axis, degrees, aft vectored.	5. For equipment weighing more than 80 pounds, the vibration W_o level may be reduced according to Curve B, Figure 514.2-2A. 6. For $70° < \theta \leq 180°$, use θ = 70° to compute W_o. 7. For engines with afterburners use W_o which is 4 times larger than W_o computed using maximum V_c and V_f without afterburner.



RANDOM VIBRATION ENVELOPE



REDUCTION FACTOR FOR MASS LOADING

Figure 514.2-2A. Random Vibration Test Curve and Mass Loading Reduction Factor for Jet Aircraft Equipment.

TABLE 514.2-III
Test procedure and time schedule chart for equipment installed in helicopters-equipment category (c)

Equipment mounting configuration	Procedure number	Procedure part number	Test time schedule (per axis)		Fig. 514.2-3 Curve (note 1)
			Sinusoidal cycling (4.5.1.3)	Sweep Time (Note 3)	
Without vibration isolators	1	1	3 hrs	36 min	M
With vibration isolators (note 2)	1	1	3 hrs	36 min	M
		2	30 min	30 min	B
Normally with vibration isolators but tested without isolators	1	2	30 min	30 min	B

Note 1: For sinusoidal vibration cycling tests of items mounted in helicopters and weighing more than 80 pounds, the vibratory accelerations shall be reduced by 1 g for each 20-pound increment of weight over 80 pounds. Acceleration derating shall apply only to the highest test level of the selected test curve. However, the vibratory acceleration shall in no case be less than 50 percent of the specified curve level.

Note 2: Test items of equipment normally provided with vibration isolators first shall be tested with the isolators in place.

Note 3: Sweep for curve M is 5-2000-5Hz, curve B is 5-500-5 Hz.

B. Curve selection chart for category (c) equipment

Selection criteria	Curve
Equipment designed for installation without vibration isolators	M
Equipment installed on vibration isolated panels or racks when the panel or rack is not available for test or when the equipment is tested with the isolators removed as specified by the applicable procedure.	B

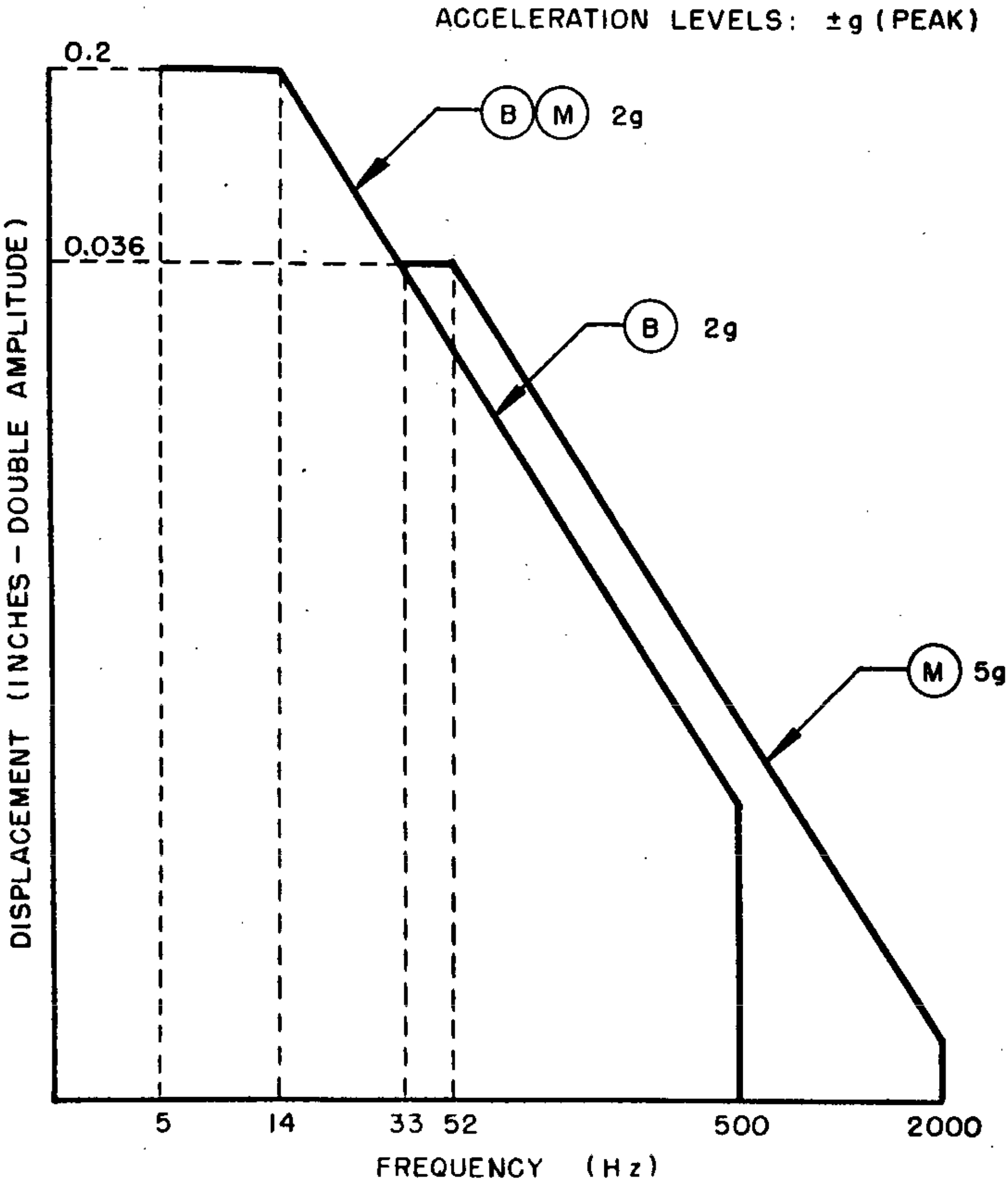


Figure 514.2-3. Vibration Test Curves for Equipment Installed in Helicopters, Equipment Category c.

Table 514.2-IV. Vibration Criteria for External Stores Carried on Airplanes - Categories d.1 and d.2

Parametric Equations for Figure 514.2-4 and 514.2-4A

Eq (1)[1, 2]: $W_1 = (5)(10^{-3})\ (N/3T)^{1/4}(A_1)(B_1)(C_1)(D_1)(E_1)g^2/Hz$

Eq (2)[1, 2]: $W_2 = (5)(10^{-5})(q/\rho)^2(N/3T)^{1/4}(A_2)(B_2)(C_2)(D_2)(E_2)g^2/Hz$

Eq (3)[3, 4]: $f_1 = 10^5\ (t/R^2)Hz$

Eq (4)[3, 4]: $f_2 = f_1 + 1000\ Hz$

Location, Configuration, Special Adjustments	Factor	
	A_1	A_2
TER (tri-ejection rack, cluster mount)	1	2
MER (multiple ejection rack, cluster mount)	2	4
Single station	1	1
	B_1	B_2
Aft half of air fired missiles	1	4
Aft half of all other stores	1	2
Forward half of all stores	1	1
	C_1	C_2
Blunt nosed stores, single station and TER	2	4
Blunt nosed stores, MER	1	2
All other stores	1	1
	D_1	D_2
Free fall munitions with nonintegral finned sheet metal tail cones	8	16
Air fired missiles	1	1
All other stores	4	4
	E_1	E_2
Firebombs (jelly filled)	1/2	1/4
All other conditions	1	1

Representative parameter values to be used for captive flight when specific parameters are not available

Store Type	Max q	ρ	N Endurance	T Endurance	f_1 (Hz)	f_2 (Hz)
Missile, air to ground	1600	100	5	None	500	1500
Missile, air to air	1600	100	100	1	500	1500
Instrument pod	1800	50	500	1	500	1500
Dispenser (reusable)	1200	50	50	1	200	1200
Demolition bomb	1200	120	3	None	125	2000
Fire bomb	1200	40	3	None	100	1100

Definitions

q = maximum flight dynamic pressure in lbs/ft^2 (see note 1).

ρ = average store weight density in lbs/ft^3 (total weight ÷ total volume)

t = local store average skin thickness where R is measured (inches)

R = one-half the average of the major and minor diameters (inches) for a store with an elliptical cross-section (for cylindrical sections use local geometry; for conical sections use smallest f_1 calculated using geometry within one foot of equipment mounting point; for cast irregular shaped cross-section, R shall be one-half the longest inscribed cord; for monocoque irregular cross-section f_1 = 300 Hz).

N = maximum number of anticipated service missions (functional test, N = 3; endurance test, N = ≥ 3).

T = test time per axis in hours (functional test, T = 1; endurance test, T ≥ 1).

Notes

1. For endurance test, q = 1200 psf or maximum q, whichever is less. For functional test, q = 1800 lbs/ft^2 or maximum q, whichever is less.

2. If functional test level is equal to or larger than the endurance test level when T = 1, no endurance test is required, except as noted in 4.6.3.1.2.

3. Free fall stores with tail fins, used f_1 = 125 Hz; $f_2 = 10^5(t/R^2) + 1000$ Hz.

4. For general use fuzes which can be used in several stores; use W_1 = .04 g^2/Hz; W_2 = 0.15 g^2/Hz; f_1 = 100 Hz; f_2 = 1000 Hz. T = 30 min/axis.

5. Acceptance range for parameter values: $40 \leq \rho \leq 150$, $.001\ t/R^2 \leq .02$

   If calculated values fall outside these limits, use these limit values.

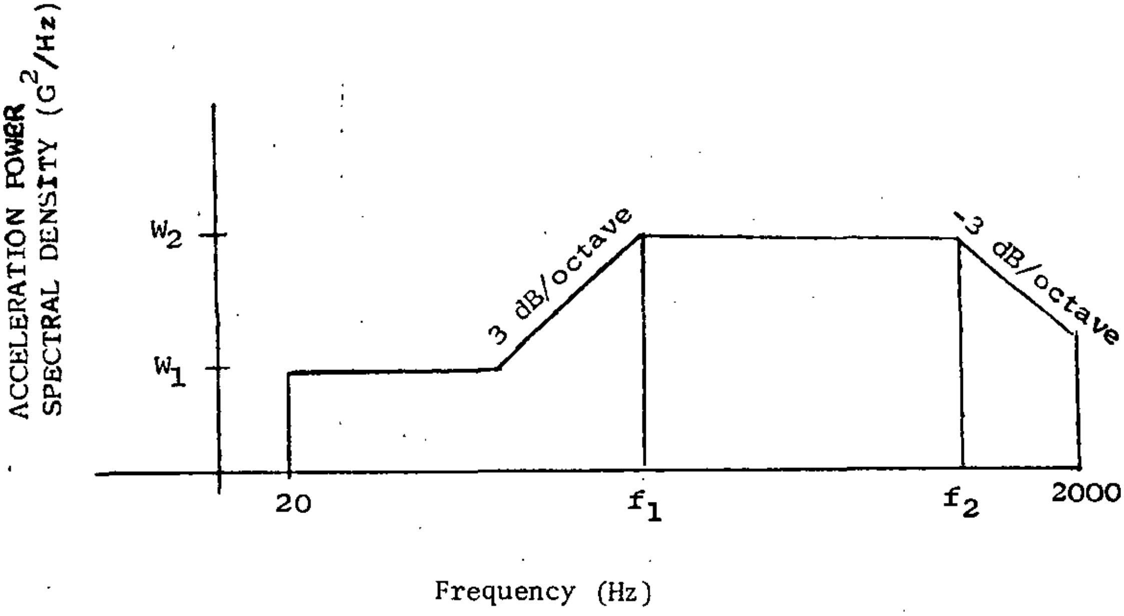
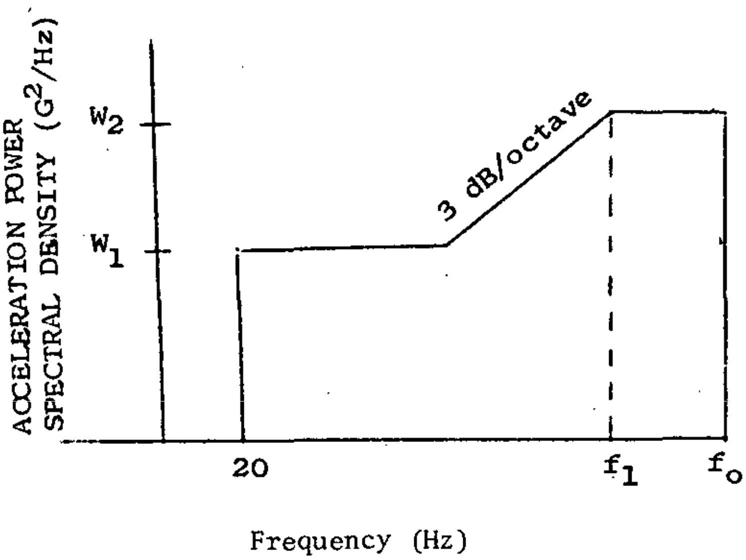


Figure 514.2-4. Vibration Test Levels for Equipment Installed in External Stores Carried on Airplanes



Use table 514.2-IV and 4.6.3.2.3 for parameter values.

Figure 514.2-4A. Vibration Test Curve for Assembled External Stores Carried on Airplanes

Table 514.2-IVA. Cycling Period and Rate, and Time Schedule Chart for Externally Carried Stores for Helicopters, Category d.3

Excitation Axis	Sinusoidal cycling (See Test Procedure 4.6.3.3.3)			(See Test Procedure 4.6.3.3.4)				
	Time Schedule		Curve (See figure 514.2-4B)	Test time per dwell	Test Level Curves			
	Sweep time 5-500-5 Hz	Total test time			11 Hz	22 Hz	33 Hz	44 Hz
Vertical	15 Minutes	See table B	A	See figure 514.2-4C	See figure 514.2-4D			
					VA	VB	VC	VD
Transverse	15 Minutes	See table B	B	See figure 514.2-4C	See figure 514.2-4E			
					TA	TB	TC	TD
Longitudinal	15 Minutes	See table B	C	See figure 514.2-4C	See figure 514.2-4F			
					LA	LB	LC	LD

Table 514.2-IVB. Sinusoidal Cycling Test Time

Number of Missions	Cycling Time per Axis (Minutes)
0-50	30
51-100	60
101-∞	90

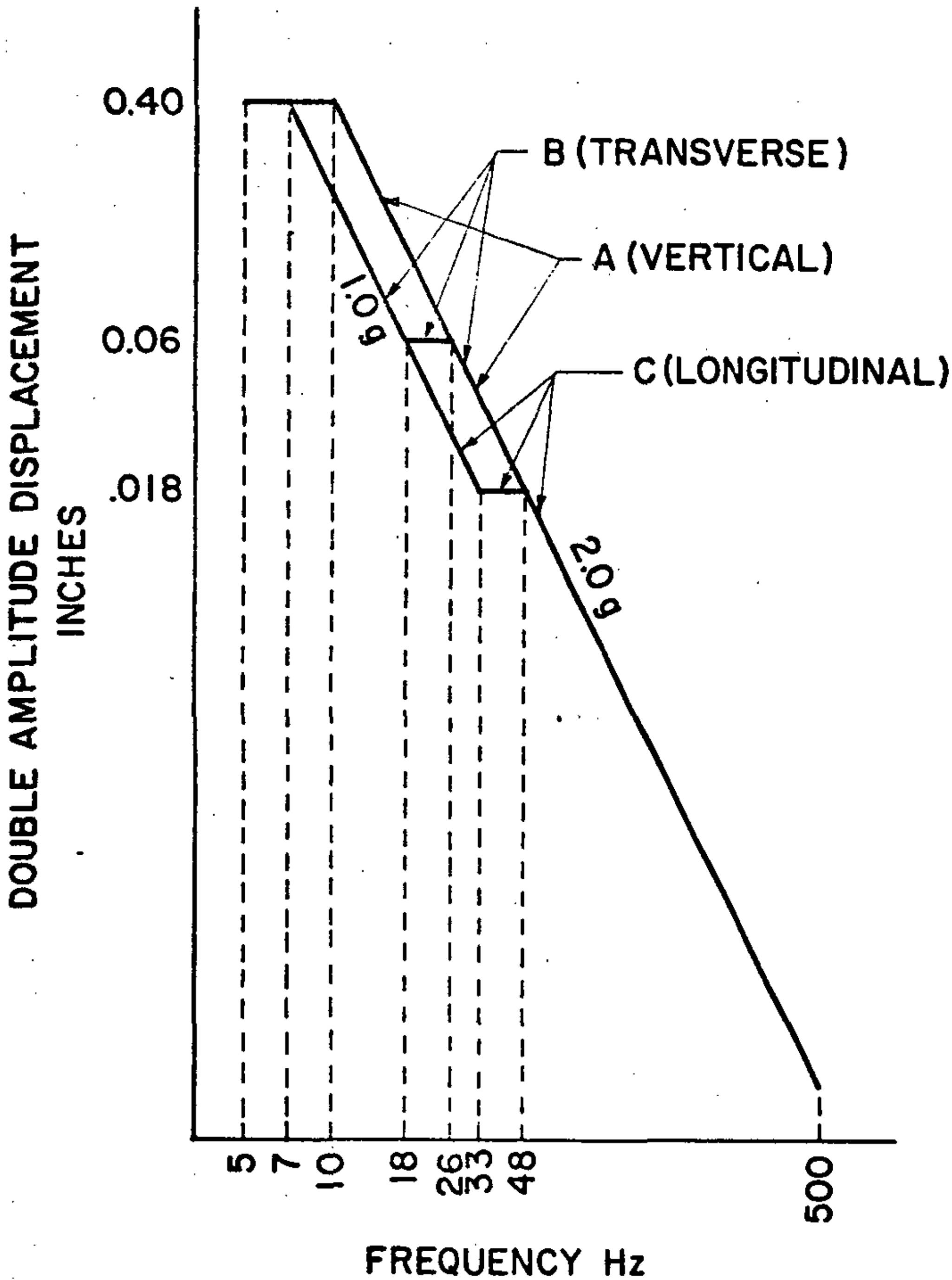


Figure 514.2-4B. Vibration Test Curves for Cycling Test for Externally Carried Stores for Helicopters, Equipment Category d.3.

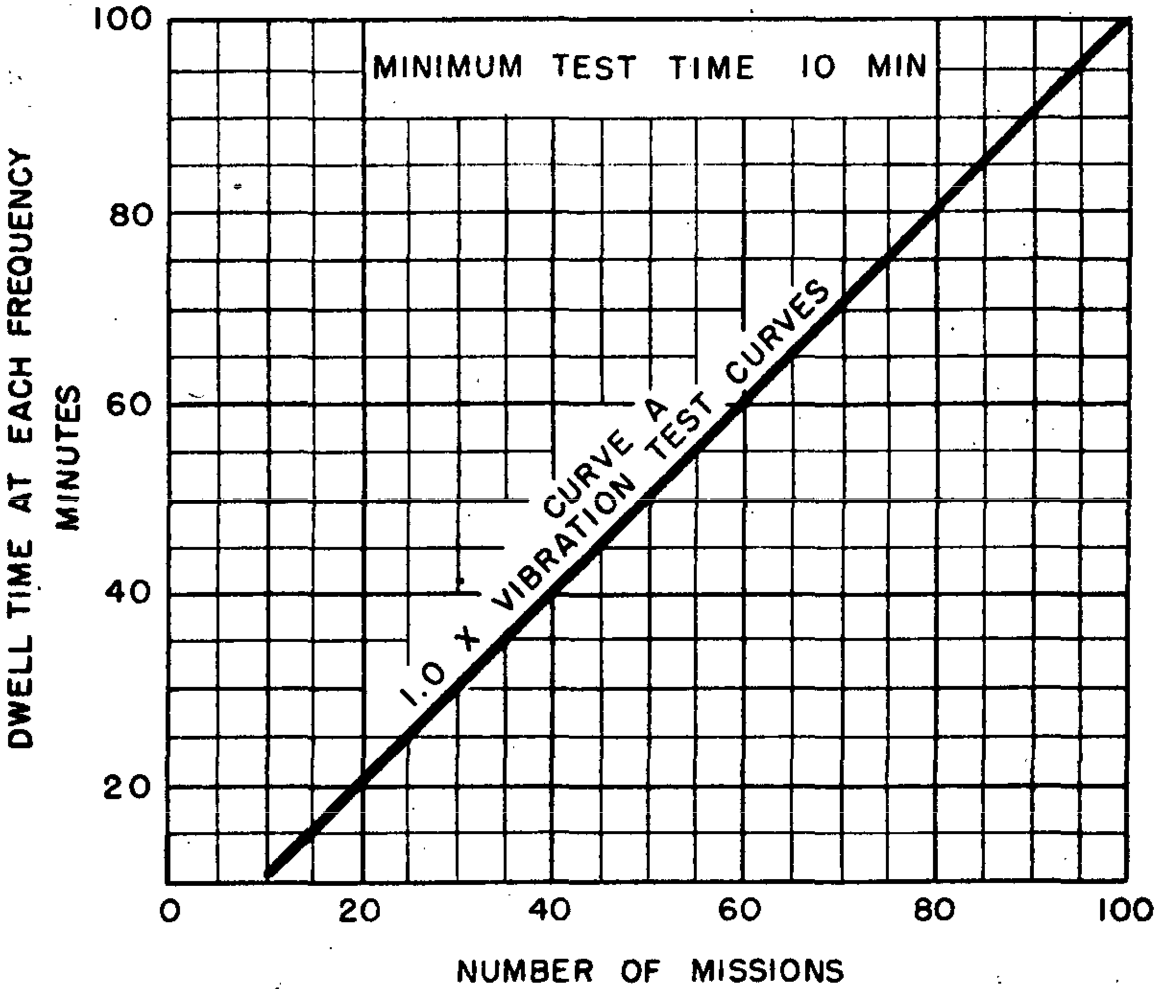


Figure 514.2-4C. Time Curves for Dwell Test for Externally Carried Stores for Helicopters, Equipment Category d.3.

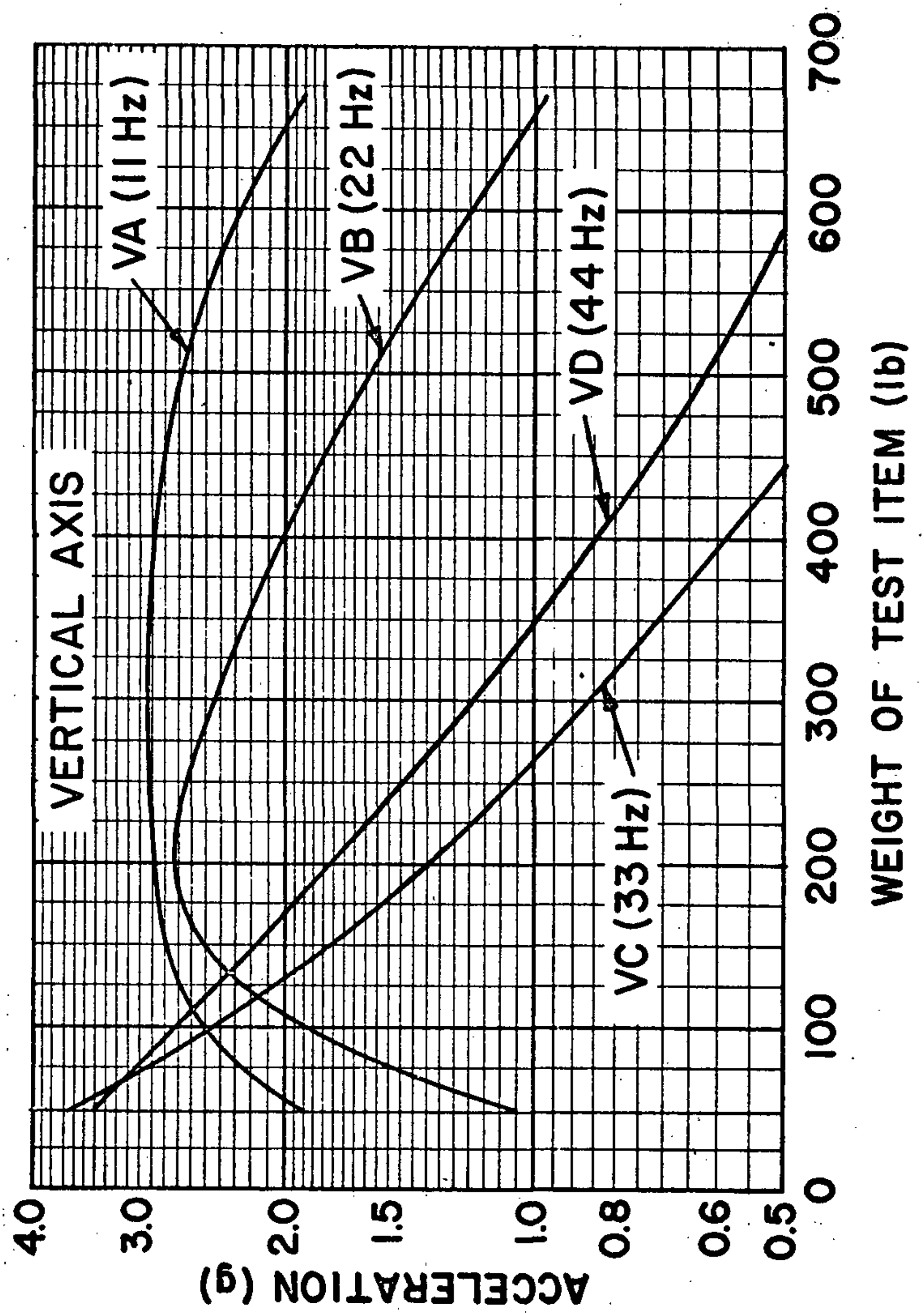


Figure 514.2-4D. Vibration Test Curves for Dwell Tests, Vertical Axis, for Externally Carried Stores for Helicopters, Equipment Category d.3.

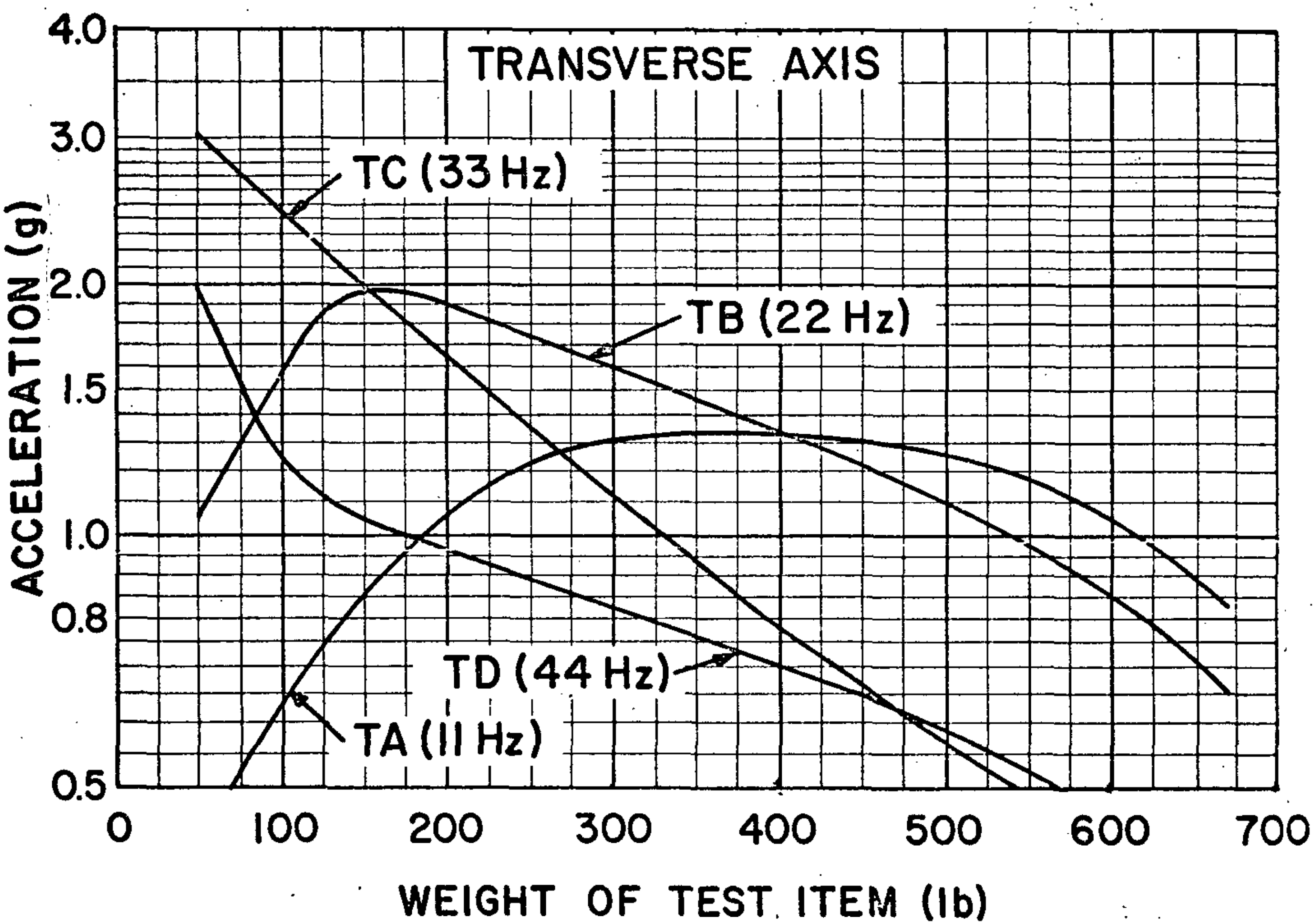


Figure 514.2-4E. Vibration Test Curves for Dwell Tests, Transverse Axis, for Externally Carried Stores for Helicopters, Equipment Category d.3.

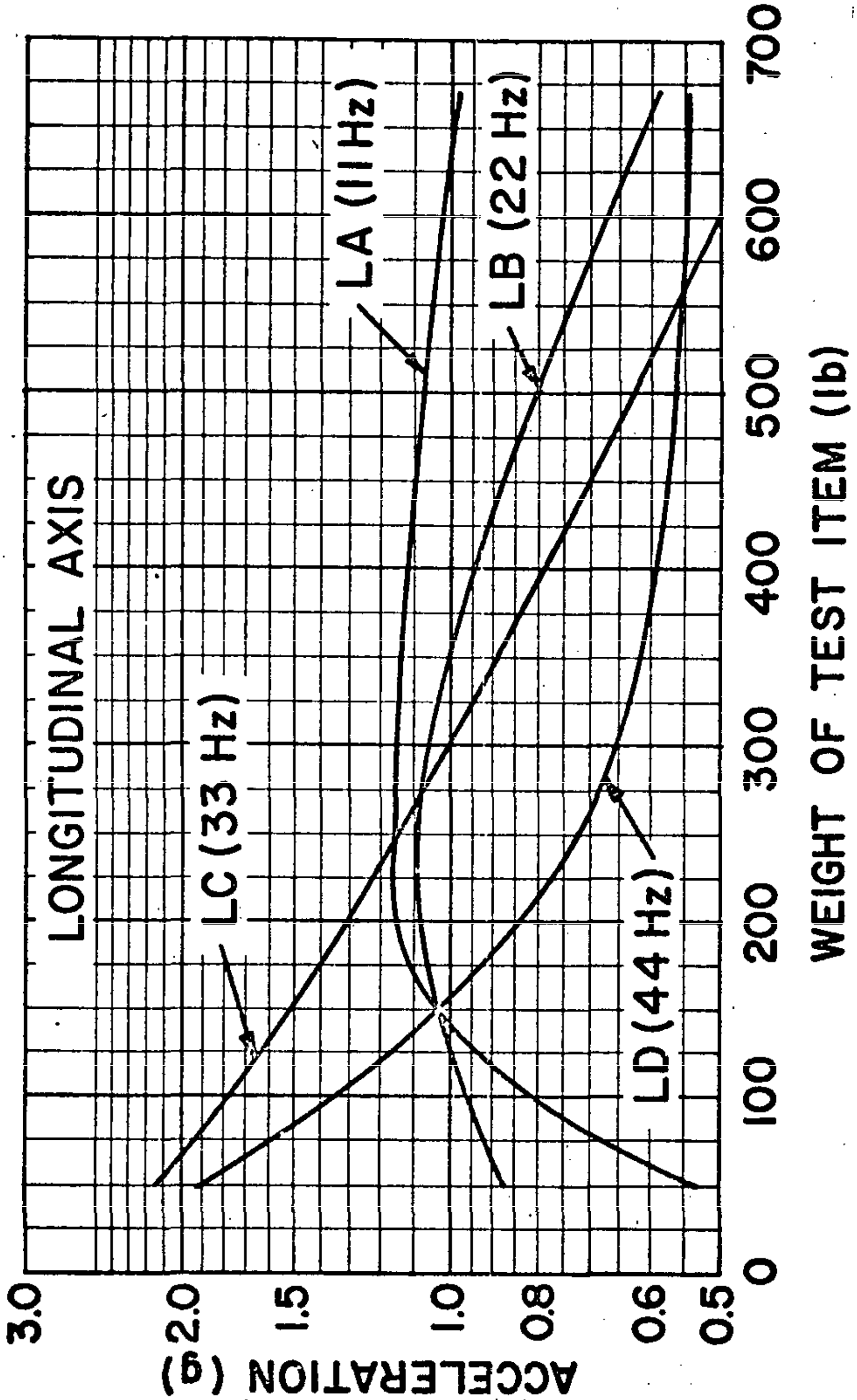


Figure 514.2-4F. Vibration Test Curves for Dwell Tests, Longitudinal Axis, for Externally Carried Stores for Helicopters, Equipment Category d.3.

Table 514.2-V. Test Procedure and Time Schedule Chart for Equipment Installed in Ground Launched Missiles, Equipment Category e.

A. Procedure Selection and Time Schedule Chart

Equipment mounting configuration	Procedure number	Procedure part number	Applicable tests (see 4 for test procedures): Sinusoidal cycling (4.5.1.3)	Applicable tests: Random (4.5.2)	Test time schedule (per axis): Sinusoidal cycling time (4.5.1.3)	Test time schedule: Sweep time 5-2000-5 Hz	Test time schedule: Random time note 3/	Figure 514.2-V Curve 1/
Without vibration isolators	V	1	X		30 min	20 min		One of P thru U
		2		X			30 min	One of AE thru AP
With vibration isolators 2/	VI	1	X		30 min	20 min		One of P thru U
		2	X		30 min	20 min		N
		3		X			30 min	One of AE thru AP
Normally with vib. isolators but tested without isolators	VII	1	X		30 min	20 min		N
		2		X			30 min	AE

1/ For sinusoidal vibration resonance tests and cycling tests of items mounted in missiles and weighing more than 80 pounds, the vibratory accelerations shall be reduced by ±1g for each 20-pound increment of weight over 80 pounds. Acceleration derating shall apply only to the highest test level of the selected curve. However, the vibratory acceleration shall in no case be less than 50 percent of the specified curve level.

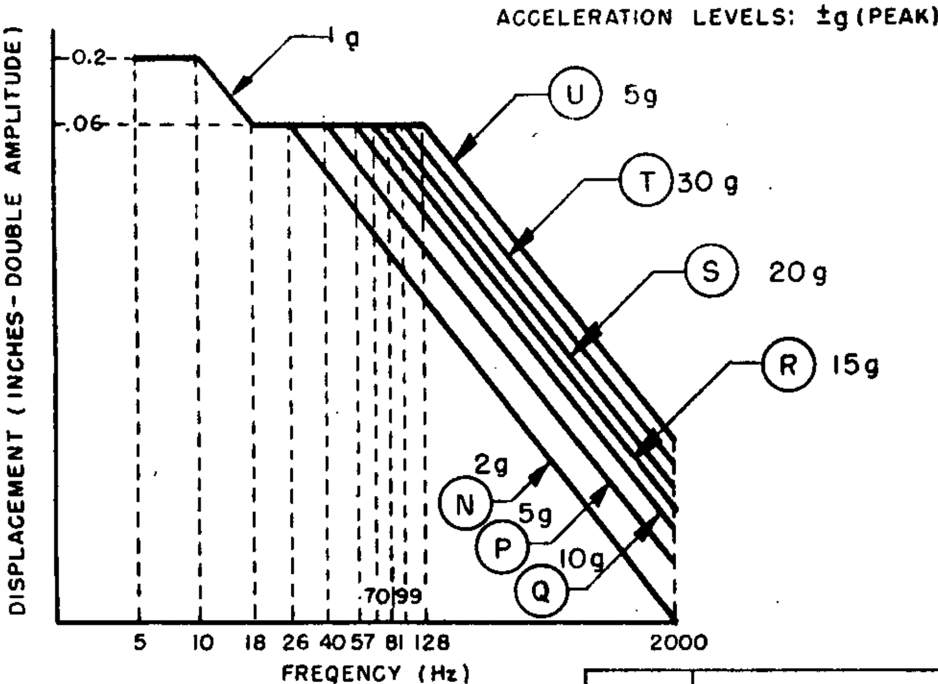
2/ Test items of equipment normally provided with vibration isolators first shall be tested with the isolators in place (part 1). The isolators then shall be removed, and the test item rigidly mounted and subjected to the test level indicated (part 2). Isolators shall be replaced and the test item subjected to the test level indicated (part 3).

3/ When flight distances of missiles are less than 100 miles, the test time is reduced to 5 minutes.

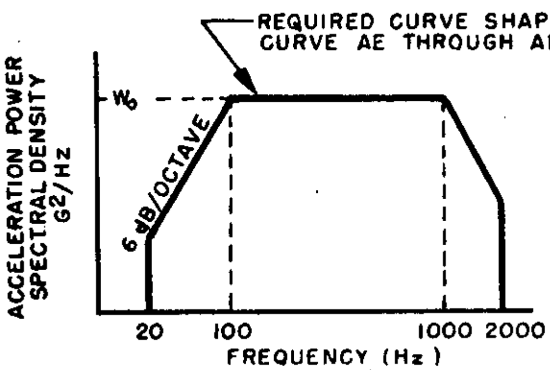
B. Curve Selection Chart for Category e. Equipment

Equipment location by vehicle section	Approximate thrust (power)	Vibration test curves (Figure 514.2-V): Sinusoidal	Vibration test curves (Figure 514.2-V): Random
All except booster	ALL	P or Q	AE, AF, or AG
By individual booster stage	250,000 lbs or less	Q or R	AH, AJ, or AK
	250,000 lbs to 500,000 lbs	R or S	AK, AL, or AM
	Over 500,000	T or U	AM, AN, or AP

SINUSOIDAL VIBRATION CURVES



RANDOM VIBRATION CURVES



RANDOM VIBRATION ENVELOPE

TEST CURVE	ACCELERATION POWER SPECTRAL DENSITY W_0 (G^2/Hz)	COMPOSITE G-RMS MINIMUM
AE	0.02	5.4
AF	0.04	7.6
AG	0.06	9.3
AH	0.10	12.0
AJ	0.20	16.9
AK	0.30	20.7
AL	0.40	23.9
AM	0.60	29.3
AN	1.00	37.9
AP	1.50	46.4

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

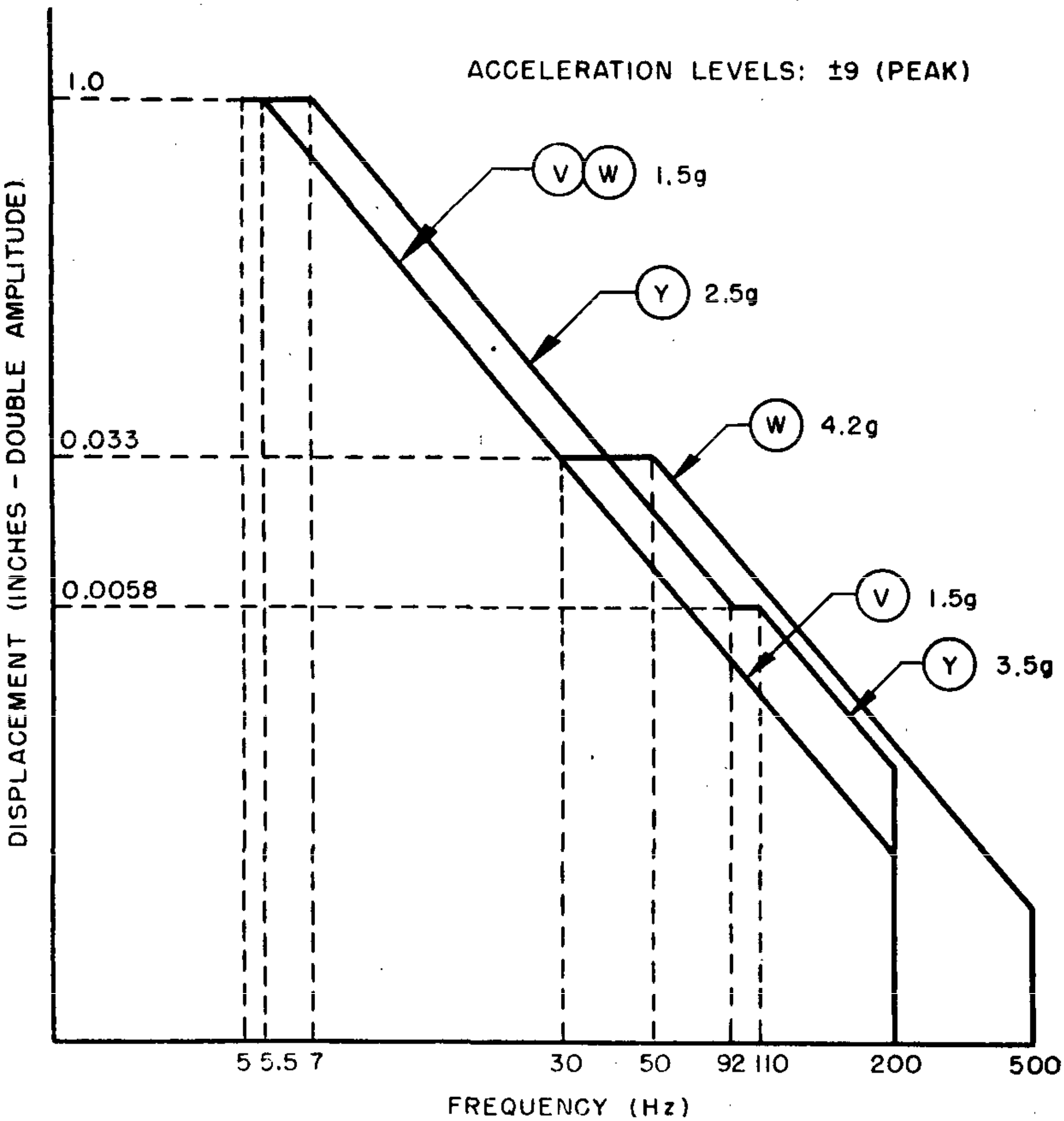
WHERE f_1 AND f_2 ARE THE LOWER AND UPPER TEST FREQUENCY LIMITS RESPECTIVELY W(f) IS THE ACCELERATION POWER SPECTRAL DENSITY IN G^2/Hz UNITS

Figure 514.2-5. Vibration Test Curves for Equipment Installed in Ground Launched Missiles, Equipment Category e.

Table 514.2-VI. Test Procedure and Time Schedule Chart for Equipment Installed in Ground Vehicles, Equipment Category f

Equipment Conditions	Procedure Number	Procedure Part Number	Applicable Tests		Test Time Schedule (Per Axis)			Curve
			Sinusoidal Cycling (4.5.1.3)	Bounce Vehicular (4.6.10.2)	Sinusoidal Cycling Time (4.5.1.3)	Maximum Cycling Time	Sweep Time	
					Schedule A			
Tracked Vehicles	VIII		X		30 min/1000 miles 2/	3 hours	15 min 5-500-5 Hz 1/	W
					Schedule B			
Wheeled Vehicles	VIII		X		30 min/1000 miles 2/	5-1/2 hours	12 min 5-200-5 Hz 1/	V or Y 3/
Vehicle and Mileage Unknown	VIII		X			3 hours	15 min 5-500-5 Hz 1/	W
To be used only when specified	IX	2		X	see 4.6.10.2			
Vans and shelters	XIII	2		see 4.6.14.2				

1/ Sweep time shall be increased by 3 minutes if test frequencies go to 2 Hz.
2/ Cycling time shall be 30 min/1000 miles or as specified in the equipment specification except that it shall not exceed the maximum specified in table 514.2-VI.
3/ Curve V is for equipment installed in wheeled vehicles except for two-wheeled trailers. Curve Y is for equipment installed in two-wheeled trailers.



Note: All curves shall be extended to 2 Hz when test item resonances below 5 Hz are expected

Figure 514.2-6. Vibration Test Curves for Equipment Installed in Ground Vehicles, Equipment Category f.

Table 514.2-VII. Test Procedure and Time Schedule for the Transportation of Cargo, Equipment Category g.

Transport Mode	Procedure	Procedure Part Number	Figure 514.2-7 Curve 5/	Applicable Test	Sweep Time 4/
Rail, air, sea, truck or simitrailer 1/	X		AW	Sinusoidal Cycling for 84 min Per Axis	12 min 5-200-5 HZ
Any of above plus tracked vehicle 2/	X		AV	Sinusoidal Cycling for 84 min Per Axis	12 min 5-200-5 HZ
Any of above plus 2-wheeled trailer 2/	X		AX	Sinusoidal Cycling for 84 min Per Axis	12 min 5-200-5 HZ
Loose Cargo 3/	XI	2	See 4.6.12.2		

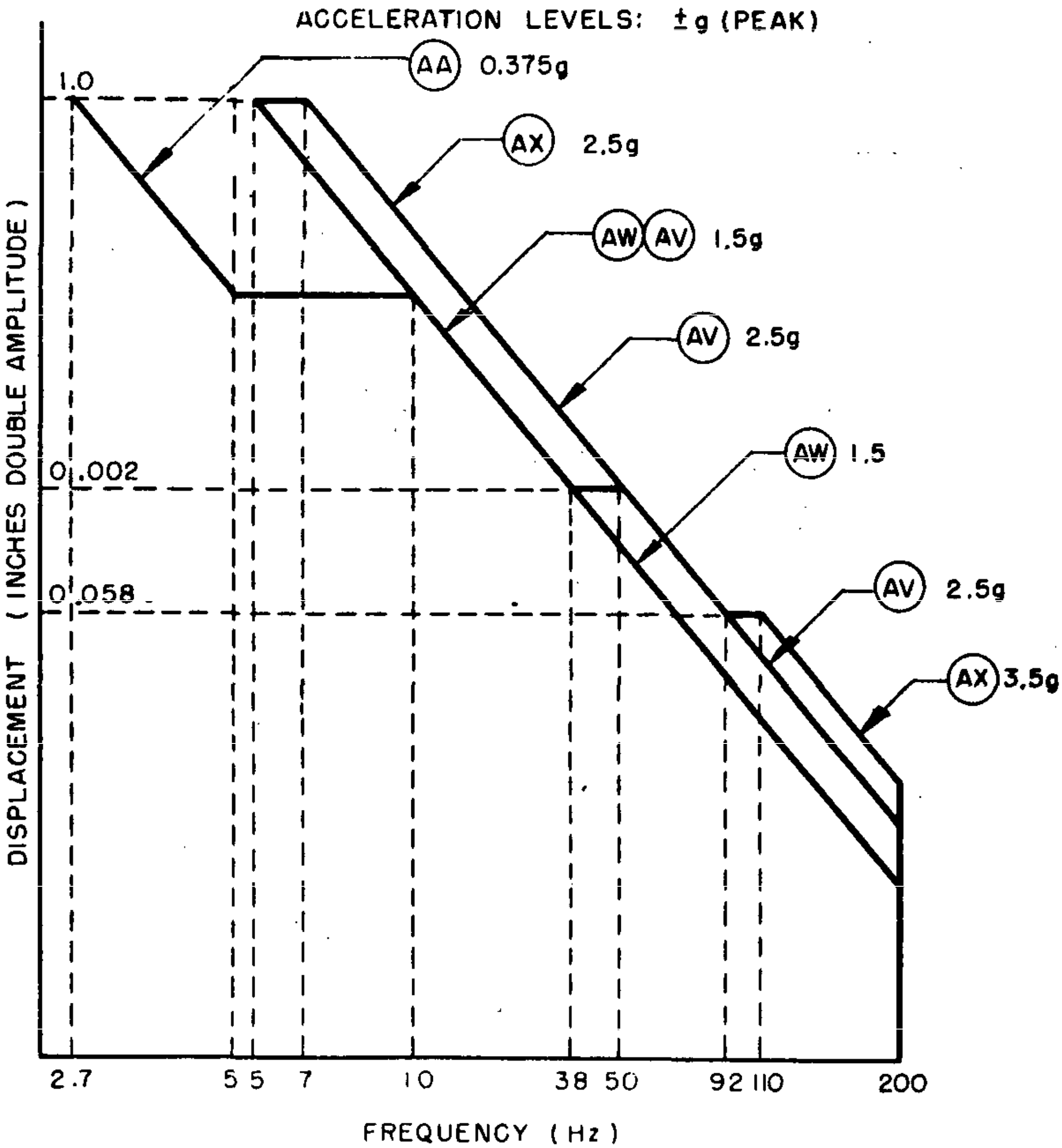
1/ The normal transport of items as secured cargo, with land transport over paved roadways.

2/ The transport of items as secured cargo to include land transport over paved roads, unimproved roads and cross-country terrain.

3/ When transit case or combination case is provided for the test item, the case shall be included in the test setup.

4/ Sweep time may be 15 minutes if test requirements go to 2 HZ.

5/ For vibration isolated items, curve AA is to be used in the lower frequency range (below 13 HZ) and the curve appropriate to the mode of transportation for the higher frequencies.



NOTE: ALL CURVES SHALL BE EXTENDED TO 2 Hz WHEN TEST ITEM RESONANCES BELOW 5 Hz ARE EXPECTED.

Figure 514.2-7. Vibration Test Curves for Equipment Transported as Secured Cargo, Equipment Category g.

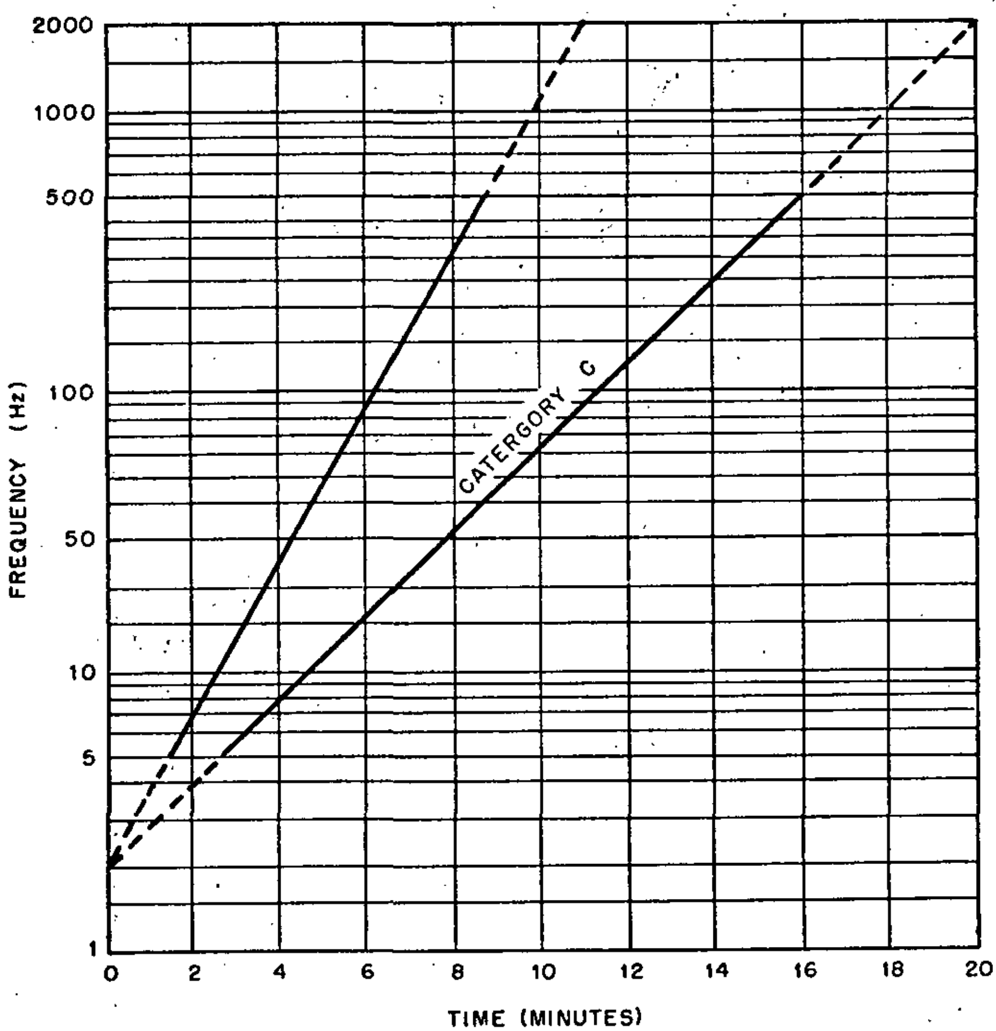


Figure 514.2-10. Logarithmic Sweep

METHOD 515.2

ACOUSTICAL NOISE

1. PURPOSE. The acoustical noise test is performed to determine the effects on equipment of fluctuating pressure fields associated with turbulent aerodynamic flow and acoustic noise that are characteristic of aircraft, missiles, and other high-performance vehicles. The acoustical noise test complements conventional sinusoidal and random vibration tests which are for structure borne vibrations.

2. APPARATUS. A suitable type test chamber shall be used to apply the conditions as specified in the following procedures. Measuring equipment shall be suitable to accomplish the required analysis.

3. PROCEDURE. The basis for selecting a test procedure for a particular category shall be according to 3.1.1.

3.1 Definitions and terms. A comprehensive list of standard terminology is titled Acoustical Terminology (including Mechanical Shock and Vibration) contained in ANSI-S1.1-1960.

3.1.1 Test selection. For the purpose of this test method, equipment is categorized as follows:

a. Equipment mounted either external or internal to the vehicle structure (see 3.2, 3.3, and 3.4). In general, equipment located in areas where noise levels are 130 dB overall or less will not require testing to noise environments. This test is not a substitute for the conventional sinusoidal or random vibration tests of Method 514.2.

b. Assembled externally carried aircraft stores (see 3.5). This test is performed to determine if a complete store as a system is constructed to withstand its expected aerodynamic environment and to insure that performance degradations or malfunctions will not be produced by the service environment.

3.2 Criteria for application. Some equipment is insensitive to acoustic stimulation even at very high levels. Other equipment may respond in a manner that will modify or disrupt the equipment function and in extreme cases mechanical failure may result. Equipment that is sensitive to vibration is usually sensitive to sound field exposure. For this reason a suitable vibration test is often a good indicator of acoustic sensitivity. However, it is possible that high frequency resonances of some responding equipment elements may be overlooked during the vibration test due to the high frequency limitations of the shaker and vibration attenuation of the fixture and the equipment under test. Of importance is the fact that some equipment may possess both sensitive and insensitive characteristics, and it may be difficult to ascertain, before a test is performed, whether the equipment is sensitive to acoustic stimulation. The following criteria are presented as a guide to initially determine whether equipment is sensitive to acoustic stimulation. Such criteria cannot be considered as the *only* determining factors. The final decision, whether to perform an acoustical noise test, must be supplemented by such additional factors as a description of the characteristics and duration of the end use acoustic environment, the location of the equipment within the vehicle structure, and a consideration of special mounting means or protective enclosures employed for the equipment.

3.2.1 Equipment insensitive to acoustic stimulation. This equipment is likely to have small surface areas, high mass to area ratios, and high internal damping. Examples are as follows:

a. High density modules, particularly the solid or encapsulated type.

b. Modules or packages with solid state elements mounted on small constrained or damped printed circuit boards or matrices.

c. Valves, hydraulic servo controls, or auxiliary power unit pumps.

d. Equipment surrounded by heavy metallic castings, particularly those that are potted or are encased within the casting by attenuating media.

3.2.2 Equipment sensitive to acoustic stimulation. This equipment is normally classified as microphonic or usually having large compliant areas of exposure, low mass to area ratios, or low internal damping. Examples are as follows:

a. Equipment containing microphonic elements with high frequency resonances such as electron tubes, waveguides, klystrons, magnetrons, piezoelectric components, or relays attached to thin plate surfaces.

b. Equipment containing or consisting of exposed diaphragmatic elements such as pressure sensitive transducers, valves, switches, relays, or flat spiral antenna units.

3.3 Selection of test intensity. The noise levels are divided into four intensity categories as listed in table 515.2-I. The categories are in order of increasing severity (overall sound pressure level) from A through D. The category should be selected as appropriate for the expected noise level of the end use environment.

TABLE 515.2-I Acoustical Noise Test Category

Category	Test overall sound pressure level (dB1/)	Typical applications		Exposure time (minutes)
		Vehicle	Equipment location	
A	140	Aircraft	Majority of locations	30
B	150	Aircraft	Near the noise source or in the noise cone, if separated by thin partitions	30
C	160	Aircraft	External stores or open exterior compartments near the noise source or subject to the noise cone environment of any aircraft	30
		Rocket	Majority of locations, exclusive of booster or engine compartments	8
D	165	Rocket	Booster or engine compartment, on site launch equipment or externally mounted pods near the noise source	8

1/Reference 2×10^{-4} dynes/cm^2 (2×10^{-5} newtons/m^2).

3.4 Procedure I

3.4.1 Test setup. The test item shall be softly suspended in the test chamber by means of springs or elastic cord. If a mounting structure is required between the soft suspension and the test item or to hold the soft suspension care must be exercised to assure that no spurious acoustic or vibratory inputs are introduced. The natural frequency of suspension shall be less than 25 Hz. The test item shall be exposed on every surface to the sound field by centrally locating it in the test chamber. The test item volume shall be no more than 10 percent of the test chamber volume. When the test chamber is rectangular, no major surface of the test item shall be installed parallel to the chamber wall. A reverberation type test chamber shall be used and shall be suitably formed and proportioned to produce a duffuse sound field and a uniform sound energy density throughout the enclosure.

3.4.2 Performance of test

Step 1 - The overall sound pressure level for the specified test category of table 515.2-I shall be introduced into the test chamber to conform to the octave band spectrum specified on figure 515.2-2. The average sound pressure distribution (overall level) shall be uniform within -2 to +4 dB of the desired value. The sound pressure field shall be measured without the test item mounted in the test chamber. Measurements shall be made by using a microphone (more than one if desired) to define the sound field within the test volume (central 10 percent of the chamber volume).

Step 2 - The test item shall be placed in the chamber as specified in 3.4.1. At least three microphones shall be monitored. They shall be located in proximity to each major dissimilar test item surface, at least 18 inches from the test item surface or one-half the distance to the nearest chamber wall, whichever is less. The average overall sound pressure distribution around the test item shall be measured and be uniform within -2 to +4 dB of the desired value. However, for large or irregularly shaped items where this tolerance cannot be achieved, the tolerance shall be ±6 dB. Test times shall be as specified in table 515.2-I. The operation of the test item during the test shall be monitored when and as specified. When measurements are made during or following the test, they shall be compared with the data obtained in accordance with General Requirements, 3.2. At the conclusion of the test, the test item shall be inspected in accordance with General Requirements, 3.2.

3.5 Procedure II acoustic testing for assembled externally carried aircraft stores

3.5.1 This acoustic test is performed to determine that the assembled store is constructed to withstand and perform in the expected dynamic environment. Procedure IIB of Method 515.2, assembled externally carried store vibration test, shall also be conducted to insure thorough testing from 20 to 2,000 Hz. Acoustic testing of assembled externally carried stores is not required if the minimum value of f_0 of 4.6.3.2.3 of procedure IIB of Method 514.2 is greater than 1,200 Hz.

3.5.2 Test setup. The store should be softly suspended by means of springs or elastic cord. If a mounting structure is required between the soft suspension and the test item or to hold the soft suspension, care must be exercised to assure that no spurious acoustic or vibrating inputs are introduced. The natural frequency of suspension shall be less than 25 Hz. A suitable acoustic noise source can be a jet engine on an open-air stand, a jet engine in test cell, or an acoustic test chamber. Provision for baffles shall be made so that the frequency spectrum can be shaped to the required profiles.

3.5.2.1 Microphone placement. Three reference planes perpendicular to the longitudinal axis of the store shall be defined. The location of these reference planes shall be such that they are at positions which are one-sixth, one-half, and five-sixths of the length along the store. In each reference plane three microphones, 120 degrees apart, shall be positioned about the store. Each microphone shall be located within 18 inches from the surface of the store but no greater than one-half the distance from the nearest baffle, whichever is less.

3.5.3 Test procedure. The response of the microphones which are in each reference plane shall be averaged giving one output for each reference plane. The one-third octave band sound pressure level about the entire store shall be shaped so that at the location of each of these three reference planes the frequency spectral profile shall envelope the frequency spectral profile of figure 515.2-4 and the values of table 515.2-II. A controlled acoustic environment below 100 Hz and above 2,000 Hz is not required but these frequencies may be present because of the nature of the test facility. For low power acoustic facilities which cannot excite the entire frequency range at one time, it is permissible to break the test into smaller frequency segments. The testing time for each of these segments shall be the same as required if the entire spectrum is excited simultaneously.

3.5.3.1 Captive flight test. Two tests, functional and endurance, shall be conducted using their respective test levels given in table 515.2-II. No endurance test is required if, for a 1-hour endurance test, the test level L_O is equal to or less than the corresponding functional test level. During the functional test, the store shall perform according to the system specification operation requirements (see General Requirements, 3.2). This test shall be for 1 hour. Proper performance of the store is required only after conclusion of the endurance test (see General Requirements, 3.2).

3.5.3.2 Free flight functional test. For stores that are deployed by separation from the aircraft (free flight) such as bombs and missiles, a free flight functional test shall be conducted in addition to the captive flight tests of 3.5.3.1. The equipment shall perform according to the equipment specification operating requirements (see General Requirements, 3.2) during the functional testing. 3.5.2, 3.5.2.1, and 3.5.3, table 515.2-II, and figure 515.2-3 shall be used to determine the test procedures, levels and frequency spectra for the free flight test except as noted below. In this case, factor (N/3T) shall be set equal to one and no MER or TER cluster carriage factor shall be used. The value of q shall be the maximum value attainable during free flight. The duration of this functional test shall equal the maximum free flight time expected at maximum q, but not less than 30 seconds. In the event that all free flight functional checks are made during the captive functional test and the captive functional test levels are larger than or equal to those derived here (3.5.3.2), no free flight functional test is required.

3.5.4 References

a. Dreher, J. F.; Lakin, E. D.; Tolle, E. A.; "Vibracoustic Environment and Test Criteria for Aircraft Stores During Captive Flight," Shock and Vibration Bulletin No. 39, Supplement (pp 15-40) NRL, Washington, D.C., April 1969.

b. Dreher, J. F., "Effects of Vibration and Acoustical Noise on Aircraft/Stores Compatibility," Proc. Aircraft Compatibility Symp., Vol. 6, pp 245-272, Eglin AFB, Florida, November 1969.

c. Burkhard, A. H., "Acoustic Testing to Simulate the Flight Vibration Environment of Aircraft Stores," AFFDL-TR-73-110, February 1974.

d. Burkhard, A., "Captive Flight Acoustic Test Criteria for Aircraft Stores," Shock and Vibration Bulletin No. 43 part 3 (pp 113-126), NRL, Wash, D.C., January 1973.

4. SUMMARY. The following details shall be specified in the equipment specification or test plan:

a. Procedure number.

b. Pretest data required (see General Requirements, 3.2).

c. Failure criteria.

d. Test category (see 3.3).

e. Whether operation during the test is required, and if and how the operation is to be monitored.

f. Necessary parameters for calculating test levels for Procedure II.

Table 515.2-II Acoustic Test Levels for Assembled Externally Carried Aircraft Stores

Functional Test

L_o [1, 5, 6, 7] = 20 Log (q_1) + 11 Log (X) + 7 Log (1-cos β) + 72

f_o [2, 3] = 600 Log (X/R) + C

Endurance Test

L_o [1, 5, 6, 7] = 20 Log (q_2/q_1) + 2.5 Log (N/3T) + functional level

f_o [2, 3] = 600 Log (X/R) + C

Definitions

q_1 = maximum captive flight dynamic pressure $(lbs/ft^2) \leq 1800$
q_2 = 1200 psf or maximum captive flight dynamic pressure (whichever is lower) (lbs/ft^2)
N = maximum number of anticipated service missions (minimum N = 3)
R[4] = local radius of store in inches
X = distance from nose of store along axis of store in inches
T = test time in hours (minimum T = 1 hour)
C = -200 locations within one D of either aft end of store or aftward of re-entrant angle
C = 400 all other locations
A = -6 dB/octave $f_o > 400$ Hz
A = -2 dB/octave $f_o \leq 400$ Hz
D[4] = maximum store diameter in inches
β = local nose cone angle at X equals 1 { Tan β = (R/X) (ref Fig 515.2-5) }

Representative Parametric Values to be used for captive flight when specific parameters are not available

Store Type	N Endurance	Local Nose Cone Angle Degrees	q max	f_o Nose Section	f_o Middle Section	f_o Aft Section
Air-to-Air Missile	100	69	1600	500	1000	500
Air-to-Ground Missile	3	12	1600	800	630	630
Instrument Pod	500	69	1800	500	1000	500
Reusable Dispenser	50	11	1200	630	1000	400
Demolition Bomb	3	24	1200	500	1000	630
Flat Nose Store	3	90	1200	400	630	315

NOTES

1. Raise computed L_o level by 3 dB for a store carried in a TER cluster rack; by 6 dB for a MER cluster rack.

2. If calculated f_o is above 2000 Hz use upper frequency limit of 2000 Hz. If calculated f_o is below 200 Hz use 200 Hz.

3. Round off f_o upwards to a one-third octave band center frequency.

4. For stores which do not have circular cross-sections the radius used in the formulas shall be the radius of the circle which circumscribes the cross-section of the store.

5. For locations on flat nose stores ($80° \leq \beta \leq 90°$) where $X < 100$

Functional test

$$L_o = 20 \text{ Log } (q_1) - 6 \text{ Log } (X) + 96$$

Endurance test

$$L_o = 20 \text{ Log } (q_2) - 6 \text{ Log } (X) + 96 + 2.5 \text{ Log } (N/3T)$$

6. For long cylindrical section, > 2D, use for locations more than one D aftward into the cylindrical section

Functional test

$$L_o = 20 \text{ Log } (q_1) + 84$$

Endurance test

$$L_o = 20 \text{ Log } (q_2) + 84 + 2.5 \text{ Log } (N/3T)$$

7. For changing radius section either aft of a long cylindrical section or when $X > 100$ on a flat nose store, redefine X so that $X = 1$ at beginning of this section

Functional test

$$L_o = 20 \text{ Log } (q_1) + 11 \text{ Log } (X) + 84$$

Endurance test

$$L_o = 20 \text{ Log } (q_2) + 11 \text{ Log } (X) + 84 + 2.5 \text{ Log } (N/3T)$$

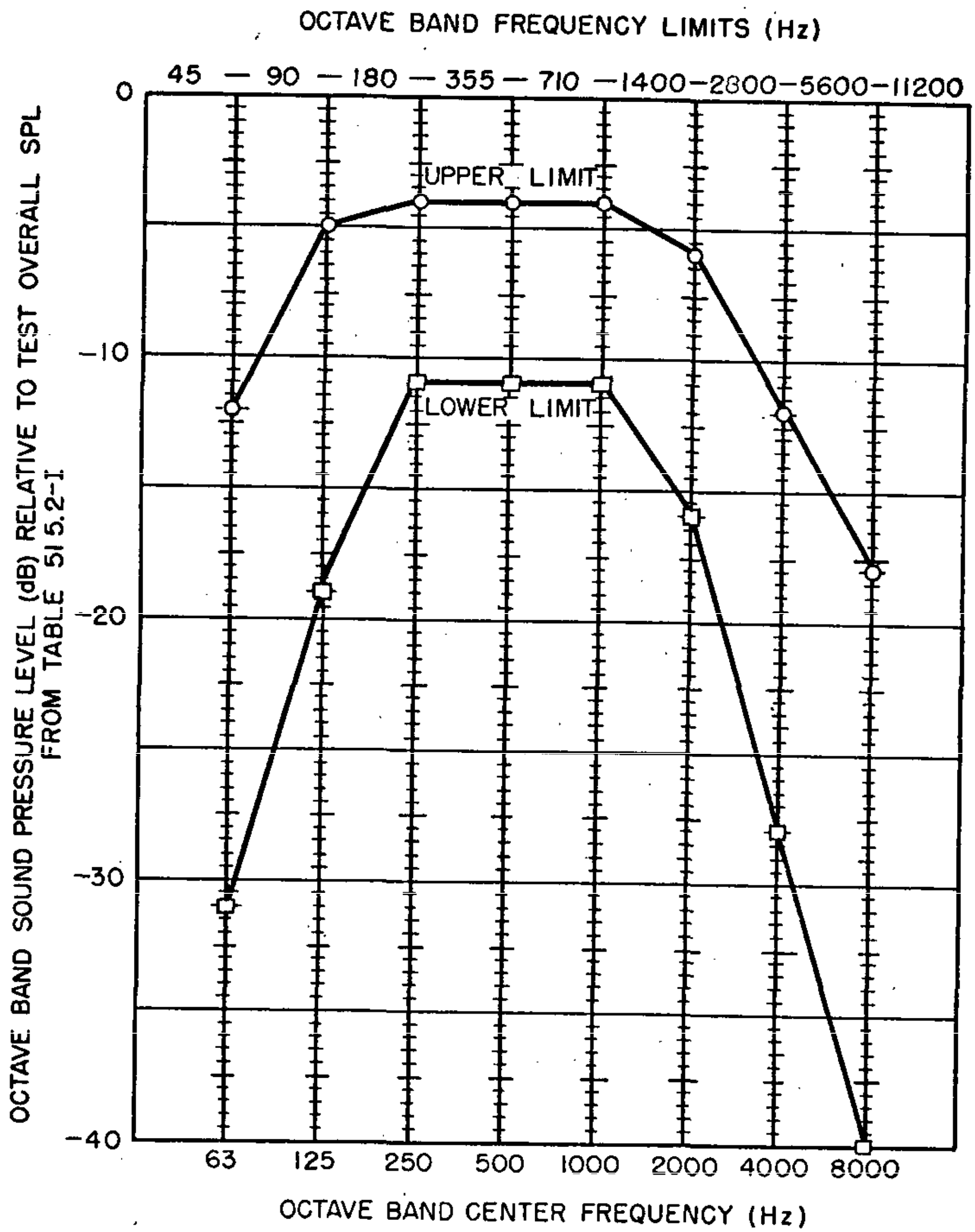
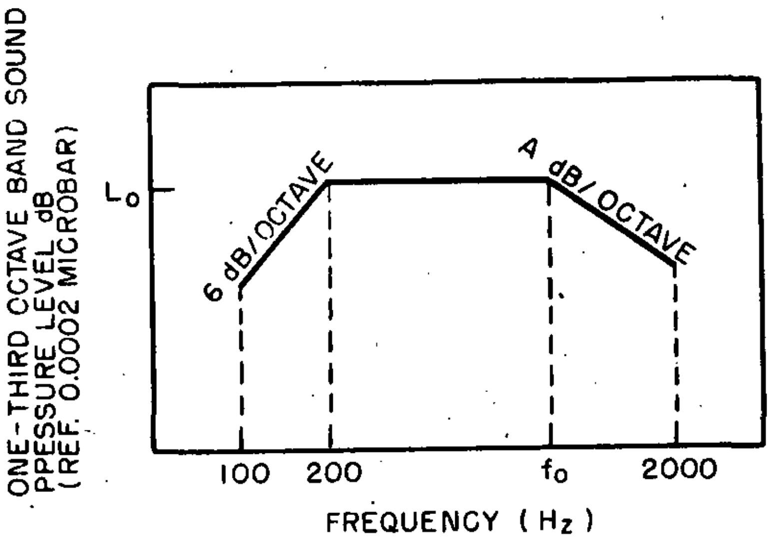


Figure 515.2-2. Octave Band Spectrum for the Acoustical Noise Test



Note: See table 515.2-II for definition and calculations.
$f_o = 600 \log (X/R) + c$
$A = 6$ db/octave when $f_o > 400$ Hz
$A = 2$ db/octave when $f_o \leq 400$ Hz

Figure 515.2-4. One-third Octave Band Spectrum for Acoustic Testing of Assembled Externally Carried Aircraft Stores

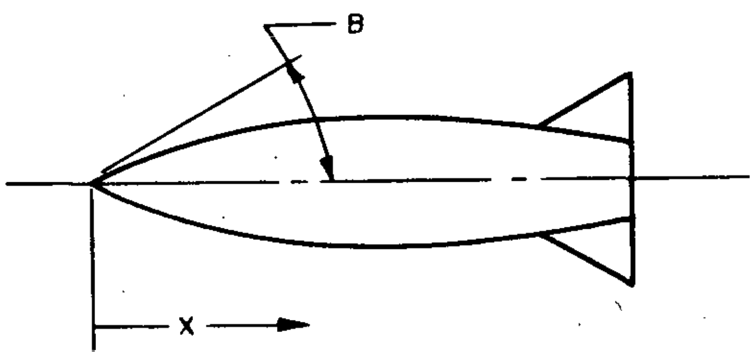


Figure 515.2-5. Typical Store Profile

METHOD 516.2

SHOCK

1. PURPOSE. The shock test is performed to determine if equipment is constructed to withstand expected dynamic shock stresses and that performance degradations or malfunctions will not be produced by the service shock environment expected in handling, transportation, and service use.

2. APPARATUS

2.1 Shock machine. The shock machine utilized for procedures I, III, and IV shall be capable of producing the specified input shock pulse shown on figure 516.2-1 or 516.2-2. The shock machine may be of the free fall, resilient rebound, nonresilient, hydraulic, compressed gas or other activating types. Apparatus for other procedures are included in the individual procedure.

2.1.1 Shock machine calibration. The actual test item, a rejected item, or a rigid dummy mass shall be used to calibrate the shock machine for conformance with the specified wave shape. When a rigid dummy mass is used, it shall have the same center of gravity and the same mass as that intended for the test item and shall be installed in a manner similar to that of the test item. (When a rigid dummy mass or rejected item is used for calibration, the waveform during the actual test may be somewhat different from that observed during calibration.) The shock machine shall then be calibrated for conformance with the specified waveform. Two consecutive shock applications to the calibration load shall produce waveforms which are all within the tolerance envelope given on figures 516.2-1 and 516.2-2. The calibrating load shall then be removed and the shock test performed on the actual test item. Provided all conditions remain the same, other than the substitution of the test item for the calibrating load, the waveform shall be considered to meet the specified test requirement. The actual test waveform shall be recorded for later use should a failure analysis be required.

2.2 Instrumentation. The instrumentation used to measure the input shock pulse, in order to meet the tolerance requirements of the test procedure, shall have the characteristics specified in the following paragraphs:

2.2.1 Frequency response. The frequency response of the complete measuring system, from the accelerometer through the readout instrument, shall be as shown on figure 516.2-3. Particular care shall be exercised in the selection of each individual instrument of the shock measuring instrumentation system in order to assure compatibility with the prescribed frequency response tolerance.

2.2.2 Accelerometer, piezoelectric. When a piezoelectric accelerometer is employed as the shock sensor, the fundamental resonant frequency of the accelerometer shall be greater than 14,000 Hz (resonant frequencies of 30,000 Hz or higher are recommended). For suitable low frequency response the accelerometer and load (cathode follower, amplifier, or other load) shall have the following characteristics:

$$RC > 0.2$$

Where R = load resistance (ohms)
C = accelerometer capacitance plus shunt capacitance of cable and load (farads)

2.2.3 Accelerometer, strain gage. A strain gage accelerometer may be used, provided the undamped natural frequency is equal to or greater than 1,500 Hz with damping approximately 0.64 to 0.70 of critical.

2.2.4 Accelerometer calibration. The accelerometer shall be dynamically calibrated to the specified accuracy.

2.2.5 Accelerometer mounting. The monitoring accelerometer shall be rigidly attached to the test item support fixture at or near the attachment point(s) of the test item.

3. PROCEDURES

3.1 Shock pulse. The shock pulses for procedures I, III, and IV shall be as shown on figure 516.2-1 or 516.2-2 (whichever is specified). All points of the acceleration waveform obtained shall lie within the area enclosed by the tolerance limit lines. It is recommended that the saw tooth shock pulse be used, since its broad frequency spectrum tends to excite all resonant frequencies.

3.2 Mounting of test item. The test item shall be rigidly attached to the shock machine table for procedures I, III, and IV, in accordance with General Requirements, 3.2. Wherever possible, the test load shall be distributed uniformly on the test platform in order to minimize the effects of unbalanced loads.

3.3 Procedure I, basic design test. This procedure shall be used for shock testing of equipment assemblies (mechanical, electrical, hydraulic, electronic, etc.) of medium size, including items which mount on vibration isolators and equipment racks. Three shocks in each direction shall be applied along three mutually perpendicular axes of the test item (total of 18 shocks). If the test item is normally mounted on vibration isolators, the isolators shall be functional during the test. The shock pulse shape shall be in accordance with either figure 516.2-1 or 516.2-2, of amplitude a or b and time duration c or d, as specified. The test item shall be operating during the test if required by the equipment specification. At the conclusion of the test, the test item shall be operated and inspected and results obtained in accordance with General Requirements, 3.2.

3.4 Procedure II, transit drop test

3.4.1 Purpose. This procedure shall be used for equipment, in its transit or combination case as prepared for field use, to determine if the equipment is capable of withstanding the shocks normally induced by loading and unloading of equipment. (This is not the logistics shipping environment experienced by shipping containers.)

3.4.2 Test conditions. The test item shall be in its transit or combination case. For equipment 1,000 pounds or less, the floor or barrier receiving the impact shall be of 2-inch plywood backed by concrete. For equipment over 1,000 pounds, the floor or barrier shall be concrete.

3.4.3 Performance of test. Subject the test item to the number and heights of drop as required in table 516.2-I. Upon completion of the test, the test items shall be operated and inspected and results obtained in accordance with General Requirements, 3.2.

TABLE 516.2-I. Transit Drop Test (Procedure II)

Weight of test item and case	Largest dimensions (inches)	Notes	Height of drop (in.)	No. of drops
Under 100 pounds man-packed or man-portable	Under 36	A	48	Drop on each face, edge, and corner D/
	36 and over	A	30	Total of 26 drops
100 to 200 pounds, inclusive	Under 36	A	30	
	36 and over	A	24	Drop on each corner
Over 200 to 1,000 pounds, inclusive	Under 36	A	24	
	36 to 60	B	36	Total of 8 drops
	Over 60	B	24	
Over 1,000 pounds	No limit	C	18	Drop on each bottom edge. Drop on bottom face or skids. Total of 5 drops.

NOTES:

A. Drops shall be made from a quick-release hook, or drop tester. The test item shall be so oriented that upon impact a line from the struck corner or edge to the center of gravity of the case and contents is perpendicular to the impact surface.

B. With the longest dimension parallel to the floor, the transit or combination case, with the test item within, shall be supported at the corner of one end by a block 5 inches in height, and at the other corner or edge of the same end by a block 12 inches in height. The opposite end of the case shall then be raised to the specified height at the lowest unsupported corner and allowed to fall freely.

C. While in the normal transit position, the case and contents shall be subjected to the edgewise and cornerwise drop test as follows (if normal transit position is unknown, the case shall be so oriented that the two longest dimensions are parallel to the floor):

1. Edgewise drop test. One edge of the base of the case shall be supported on a sill 5 to 6 inches in height. The opposite edge shall be raised to the specified height and allowed to fall freely. The test shall be applied once to each edge of the base of the case (total of four drops).

D. Two test items may be used. Drop one test item on each face and corner (total of 14 drops). Drop a second test item on each edge (total of 12 drops).

3.5 Procedure III, crash safety test. This procedure shall be used to determine the structural integrity of equipment mounting means. The test item or dummy load shall be attached by its normal points of attachment. The test item or dummy load shall be subjected to two shocks in each direction along three mutually perpendicular axes of the equipment (total of 12 shocks). The shock pulse shape shall be in accordance with either figure 516.2-1 or 516.2-2, of amplitude a or b and time duration c or d, as specified. There shall be no failure of the mounting attachment and the test item or dummy load shall remain in place and not create a hazard. However, bending and distortion shall be permitted.

3.6 Procedure IV, high intensity test. This procedure shall be used where high acceleration, short time duration shock excitation results from handling, stage ignition, separation, re-entry, and high velocity aerodynamic buffeting experienced by missiles and high performance weapon systems. Two shocks shall be applied to the test item in each direction along each of three mutually perpendicular axes (total of 12 shocks). The shock pulse shape shall be in accordance with either figure 516.2-1 or 516.2-2, of amplitude a or b and time duration c or d, as specified. The test item shall be operating during the test if required by the equipment specification. At the conclusion of the test, the test item shall be operated and inspected and results obtained in accordance with General Requirements, 3.2.

3.7 Procedure V, bench handling test. This procedure shall be used to determine the ability of equipment to withstand the shock encountered during servicing. The chassis and front panel assembly shall be removed from its enclosure, as for servicing, and placed in a suitable position for servicing on a horizontal, solid wooden bench top at least 1-5/8 inches thick. The test shall be performed, as follows, in a manner simulating shocks liable to occur during servicing.

Step 1 - Using one edge as a pivot, lift the opposite edge of the chassis until one of the following conditions occurs (whichever occurs first):

a. The chassis forms an angle of 45 degrees with the horizontal bench top.

b. The lifted edge of the chassis has been raised 4 inches above the horizontal bench top.

c. The lifted edge of the chassis is just below the point of perfect balance.

Let the chassis drop back freely to the horizontal bench top. Repeat, using other practical edges of the same horizontal face as pivot points, for a total of four drops.

Step 2 - Repeat step 1, with the test item resting on other faces until it has been dropped for a total of four times on each face on which the test item could be placed practicably during servicing. The test item shall not be operating during the test. At the conclusion of the test, the test item shall be operated and inspected and results obtained in accordance with General Requirements, 3.2.

3.8 Procedure VI, rail impact test. This procedure shall be used to determine the effect that impact, due to shipping by rail will have on equipment. If an item can be shipped in two orientations, it shall be impacted once in each direction of each orientation at speeds of 8, 9, and 10 miles per hour ±5 percent (total of 12 impacts). If an item can be shipped only in one orientation, it shall be impacted twice in each direction of that orientation at speeds of 8, 9, and 10 miles per hour (a total of 12 impacts).

3.8.1 Apparatus. The following equipment will be necessary to perform this test:

a. Three ordinary railroad cars, with standard draft gear couplings.

b. A prime mover for moving the cars.

c. A calibrated means to determine that the speed at the time of impact is 8, 9, 10 mph, within ±5 percent.

d. Accelerometers and associated circuitry to measure the impact shock, and equipment response, if these measurements are specified.

3.8.2 Performance of test

a. Two cars will act as buffer cars and be located on a level section of track. The airbrakes shall be set in the emergency application position on both cars. The total buffer load excluding car weights shall be 140,000 pounds minimum.

b. The test item shall be mounted on the end of the test car in direct contact with the floor and adequately blocked and secured to prevent any longitudinal, vertical, or lateral movement. Metal banding, or wire, of sufficient size or strength shall be used to provide additional tiedown strength. Then blockings and tiedowns shall be inspected after each impact. If damaged or loosened, they shall be repaired prior to the next impact. However, tiedown attachments that are built-in parts of the test item shall not be altered or repaired during the test. Positions of the equipment with respect to the test car and whether or not packaging is necessary shall be specified. If loading and tiedowns are not specified, all loading and tiedowns shall be in accordance with recommended practices of the Association of American Railroads.

c. Impact the test car into the two loaded cars.

d. Impact shall be made in progressive steps with impacts 8, 9, and 10 miles per hour. The speed just prior to impact shall be measured by electronic or electrical means.

3.9 Related shock tests

3.9.1 High impact. Unless otherwise specified, ballistic shock tests and high impact tests shall be performed in accordance with MIL-S-901.

3.9.2 Shipboard equipment. Shock tests for shipboard equipment shall be performed in accordance with MIL-S-901.

3.9.3 Rough handling for packaged items. Tests for shipping and handling shall be performed in accordance with MIL-P-116 or FED-STD-101.

3.9.4 Fuzes and fuze components. Shock tests for safety and operation of fuzes and fuze components shall be performed in accordance/with MIL-STD-331.

3.10 Combined temperature and shock tests. Tests shall be performed at room ambient conditions unless a high or low temperature shock test is required, in which case the temperature extremes shall be as specified.

4. SUMMARY. The following details shall be as specified in the equipment specification or test plan:

a. Pretest data required (see General Requirements, 3.2).

b. Procedure number.

c. Shock pulse selection, specify shape, peak value, and duration (see 3.1).

d. Whether the rail impact shock pulse input and test item response are to be measured (see 3.8.1.d).

e. Test item positioning with respect to the test car and whether packaging is necessary for the rail impact test (see 3.8.2.b).

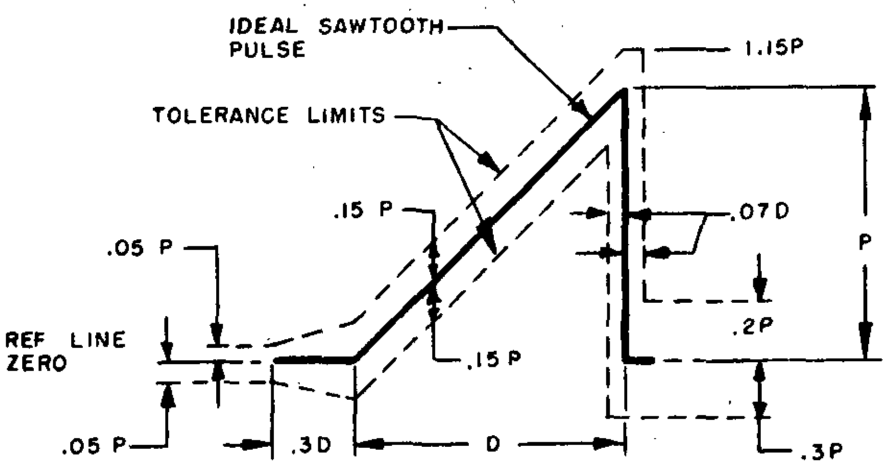
f. Temperature extremes (see 3.10).

g. Filter(s) used shall be identified.

h. Whether operation during the test is required, mode of such operation, and if and how the operation is to be monitored.

i. Loading and tiedowns (see 3.8.2.b).

j. Failure criteria.



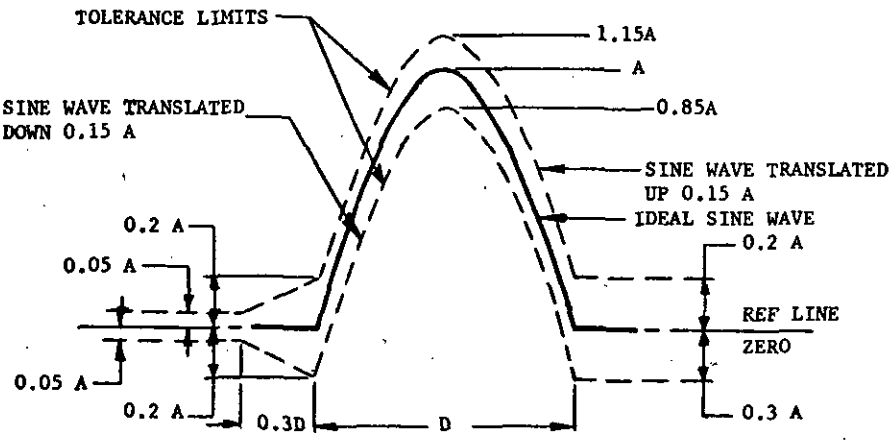
PROCEDURE	TEST	PEAK VALUE (P) g's		NOMINAL DURATION (D) ms	
		FLIGHT VEHICLE EQUIPMENT a 1/	GROUND EQUIPMENT b	FLIGHT VEHICLE EQUIPMENT c 1/	GROUND EQUIPMENT d
I	BASIC DESIGN	20	40 2/	11	11
III	CRASH SAFETY	40	75	11	6
IV	HIGH INTENSITY	100	100	6	11

1/ SHOCK PARAMETERS a AND c: RECOMMENDED FOR EQUIPMENT NOT SHOCK MOUNTED AND WEIGHING LESS THAN 300 POUNDS.

2/ EQUIPMENT MOUNTED ONLY IN TRUCKS AND SEMITRAILERS MAY USE A 20g PEAK VALUE.

NOTE: THE OSCILLOGRAM SHALL INCLUDE A TIME ABOUT 3D LONG WITH A PULSE LOCATED APPROXIMATELY IN THE CENTER. THE PEAK ACCELERATION MAGNITUDE OF THE SAWTOOTH PULSE IS P AND ITS DURATION IS D. THE MEASURED ACCELERATION PULSE SHALL BE CONTAINED BETWEEN THE BROKEN LINE BOUNDARIES AND THE MEASURED VELOCITY CHANGE (WHICH MAY BE OBTAINED BY INTEGRATION OF THE ACCELERATION PULSE) SHALL BE WITHIN THE LIMITS OF $V_i \pm 0.1 V_i$, WHERE V_i IS THE VELOCITY-CHANGE ASSOCIATED WITH THE IDEAL PULSE WHICH EQUALS 0.5 DP. THE INTEGRATION TO DETERMINE VELOCITY CHANGE SHALL EXTEND FROM 0.4D BEFORE THE PULSE TO 0.1D AFTER THE PULSE.

FIGURE 516.2-1. Terminal-peak Sawtooth Shock Pulse Configuration and its Tolerance Limits



PROCEDURE	TEST	PEAK VALUE (A) g's		NOMINAL DURATION (D) ms	
		FLIGHT VEHICLE EQUIPMENT a	GROUND EQUIPMENT b	FLIGHT VEHICLE EQUIPMENT c	GROUND EQUIPMENT d
I	BASIC DESIGN	15	30 2/	11	11
III	CRASH SAFETY	30	60	11	6
IV	HIGH INTENSITY	100	100	6	6

1/ SHOCK PARAMETERS a AND c: RECOMMENDED FOR EQUIPMENT SHOCK MOUNTED OR WEIGHING 300 POUNDS OR MORE.

2/ EQUIPMENT MOUNTED ONLY IN TRUCKS AND SEMITRAILERS MAY USE A 20g PEAK VALUE.

NOTE: THE OSCILLOGRAM SHALL INCLUDE A TIME ABOUT 3D LONG WITH A PULSE LOCATED APPROXIMATELY IN THE CENTER. THE ACCELERATION AMPLITUDE OF THE IDEAL HALF SINE PULSE IS A AND ITS DURATION IS D. THE MEASURED ACCELERATION PULSE SHALL BE CONTAINED BETWEEN THE BROKEN LINE BOUNDARIES AND THE MEASURED VELOCITY CHANGE (WHICH MAY BE OBTAINED BY INTEGRATION OF THE ACCELERATION PULSE) SHALL BE WITHIN THE LIMITS $V_i \pm 0.1\ V_i$ WHERE V_i IS THE VELOCITY-CHANGE ASSOCIATED WITH THE IDEAL PULSE WHICH EQUALS $2\ AD/\pi$. THE INTEGRATION TO DETERMINE VELOCITY CHANGE SHALL EXTEND FROM 0.4D BEFORE THE PULSE TO 0.1D AFTER THE PULSE.

FIGURE 516.2-2. Half Sine Shock Pulse Configuration and its Tolerance Limits

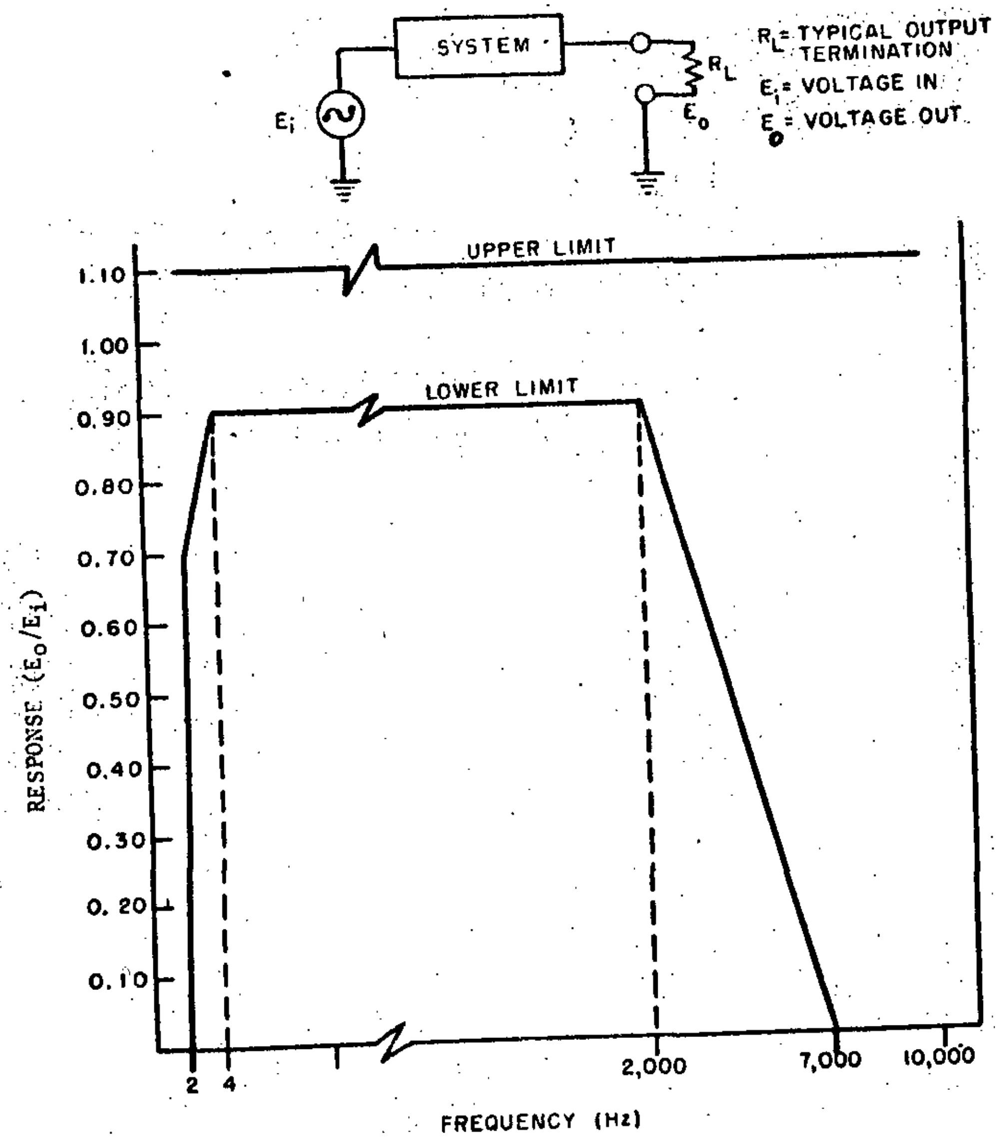


FIGURE 516.2-3. Shock Measuring System Frequency Response

METHOD 517.2

SPACE SIMULATION

(UNMANNED TEST)

1. PURPOSE. The tests described herein are intended for the evaluation of space vehicle components, space vehicle subsystems and complete space vehicles including installed equipment.

a. The space simulation test is performed to determine whether space vehicles, such as satellites, external instrumentation packages, spacecraft, and space stations with associated equipment can withstand the deleterious effects of very low pressures, low temperatures, and solar radiation. Ordinarily, this test will require establishing realistic temperature distribution across and through the test item. Aerodynamic heating is not usually considered a part of this test but may be partially simulated, if so specified, by the application of heat.

b. The details of a space simulation test depend entirely on the particular environmental condition to be simulated and on the purpose and type of test to be simulated and performed. One of the most significant environments of outer space which must be simulated is that of extremely low pressure. Effects of this environment are the change in convective and conductive heat transfer characteristics. While outer space pressures have been measured as low as 10^{-16} Torr it is generally accepted that an operating pressure of 10^{-5} Torr is sufficient to avoid convective and gaseous conductive heat transfer and electrical discharge, even though it does not duplicate space conditions in terms of gas material interaction at the surface of the test vehicle.

c. Different procedures can be used to simulate the radiant heat transfer effects of the space environment.

1.1 Procedure I utilizes the confining surfaces of the chamber to simulate the cold absorbing nature of space and the radiant heat is provided from a simulated solar spectrum input. Energy collimated within a few degrees of the true solar condition irradiates the test object held in position by a fixed or movable fixture. By a combination of motion or repositioning of the test vehicle and programmed control of the solar source, simulated orbital or space conditions are achieved.

1.1.1 Simulation of reflected solar albedo radiation and planetary emitted infrared radiation is generally accomplished by utilizing judiciously located infrared heat sources to prevent undesirable blockage of shadow.

1.2 Procedure II utilizes the confining surface of the chamber to simulate the cold absorbing nature of space and the radiant heat is provided from an infrared source.

1.3 Procedure III utilizes the confining temperature controlled surfaces of the chamber to force a given calculated temperature on the test object.

1.4 Procedure IV utilizes an infrared source to program heat around the object in zones to simulate orbital skin temperature.

1.5 Procedure V utilizes a conductive temperature controlled surface for mounting internal components to simulate their heat transfer condition.

1.6 Procedure VI utilizes a chamber to simulate the pressure effect of space.

1.7 Procedure VII utilizes a cryogenic heat sink plus vehicle heaters.

2. APPARATUS. This section deals with general performance requirements of some apparatus used in space simulation testing. Performance requirements for a specific test should be called out in the equipment specification.

2.1 Thermal vacuum chamber. The test chamber shall be capable of providing a vacuum of at least 10^{-6} Torr with the test item installed. Vacuum gauges shall be calibrated in accordance with ASTM E-297-70.

2.1.1 Pressure levels recommended for various effects simulation are given in table 517.2-I.

Table 517.2-I. Pressure Level for Effects Simulation

Structural	760 to 0 Torr
Radiant heat transfer	Below 10^{-5} Torr
Dielectric strength	Below 10^{-5} Torr
Material evaporation	To 10^{-7} Torr
Surface effects	Below 10^{-9} Torr

2.2 Heat source (radiant). Heat source systems shall be capable of producing the heating effects of solar energy, planet radiation, and albedo on test specimens within the space simulator.

2.2.1 Solar simulator. The simulator shall be capable of providing radiant energy corresponding to that of the Sun in space. The total solar energy shall be equal to the applicable value of table 517.2-II, column 2. The degree to which the solar environment must be simulated for particular tests is specified in table 517.2-IV.

Table 517.2-II. Average Radiation Characteristics of Planets

Planet	Incident radiation intensity (w/m²)	Planet ALBEDO	Planet thermal radiation (w/m²)	Planetary equivalent black body temperature (K°)
Earth	1383	0.34	213	250
Mars	583	0.148	134	226
Venus	2586	0.67	226	249
Earth's moon	1353	0.072	336	284

Performance requirements for a specific test should reference the space solar simulator classification specified in table 517.2-III.

Table 517.2-III. Solar Simulator Classification

	Class I	Class II	Class III
Uniformity	±3% max.	±5.0% max.	Greater than ±5%
Solar beam divergence angle	< 2°	< 4°	Greater than 4°
Spectrum	In accordance with table 517.2-IV	1/	2/

1/ Calculated effective absorptance within 5 percent of calculated Johnson solar absorptance.

2/ Calculated effective absorptance within 10 percent of calculated Johnson solar absorptance.

Temporal variation of intensity in the test volume shall not deviate from the average as listed in table 517.2-III for that class uniformity. Intensity and uniformity measurements shall be made with a sensor of area equal to 0.1 of 1 percent of the rated area but in no case smaller than 1 cm^2 or larger than 10 cm^2.

It is likely that the spectrum of the simulated radiation will differ in certain wavelength regions from the spectrum of the assumed true solar radiation, listed in table 517.2-IV. Total effective absorptance of the surface of the test item should not differ significantly from the total solar absorptance value if test item temperature errors are to be avoided.

Table 517.2-IV. Solar Electromagnetic Energy Distribution

Band No.	Percent of total solar irradiance	Wavelength band (angstroms)	Allowable variation of band energy, percent
1	2.7	2,500-3,300	±50
2	19.7	3,300-5,000	±25
3	24.3	5,000-7,000	±10
4	16.5	7,000-9,000	±10
5	11.0	9,000-11,000	±15
6	12.2	11,000-15,000	±20
7	9.7	15,000-25,000	±30

2.2.2 <u>Heat flux simulator.</u> The thermal effects of the space environment upon a spacecraft may be simulated using radiant energy sources entirely in the infrared (heat) portion of the spectrum under either of the following conditions:

a. If a piece of equipment is shielded from direct view of Sun and planets in flight mode

b. If a spacecraft or a piece of equipment which is directly viewed by the Sun and planets is configured such that a thermal source will supply the same heating effect as a source simulating the spectrum and collimation of the sun would. This would be applicable for an equipment: (1) with a uniform external finish α/ε (Alpha/Epsilon), (2) with no sensitive parts mounted in deep crevices, where the collimation of the radiation would be important, or (3) where the rotational motion in space would be such as to result in effectively uniform solar planet illumination sufficient to cancel the effects of crevices and nonuniform α/ε surface finishes.

2.2.2.1 Open structure line source. Quartz lamps, carbon cloth, tungsten wire, strip and tubular heaters, and other similar means may be utilized to simulate the heating effects of solar energy, planet radiation, and albedo on test specimens within cryogenically cooled space simulation chambers. Radiation units and supporting structures shall be designed for minimum blockage area, ease of mounting, low out-gassing, and controllability of radiation intensity.

2.3 Heat sink (radiant). Both the temperature and emissivity, or blackness, of the cryogenic shrouds are important parameters in simulating the blackness of space. The low temperature reduces the radiation emitted by the walls in accordance with the Stefan-Boltzmann Law, and the high emissivity causes the walls to absorb any radiation impinging upon them rather than reflecting the energy back to the test vehicle. A 100° Kelvin wall with a 0.95 emissivity will simulate the space environment to within 1 percent for a 300° Kelvin vehicle. Radiation can leave the surface of the chamber by either reflection or emission and control of both is necessary to maintain good simulation of the space environment. Total reflected and emitted radiation, exclusive of the solar simulation arriving at the test vehicle shall be less than 50 watts per square meter.

2.3.1 Warm surfaces, such as windows, feed-through ports, chamber walls, etc, should be kept to a minimum and should be covered with cooled plates when they are not in use.

2.4 Contamination controls. Contamination levels shall be controlled and measured to insure that emissivity and absorptive values are not altered by more than 5 percent of the initial values of the flight or test hardware from time of acceptance of test article to completion of the test.

3. PREPARATION FOR TEST

3.1 Information required. In preparing the specimen for a test, typical information required is:

a. Need for simulating planet/moon radiation and albedo.

b. Rotational modes and attitude orientation, as applicable.

c. Programming solar radiation in accordance with the mission (considering the day and night orbiting periods plus cislunar and translunar missions).

d. Equipment operation duty cycles.

e. Duration of test.

f. Method for monitoring test item during test.

g. Operating parameters to be monitored.

h. Allowable deviation from specified tolerances.

i. Coupling of radio frequency outputs to dummy loads.

j. Substitution of power source having volt-ampere characteristics similar to the vehicle's primary power supply.

k. Emission of fuels and oxidizers.

l. Statement of reliability and failure criteria.

m. Peripheral heating and cooling devices to maintain proper conditions of equipment under test until flight conditions are established.

n. Aerodynamic heating simulation requirement.

o. Vehicle surface emissivity and absorptivity.

p. Vehicle thermal balance computations.

q. Minimum heating conditions (i.e., the coldest condition which is often the most difficult to achieve).

r. Auxiliary power to supplement power rquirement for chamber and equipment under test.

s. Other applicable requirements.

3.2 Simulator performance parameter validation. The instrument performance chart, table 517.2-V, indicates the level of performance required of instruments for indicated parameters: absolute accuracy, reproducibility, response time, view angle, discrimination or sensitivity, and miscellaneous items for the evaluation of solar simulation.

3.3 Test duration. When the intended mission time of the test item is such that the test item will be exposed to low pressure conditions for periods in excess of 24 hours, the test chamber shall be maintained at a pressure of at least 1 x 10^{-5} Torr for not less than 24 hours to properly validate the performance of the test item. Test item with intended flight times of less than 24 hours shall be exposed to low pressure for a time equal to or longer than the actual intended flight time to properly validate the performance of the test item.

Table 517.2-V. Solar Simulator, Instrumentation Performance Requirements

Parameter	Absolute accuracy	Repeatability	Response time	Miscellaneous
Total irradiance	±3%	±1%	1 min. max.	Spectral sensitivity ±2% for 2500-25,000 Angstrom (See note 1)
Irradiance uniformity	N/A	±1%	1 min. max.	Scan time must be compatible with response time (See note 1)
Solar subtense angle divergence	1/4°	1/4°	N/A	Reference to axis of chamber See note 1
Temporal stability	±5%	±5%	1 sec.	See note 2
Spectral distribution				See note 3

NOTES: 1. View angle should be 5 degrees or greater than the solar subtense angle.

2. Temporal stability as used in this standard means the intensity fluctuation of the source where the source is defined in its broadest sense to include the optics. No quantitative value can be given that will serve as a universal stability standard to which all sources must comply. It is self evident that the time constant of the test object or perhaps a local area of interest would have a direct bearing on the resulting criterion. Further, by the broadest interpretation of temporal stability, intensity variations during

periods of lamp or electrode replacement must be considered. For the present, it appears appropriate to merely state that the periods of fluctuation must be considerably less than the time constant of the test area of interest.

3. Spectral distribution shall be measured at a carefully defined point in the beam. The bandwidth shall be no longer than that indicated in table 517.2-IV. Bandwidths of 500 Angstrom are preferable. The total area under the spectral curve shall be normalized to 1353 w/m^2 for comparison with the Johnson Spectral Curve having equivalent units. The accuracy shall be the smallest number in the applicable level of table 517.2-V. Calibration of spectral measuring equipment shall conform to current NBS recommended practices. If some other means of measuring spectral distribution should be used as a multiple filter radiometer, then proof of its calibration against the same source through use of accurate measurements with a monochromator shall be furnished.

4. PROCEDURES

4.1 Procedure I, solar simulation. The test item shall be subjected to a pressure of 10^{-5} Torr or lower in order to virtually eliminate heat transfer by convection. The test item shall initially see black coated chamber walls maintained at 100°K in order to simulate the heat sink of space. Simulated solar radiation shall be applied to the test item from the direction corresponding to that of the Sun in space.

The test object shall be mounted in the test chamber (Apparatus 2.1) having a cryogenic heat sink (Apparatus 2.3) and a solar simulator (Apparatus 2.2.1). The specimen shall be installed in the test volume on a fixture supported by low heat conduction means. If orbital simulation is required, the fixture shall provide means of motion. Albedo and planetary radiation may be simulated by the use of heat flux sources (Apparatus 2.2.2).

Recommended parameters for specific solar test requirements are specified in table 517.2-VI.

Table 517.2-VI. Significant Parameters for Solar Simulation

Parameter	Actual space condition	Thermal tests	Solar cell tests 2/	Collector type power systems	System tests
Intensity	1353W/M^2	1200-1600	1200-1400	1200-1400	1200-1400
Uniformity 1/	---	Class II	Class I	Class III±10%	±2 to 5%
Solar subtense angle	32'	Class I	Class III	1°	Class II
Spectral	Reference NASA SP8005	TABLE 517.2-IV			
Cold, black space	10^{-6} watts/M^2	Less than 50 W/M^2 received at test article			

1/ In test plane
2/ Near Earth orbit

4.1.1 Performance of test. The test item shall be prepared in accordance with General Requirements, 3.2. The temperature control surfaces of the test item shall not directly face any abnormal heat source. Any operational performance check shall be accomplished in accordance with General Requirements, 3.2. All equipment shall be operated (excluding any propulsion system) and measurements made as specified in the vehicle or equipment specification. The test chamber shall then be reduced to that pressure determined through compliance with 2.1 of this test method and the chamber walls cooled or below 100°K. Thermal energy corresponding to the applicable value and manner of exposure determined through compliance with 2.2.1 of this method shall then be applied to the test item. The normal rotational mode of the test item along with other requirements and conditions shall then be established and maintained throughout the test. Measurements made during the test shall be compared with the data obtained in accordance with General Requirements, 3.2. At the conclusion of the test, the test chamber shall be returned to standard ambient conditions and stabilized and the test item inspected in accordance with General Requirements, 3.2.

4.2 Procedure II, heat flux simulation. The test object shall be located within the test chamber (Apparatus 2.1) having a cryogenic heat sink (Apparatus 2.3). A heat flux simulation source (Apparatus 2.2.2) shall be provided surrounding the test object and thermally isolated from it. The test object shall be supported by low heat conduction means. The test shall be performed as described in 4.1.1.

4.3 Procedure III, heat-flux simulation with thermal canister. The test object shall be located within the test chamber (Apparatus 2.1) having a cryogenic heat sink (Apparatus 2.3) with a thermal canister. The test object shall be mounted within the canister by low heat conduction means. The test shall be performed as described in 4.1.1.

4.4 Procedure IV, heat flux simulation variable temperature shroud. The test object shall be located within the test chamber (Apparatus 2.1) having a variable temperature shroud. The test object shall be mounted within the shroud by low heat conduction means. The test shall be performed as described in 4.1.1.

4.5 Procedure V, heat flux with conductive source and cryogenic shroud. The test object shall be located within the test chamber (Apparatus 2.1) having a cryogenic heat sink (Apparatus 2.3). The test object shall have a conductive source attached to it and shall be supported by low heat conduction means.

4.6 Procedure VI, vacuum simulation. The test object shall be located within the test chamber (Apparatus 2.1). Its volume should be preferably much smaller than chamber volume. All test fixtures should be vacuum compatible.

4.7 Procedure VII, heat flux simulation with vehicle heaters. The test object shall be located within the test chamber (Apparatus 2.1) having a cryogenic heat sink (Apparatus 2.3). The test object shall have vehicle heaters (heater blankets or fluid system) attached to its surface.

5. DEFINITIONS. Terms frequently used in solar simulation in conjunction with thermal vacuum testing are as follows:

a. Absorptance. Absorptance is the ratio of the absorbed radiant flux to the incident radiant flux. Total absorptance refers to absorptance measured over all wavelengths. Spectral absorptance refers to absorptance measured at a specified wavelength.

b. Albedo. Albedo is the ratio of the amount of electromagnetic radiation reflected by a body to the amount incident upon it. This fraction is often expressed as a percentage, such as 34 percent for earth albedo. The spectrum of reflected energy is generally different from that of the incident radiation.

The definition of albedo, while identical with reflectance, is commonly used in astronomy and meteorology to describe the reflectivity of planetary bodies and their atmospheres to solar radiation.

c. Black body. A black body is defined to be a body which absorbs all incident energy. Therefore its absorptance α, is equal to 1 for all wavelengths. According to Kirchoff's law, such an object will be a perfect emitter of radiation at all wavelengths.

d. Collimation angle. See Solar subtense angle.

e. Emissivity (ε). Emissivity is the ratio of the radiant flux emitted by a specimen to that emitted by a black body radiator at the same temperature and wavelength. Generally refers to a specific sample or measurement of a specific sample. Total hemispherical emissivity is the energy emitted over the hemisphere above the emitting element for all wavelengths. Normal emissivity refers to the emissivity normal to the surface to the emitting body.

f. Radiance. Radiance is radiant flux emitted in a specified direction per unit projected area of surface, per unit solid angle. The preferred symbol for this quantity is L, and is usually expressed in units of

$$\text{Watts cm}^{-2}\ \text{sr}^{-1}$$

The irradiance (radiant flux density) produced by radiation from the source upon a unit surface area oriented normal to the line between source and receiver, divided by the solid angle subtended by the source at the receiving surface, is equal to source radiance if the receiver to source distance is large relative to the source size.

If the radiant source is a perfectly diffuse radiator (that is, emits exactly according to Lambert's Law), then its radiance is equal to its emittance per unit solid angle.

g. Radiant energy (Q). Radiant energy is energy emitted, transferred or received as radiation.

h. Radiant flux, also, radiant power (ϕ). Radiant flux, also radiant power, is the average radiant energy emitted, transferred or received as radiation per unit time per unit area.

i. Radiation, infrared. Infrared radiation is radiation for which the wavelengths are greater than those for visible radiation and less than about 0.1 millimeter.

j. Solar beam incident angle. The solar beam incident angle is the angle measured at an arbitrary point in the test volume (see figure below) between the incident rays striking that point and a line parallel to the axis of the solar beam. The angle shall be measured so that 95 percent or more of the solar energy incident at the aforementioned point is included. The maximum incident angle, usually found at the extreme edge of the test volume (or plane), is sometimes referred to as the solar beam divergence angle.

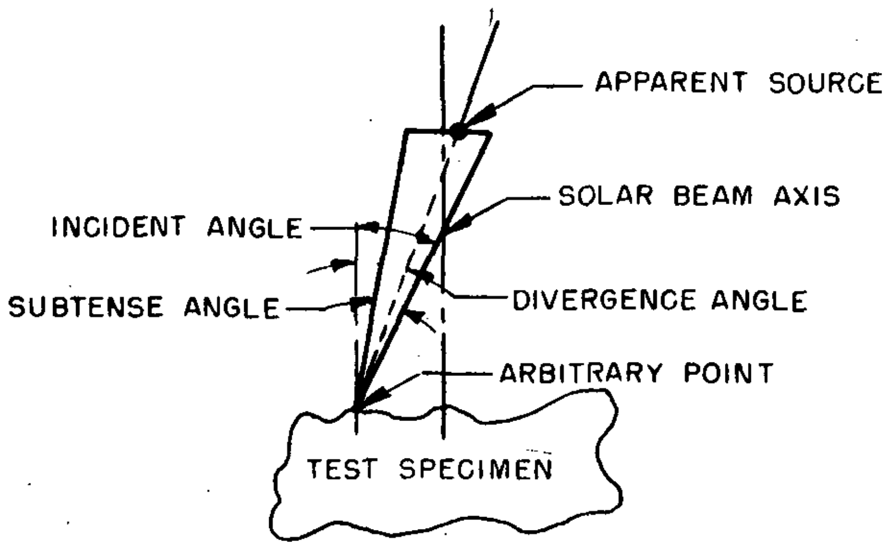


Figure 517.2-1. Geometrical Relationship of Solar Subtense and Incident Angle

k. Solar subtense angle. The solar subtense angle is that angle subtended by the maximum dimension of the apparent source at an arbitrary point on the test specimen. (See figure above.)

NOTE: The terms decollimation angle and field angle are sometimes used for subtense angle. The term subtense angle is preferred. The angle shall be measured so that 90 percent or more of the simulated solar energy incident at any point in the test volume is received from the apparent source as herein defined.

l. Solar constant. Solar constant is the rate at which solar radiation is received outside the Earth's atmosphere on a surface normal to the incident radiation and at the Earth's mean distance from the Sun.

m. Solar absorptance. This relates the absorptance of (α_s) a test item irradiated with a solar simulator to the absorptance the test item would experience from the Sun.

6. SUMMARY. *The following details shall be as specified in the equipment* specification:

a. Pretest data required (see General Requirements, 3.2).

b. All information necessary for the completion of 3.1a through 3.1b.

METHOD 518.1

TEMPERATURE-HUMIDITY-ALTITUDE

1. PURPOSE. The temperature-humidity-altitude test is conducted to determine the effects of cycling between low temperature/low pressure and high temperature/high humidity as may be obtained in service by flying equipment between extreme environments.

2. APPARATUS. Temperature-humidity-altitude chamber. No rust or corrosive contaminants shall be imposed on the test item by the test facility.

3. PROCEDURE I

Step 1 - Prepare the test item in accordance with General Requirements, 3.2.

Step 2 - Reduce the chamber temperature to -54°C (-65°F) within 2 hours.

Step 3 - Reduce the chamber pressure at a rate of 1,000 to 1,500 ft/min to 50,000 feet altitude while maintaining the specified -54°C (-65°F) temperature. The time from the start to the completion of step 3 shall be 2-1/2 hours.

Step 4 - Within 30 minutes, raise the chamber pressure to standard ambient pressure, return the chamber temperature to standard ambient temperature, and then, raise the chamber humidity to 95 percent RH.

Step 5 - Maintain temperature and humidity conditions for 2-1/2 hours.

Step 6 - During the next 30 minutes, increase the temperature to 65°C (149°F) and maintain humidity at 95 percent RH.

Step 7 - Maintain temperature and humidity conditions of step 6 for 6 hours.

Step 8 - During the next 8 hours, reduce the chamber temperature at a uniform rate to standard ambient temperature while maintaining humidity at 95 percent RH.

Step 9 - Maintain standard ambient temperature at 95 percent RH humidity for 2 hours.

NOTE: Steps 2 through 9 constitute one cycle as shown on figure 518.1-1.

Step 10 - Repeat steps 2 through 9 three more times.

Step 11 - Return to standard ambient conditions.

Step 12 - Reduce the chamber temperature to -54°C (-65°F) within 2 hours.

Step 13 - Reduce the chamber pressure at a rate of 1,000 to 1,500 ft/min to 50,000 feet altitude while maintaining the specified -54°C (-65°F) temperature. The time from the start to the completion of step 13 shall be 2-1/2 hours.

Step 14 - Within 30 minutes, return the chamber to standard ambient conditions. (Do not add humidity.)

Step 15 - After stabilization of the test item, operate and inspect the item and obtain results in accordance with General Requirements, 3.2. During this period, special attention shall be given to electrical and electronic test items for operation or malfunction resulting from arcing or corona effects.

4. SUMMARY. The following details shall be as specified in the equipment specification:

a. Pretest data required (see General Requirements, 3.2).

b. Failure criteria.

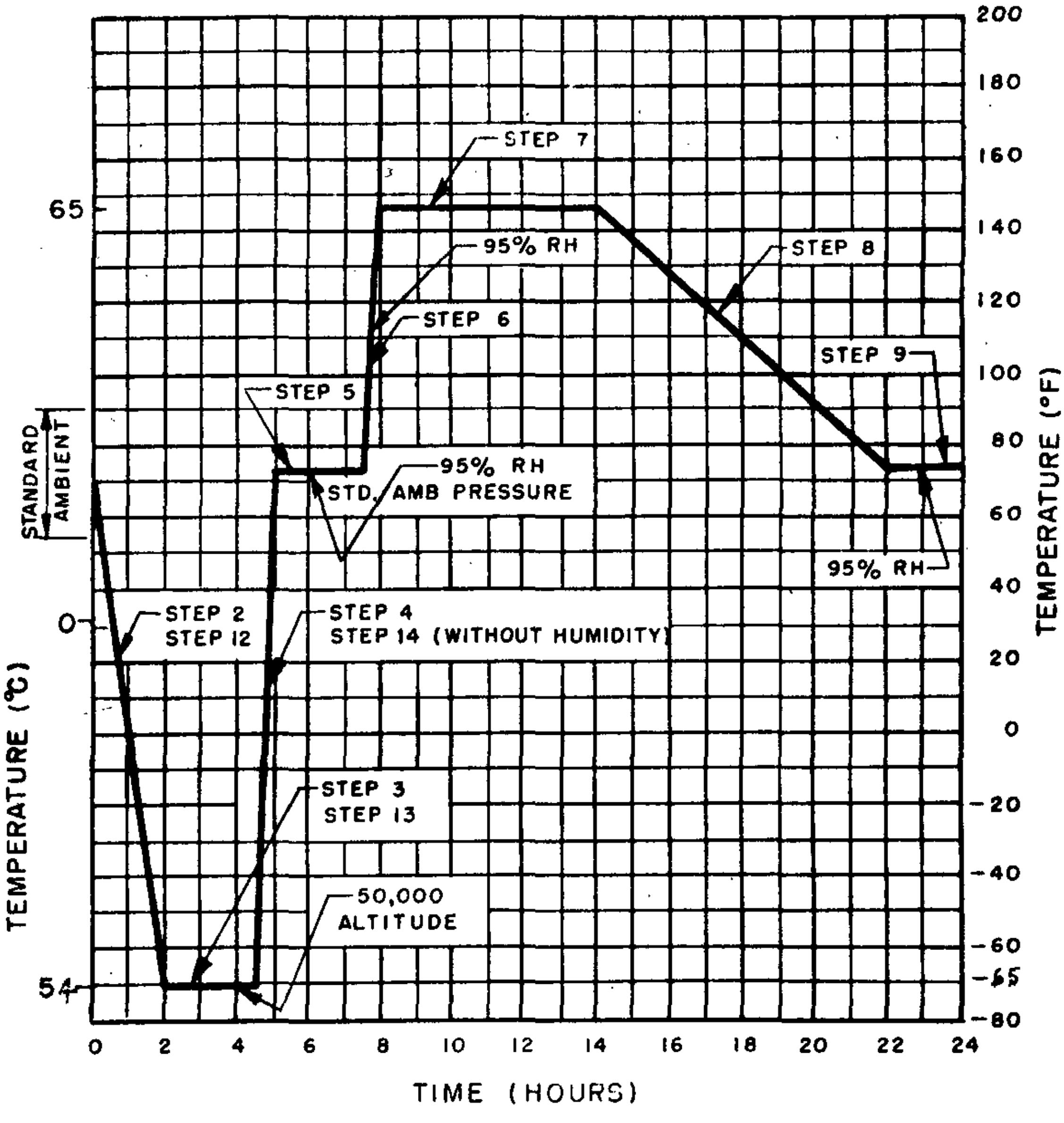


Figure 518.1-1. Temperature-Humidity-Altitude Cycle (Procedure I).

METHOD 519.2

GUNFIRE VIBRATION, AIRCRAFT

1. PURPOSE. The gunfire vibration test is conducted to simulate the relatively brief but very intense vibration fields resulting from blast pressure fields generated by repetitive firing guns mounted in, on or near the aircraft structure. This method applies to gun pod configurations and may also be used for helicopter gunships.

2. APPARATUS. Vibration shaker system with peripheral equipment and instrumentation.

3. CRITERIA FOR APPLICATION. The most severe vibration field results, primarily, from blast pressure pulses that transfer to the aircraft primary structure inducing a vibration field of maximum intensity near the gun muzzle region. This field, in an inverse relationship, decreases sharply as a function of the distance from the gun muzzle. Because of this marked variation; guns, physical locations, and ballistic parameters should be carefully and accurately identified prior to application of this test method.

In no case should this test method be substituted for conventional vibration tests but if the maximum test spectrum level of the gunfire configuration is equal to or less than the other specified vibration test levels the gunfire method need not be conducted.

3.1 Sensitive equipment. Equipments found most susceptible to gunfire are those equipments that are usually located within a 3-foot radius of the gun muzzle and are mounted on the structural surface exposed to the gun blast. Prime examples are UHF antennas of the blade, V, and the flush-mounted configurations, including their bracketry, coaxial connectors, and cables. Next in order of failure susceptibility is equipment mounted on drop-down doors and access panels, equipment mounted in cavities adjacent to and near the aircraft surface structure, and finally, equipment located in the interior of the vehicle. Typical vulnerable equipments in these latter categories are auxiliary hydraulic and power units (including mounting bracketry), switches, relays, IR, photographic, communication and navigation equipment and radar systems; including items either shock or hard mounted.

3.2 Equipments associated with mounting structures. Equipments are classified in accordance with the structure to which they are attached and are identified as either equipments mounted on primary structure or as equipments mounted on secondary structure.

3.2.1 Primary structure. Primary structure is that structure of the aircraft which comprises the main load carrying members or elements of the aircraft. Examples of primary structure are skin, frames, rings, bulkheads, stringers and includes those consoles structurally integrated with the aircraft outer walls.

3.2.2 Secondary structure. Secondary structure is that structure to which equipment is attached onto or contained in and whose mounting points terminate at the outer frame, skin, stringers, bulkheads, floors, spars or cast framing of the primary structure. Examples of secondary structure are instrument panels, trays, racks, shelves, trusses, beams, and consoles.

3.3 Determination of test spectrum. This method requires that the test spectrum for primary structure be determined first and then, if applicable--that is, for those equipments associated with secondary structure; the primary spectrum be modified to represent the final test spectrum.

The test spectrum consists of low frequency sinusoidals (basic gunfire rate and the second, third and fourth harmonics) superimposed on a continuous random vibration spectrum (see figure 519.2-1). The vibration prediction surfaces from which the spectrum for the primary structure is derived are shown in figures 519.2-2 through 519.2-4. Figure 519.2-2 represents the prediction surface for the sinusoids. Figure 519.2-3 is the surface used to obtain the high frequency random part of the spectrum. Figure 519.2-4 is the surface used to define the low frequency portion of the random spectrum. All surfaces are three dimensional isometric projections in which the surface shape varies as a function of the normalized frequency parameters f/f_0, f/f_0, and the vector distance, D. The frequency parameters are presented in this form since they are treated as variables. The distance parameter, D, represents the vector distance measured from the gun muzzle to the mean distance between equipment support points.

Note that the amplitude (vertical) scale is represented as a dB scalar ($10 \log_{10}$); thus, all values of the surfaces are referenced to 0 dB. To utilize these surfaces it is necessary to: first establish the magnitudes of the sine and the random vibration at the 0 dB level and then proceed to the D = x slice of the surface and pick off the required spectral values, relative to 0 dB.

3.3.1 Determination of the 0 dB level. The 0 dB level for the sine and random vibration is defined by the following equations.

$$G_{os} = \Gamma_s \; E/E_o \; r/r_o \; n/n_o \qquad (1)$$

$$G_{or} = \Gamma_r \; E/E_o \; r/r_o \; n/n_o \qquad (2)$$

G_{os} = 0 dB vibration level, mean squared g, sine (g^2)

G_{or} = 0 dB vibration level, accel. power spectral density (g^2/Hz)

E = blast energy of gun (ft-lbs/gun)

r = gun firing rate (Hz)

n = number of guns

E_o = blast energy of reference gun (M-61) = 55,000 ft-lbs/gun

r_o = gunfire rate of reference gun = 100 Hz

n_o = 1

Γ_s = maximum sine vibration level of reference gun = 2,000 mean squared g (g^2)

Γ_r = maximum random vibration level of reference gun = 35 g^2/Hz

A shortened form of (1) and (2) results when the reference parameters are inserted.

$$G_{os} = 3.64 \times 10^{-4} \; E \; r \; n \qquad (1a)$$

$$G_{or} = 6.36 \times 10^{-6} \; E \; r \; n \qquad (2a)$$

3.3.1.1 Determination of the gun blast energy (E). The gun blast energy is determined by the following equation.

$$E = fW^c/.3 - mv^2/2 \qquad (3)$$

f = specific impetus of explosive (ft/lbs/$_{lb}$)

W^c = weight/$_{round}$ of ammunition (lb/rd)

m = W_p/g = mass of projectile (lbs-sec^2/ft)

W_p = weight of projectile (lbs)

v = muzzle velocity of projectile (ft/sec)

$g = 32.17$ ft/sec^2

Table 519.2-IA is a general table which relates typical gunfire configurations to aircraft types. To facilitate identification of the ballistic parameters that are necessary to determine the gunfire vibration levels of 3.3, table 519.2-IB is provided. The table includes values of E, r, n and the muzzle velocity v; the table also includes the reference gun parameters of the M61. Table 519.2-IC is a repeat of this table using metric equivalents. Finally, a brief array of English-to-metric conversion constants are provided as specified in table 519.2-ID.

3.3.2 Adjustments of G_{os}, G_{or} (primary structure). The two 0 dB parameters shall be adjusted to account for the following additional conditions: gun standoff distance (H), gun muzzle configuration (M), equipment depth parameter (R) and equipment mass loading (W). The adjusted values G^a_{os} and G^a_{or} are the final 0 dB values from which the magnitude of any point (G_s, G_r) is established on the prediction surfaces of figures 519.2-2 through 4. These values and the individual adjustments are expressed in decibel form as follows:

$$10 \log_{10} \frac{G^a_{os}}{\Gamma_s} = 10 \log_{10} \frac{G_{os}}{\Gamma_s} + \Delta_h + \Delta_M + \Delta_R + \Delta_W \qquad (4)$$

$$10 \log_{10} \frac{G^a_{or}}{\Gamma_r} = 10 \log_{10} \frac{G_{or}}{\Gamma_r} + \Delta_h + \Delta_M + \Delta_R + \Delta_W \qquad (5)$$

$10 \log_{10} \frac{G^a_{os}}{\Gamma_s}$ = final, adjusted 0 dB value of the sine surface; referenced to Γ_s

$10 \log_{10} \frac{G^a_{or}}{\Gamma_r}$ = final, adjusted 0 dB value, of the random surface; referenced to Γ_r

Δ_h = reduction due to gun standoff distance (dB)

Δ_M = reduction due to gun muzzle configuration (dB)

Δ_R = reduction due to depth parameter (dB)

Δ_W = reduction due to mass loading (dB)

3.3.2.1 Test level reduction, Δ_h, of G_{os} and G_{or} due to gun standoff parameter (h/c). A reduction of G_{os}, G_{or} in accordance with the criteria of figure 519.2-5, shall be allowed for the case of gun configurations with muzzles mounted a perpendicular distance from the aircraft structure.

3.3.2.2 Test level reduction, Δ_M, of G_{os} and G_{or} due to free air configuration. A reduction of G_{os}, G_{or} shall be allowed for those cases in which the gun protrudes clear of and in front of the aircraft structure as shown in figure 519.2-6. The reduction shall be 6 dB; otherwise $\Delta_M = 0$ dB.

3.3.2.3 Test level reduction, Δ_R, of G_{os} and G_{or} as a function of R_s. The curve of figure 519.2-7 provides means by which G_{os} or G_{or} shall be reduced as a function of R_s.

3.3.2.3.1 Determination of the depth parameter (R_s). The depth parameter represents the shortest distance of the equipment mounting points to the aircraft surface as shown in figure 519.2-8. The measurement shall be taken from the equipment or mounting points that are nearest to the aircraft surface. If R_s is unknown or cannot be estimated, R_s shall be set at 3 inches or less.

3.3.2.4 Test level reduction, Δ_W, of G_{os} and G_{or} due to equipment mass loading. Figure 519.2-9 provides graphical means by which G_{os}, G_{or} may be reduced as a function of equipment weight. For those equipments attached directly to primary structure through vibration isolators; $\Delta_W = 0$. For equipments associated with secondary structure, $\Delta_W = 0$.

3.3.3 Determination of the distance parameter (D). The distance parameter represents the vector distance, measured (or estimated) from the gun muzzle to the mean distance between equipment support points. Where equipment support points are indeterminate, the equipment center of gravity shall represent the terminal point of D. The vector D is generated from the orthogonal distances referenced to the fuselage station, the water, and the butt line data. The D vector and the computational form is shown in figure 519.2-8.

3.3.3.1 Multiple guns, closely grouped. For configurations involving multiple guns, the origin of D is determined from the centroidal point of the gun muzzles. Figure 519.2-10 shows the origin location for a typical four-gun staggered array.

3.3.4 Application of gunfire prediction surfaces. Determine the value of D (see 3.3.3), establish the values of G^a_{os} and G^a_{or} (see 3.3.2); and using the locator grid at the top of figures 519.2-2 and 3, respectively, find the intersection points of f/f_o ($f/f_{o'}$) and D. From these points drop down vertically until the prediction surface is intersected. Measure the vertical distance with a ruler or dividers. Transfer this distance to the dB scale keeping the grid intercept in the zero dB plane. This distance, in dB, represents the magnitude of G_s or G_r referenced down from G^a_{os} or G^a_{or} (determined in 3.3.2).

The equational form for this procedure appears as the following:

$$10 \log_{10} \frac{G_s}{G^a_{os}} = dB_s \qquad (6)$$

$$10 \log_{10} \frac{G_r}{G^a_{or}} = dB_r \qquad (7)$$

G_s = a value of g^2 sine on the sinusoidal prediction surface at a given value of D and f/f_o (see figure 519.2-2)

G_r = a value of g^2/Hz on the high frequency random prediction surface at a given value of D and $f/f_{o'}$

dB_s = the value of G_s, in dB, referenced to G^a_{os}

dB_r = the value of G_r, in dB, referenced to G^a_{or}

3.3.4.1 Determination of the low frequency random spectrum. Reference to figure 519.2-4 shows that the maximum value of the low frequency random case ($G_{r\,max}$) occurs at f/f_o = 2.0 and has the same value for the high frequency spectrum at $f/f_{o'}$ = 0.7. Since $G_{r\,max}$ has been determined for the high frequency random (3.3.4), transfer this value to figure 519.2-4 and plot (see 6. for an example).

3.3.4.2 Determination of f_o and $f_{o'}$. The value of the locator frequencies, f_o and $f_{o'}$, are as follows:

Sinusoidal Surface (Figure 519.2-2

f_o = 250 Hz

f_o = 200 Hz for items mounted on the aircraft skin

High Frequency Random Surface (Figure 519.2-3)

$f_{o'}$ = see Figure 519.2-11

Low Frequency Random Surface (Figure 519.2-4)

f_o = 300 Hz

3.3.4.3 Selection of fundamental gunfire frequency and the required harmonics. These properties shall be determined as follows:

Set the gunfire rate, r, = f_1 and let $f_2 = 2f_1$, $f_3 = 3f_1$ and $f_4 = 4f_1$

Note that the low frequency limit of the sine envelope of G_s (also the low frequency random envelop, G_r) shall be equal to $f_1 - .2f_1$. The upper frequency limit of the sine envelope, only, shall extend to $f_4 + .2f_4$.

3.3.5 Multiple guns, dispersed. For configurations characterized by guns placed at separate stations as shown in figure 519.2-12, determine each D vector to the equipment locations; and from this obtain their corresponding G_s and G_r values and, finally, add each set of values to obtain the predicted level.

3.3.6 Conversion of high frequency random spectrum, G_r. The high frequency random spectrum may be readily converted to discrete spectral values by multiplying G_r by its corresponding 1/3 octave bandwidth. The bandwidth (Δf) is determined by multiplying any given frequency (f) by .23.

3.3.7 Determination of overall RMS(OARMS). The overall RMS of the sine waves and the random noise spectrum is determined as follows:

$$OARMS = [G_{s1} + G_{s2} + G_{s3} + G_{s4} + OAMS_R]^{1/2} \quad (8)$$

where: $G_{s1}, G_{s2}, G_{s3}, G_{s4}$ = magnitude of sines (g^2)

$OAMS_R$ = overall mean squared g of the random noise spectrum (g^2)

3.3.7.1 Determination of overall mean squared random noise spectrum ($OAMS_R$). The $OAMS_R$ of the spectrum is determined as follows:

$$OAMS_R = A_1 + A_a^b + A_c^d \quad \text{(See figure 519.2-13)} \qquad (9)$$

$$A_1 = G_{r\ max}\,[f_c - f_b] \qquad (10)$$

where: $f_c = 0.7f_{o'}$

$f_b = 600$ Hz

$$A_a^b = f_o\, G_{r\ max}\,[I_b - I_a] \qquad (11)$$

where: $f/f_o = a$ and $f/f_o = b$ (See figure 519.2-13)

$[I_b - I_a]$ is the difference in ordinate values of I at $f/f_o = a$ and $f/f_o = b$ (See figure 519.2-14)

$$A_c^d = f_{o'}\, G_{r\ max}\,[I_d - I_c] \qquad (12)$$

where: $f/f_{o'} = c$ and $f/f_{o'} = d$ (See figure 519.2-13)

$I_d - I_c$ is the difference in ordinate values of I at $f/f_{o'} = c$ and $f/f_{o'} = d$ (See figure 519.2-15)

3.3.7.1.1 Determination of $[I_b - I_a]$ and $[I_d - I_c]$. Refer to figure 519.2-16 and from a known value of D, select from the curve an appropriate value of β_f. From this curve pick off the appropriate values of the ordinate, I, at $f/f_o = a$ and $f/f_o = b$. Note that the properties a and b are determined from figure 519.2-13. Substitute these values in equation (11). $[I_d - I_c]$ is determined in the same manner except figure 519.2-17 is used to obtain $\beta_{f'}$; the slope factor for the high frequency random surface. Figure 519.2-15 is then used to obtain I_d and I_c. Substitute in eq. (12).

3.4 Determination of test levels (secondary structure). This paragraph shall apply to those equipment arrays located on or in secondary structure and whose aggregate of equipments and structure are of a size, weight and complexity to preclude the testing of the entire configuration as a single entity. In such cases the equipment may be removed from the secondary structure for individual vibration tests. Note that the equipment shall be excited in the isolated or hard mounted mode in compliance with the actual mounting configuration in or on the secondary structure. All other equipments not identified with secondary structure shall be associated with primary structure and treated in accordance with 3.3.

Special transfer functions have been provided in order that the primary test spectrum G_s and G_r may be operated on to reflect a response spectrum which becomes the secondary, or input, test spectrum for the appropriate equipment. The operation and the resultant response spectrum Y_s and Y_r for the sine and the random case, respectively, is shown as follows:

$$G_s \; |H(f)|^2 = Y_s \qquad (13)$$

$$G_r \; |H(f)|^2 = Y_r \qquad (14)$$

Since G_s and G_r have been expressed in decibel form (see equations 6 and 7) and $|H(f)|^2$ is also expressed in this form (see figures 519.2-18 and 519.2-19) then Y_s and Y_r may be found by algebraically adding the spectral values of the primary structure to the appropriate transfer function as follows:

$$dB_{Y_s} = dB_s + dB_H \qquad (15)$$

$$dB_{Y_r} = dB_r + dB_H \qquad (16)$$

dB_{Y_s} = sine test spectrum for equipments associated with secondary structure.

dB_{Y_r} = random test spectrum for equipments associated with secondary structure

dB_s = sine test spectrum for equipments associated with primary structure (re. $G_{s\ max}$)

dB_r = random test spectrum for equipments associated with primary structure (re. $G_{r\ max}$)

dB_H = transfer function $|H(f)|^2$ in decibel form

3.4.1 Equipment categories, secondary structure. Equipments mounted on or in secondary structures are designated in accordance with the following structural categories. Table 519.2-II provides generalized visual examples and also references corresponding transfer functions.

Category I - Equipment and groups of equipments mounted on or in racks and trays.

a. Isolated. Equipment whose secondary structure is terminated to the primary structure through vibration isolators. Examples: generators, comnavigation units, data computers, forward looking radar.

b. Hard mounted. Equipments whose secondary structure is terminated to the primary structure through rigid attachments. Examples: power supplies, control boxes, switches, intervelometers, breakers, logic modules, inverters, inertial guidance and measurement units.

Category II - Equipment mounted in or on instrument panels.

a. Isolated. Equipment whose instrument panel is isolated.

b. Hard mounted. Equipment whose instrument panel is hard mounted.

Category III - Equipment mounted in or on beams, channels and trusses. These equipments are usually large, heavy and bulky.

a. Isolated. Equipments whose secondary structure is terminated to the primary structure through vibration isolators. Examples: cameras, radar packages.

b. Hard mounted. Equipments whose secondary structure is terminated to the primary structure through rigid attachments. Examples: cameras, inertial measurement units.

3.4.2 Application of $|H(f)|^2$. From table 519.2-II select the transfer function associated with the mounting category. These categories are represented by two sets of curves (figures 519.2-18 and 519.2-19) and allow envelope adjustments owing to the weight of the equipments.

The first set of curves (figure 519.2-18) involves a selection of κ as a function of equipment weight (there are exceptions to this rule noted in table 519.2-II). This value, κ, is then inserted into the f/f_{n_1} parameter as indicated at the bottom part of the transfer function curves. Normally, W is equivalent to the total equipment weight on the shelf panel, beam or truss. If stacked arrays of equipments are involved (consoles, etc.) then W is the total weight of the assembly and f_{n_1} is the average value of the shelf array.

Finally, in dB form algebraically add $|H(f)|^2$ to G_s and G_r at a sufficient number of their corresponding frequencies to insure a smooth spectral plot. In no case shall there be less than fifteen plot points over the test spectrum.

4. TEST IMPLEMENTATION. Test procedures used shall be as specified in the equipment specification or test plan.

4.1 Test item operation. Unless otherwise specified, the test item shall be operated during application of vibration so that functional effects caused by these tests may be evaluated. When a test item performance test is required during vibration and the time required for the performance is greater than the duration of the vibration test, the performance test shall be abbreviated accordingly. At the conclusion of the test, the test item shall be operated and the results obtained in accordance with General Requirements, 3.2. The test item then shall be inspected in accordance with General Requirements 3.2.

4.2 Mounting techniques. In accordance with General Requirements, 3.2, the test item shall be attached to the vibration exciter table by its normal mounting means or by means of a rigid fixture capable of transmitting the vibration conditions specified herein. Precautions shall be taken at the mechanical interfaces to minimize the introduction of undesirable responses in the test setup. Whenever possible, the test load shall be distributed uniformly on the vibration exciter table in order to minimize effects of unbalanced loads. Vibration amplitudes and frequencies shall be measured with instrumentation that will not significantly affect the test item input control or response. The input control accelerometer(s) shall be rigidly attached to the vibration table or to the intermediate structure, if used, at or as near as possible to the attachment point(s) of the test item.

5. TEST PROCEDURES

5.1 Procedure I, sine superimposed on random vibration. The test item shall be subjected to vibration along each mutually perpendicular axis. The excitation shall consist of four sinusoids superimposed over a random vibration background. The sinusoids shall be at frequencies representing the basic gunfire rate, and the second, third and fourth orders (f_1, f_2, f_3, f_4). Synchronously, the frequencies shall be swept over a bandwidth equal to $\pm.2f_1$, $\pm.2f_2$, $\pm.2f_3$, $\pm.2f_4$ beginning at the low frequency end and ending at the high frequency limit. The sweep time for the combination sine sweep and random vibration shall be 15 minutes per axis. The instantaneous peaks of the random vibration may be limited to 2.5 times the rms spectral acceleration level. The test envelope tolerances shall be as indicated in table 519.2-III and figures 519.2-20, 519.2-21 and 519.2-22.

5.2 Procedure II, single direction test. If the equipment item is mounted with the base peripherally attached onto and in the plane of the aircraft skin, then the test direction may be restricted to the direction normal to the aircraft skin (see figure 519.2-23). The total test time in this case shall be 30 minutes.

5.3 Procedure III, alternate test. For large equipment located near the gun muzzle, the overall test levels may exceed the force capabilities of all but the largest shaker systems. For such cases the sinusoidals may be separated from the random vibration and each test run independently -- each test shall run for 15 minutes per axis.

5.4 Procedure IV, alternate test (Pulse method). If no equipment is available to provide a test in accordance with Procedure I then a swept repetitive pulse technique may be used as an alternate method; provided that the pulse method is in compliance with the following requirements.

5.4.1 Spectral content. The generated spectrum shall consist of discrete acceleration magnitudes whose frequencies (f) correspond to the expression $f = nf_1$: where f_1 is the basic gunfire rate and n = 1, 2, 3 ...k. The last integer (k) is that value of n for which nf_1 is nearest to the maximum test frequency, 2 KHz.

5.4.2 Spectral magnitude and shape. The pulse test spectrum shall be defined by an envelope that outlines the discrete magnitudes of the low frequency sinusoids (formerly derived for Procedure I) and extends to connect with the envelop of the converted high frequency random spectrum as derived in 3.3.6. Note that the low frequency random spectrum of Procedure I is not used.

5.4.3 Pulse sweep parameters. The cycling time shall be the same as in 5.1 and the pulse rate (f_1) shall be continuously swept over the frequency bandwidth range as defined for f_1 in 5.1.

6. SUMMARY. The following details shall be specified in the equipment specification or test plan.

a. Gun identification and ballistic parameters (see tables 519.2-IA, 519.2-IB, 519.2-IC).

b. Gun configuration and location (see 3.3.2 and 3.3.3).

c. Equipment location on/in aircraft (fuselage station, water and butt line coordinates).

d. Equipment category (see 3.2.1, 3.2.2 and 3.4.1).

e. Distance from aircraft surface to nearest point of equipment (see 3.3.2.3.1).

f. Equipment weight (see 3.3.2.4, 3.4.2).

g. Test procedures (see 5).

REFERENCES

1. R. W. Sevy, E. E. Ruddell, "Low and High Frequency Aircraft Gunfire Vibration; Prediction and Laboratory Simulation," AFFDL-TR-74-123, August 1974.

2. R. W. Sevy, J. Clark, "Aircraft Gunfire Vibration; The Development and the Synthesis of Equipment Vibration Techniques," AFFDL-TR-70-131, November 1970.

7. EXAMPLES. The following examples are provided to facilitate the synthesis of the test spectrum for a number of typical cases ranging from equipments located on primary structure to those equipments associated with secondary structure.

7.1 An aerial refueling unit weighing 75 pounds is located in the nose section of the A-10 aircraft. The GAU/8, a 30 mm cannon is to be used and the firing rate (r) is to be 70 rounds/sec. The unit inserts into the aircraft flush with the skin and is bolted directly to the primary structure. The D vector is 48 inches and $R_s = 0$.

7.1.1 Determination of G_{os} and G_{or}. From 3.3.1 select equation (1) or (1a).

$$G_{os} = \Gamma_s \, E/_{E_o} \, r/_{r_o} \, n/_{n_o}$$

$$\Gamma_s = 2000 \, g^2$$

$$E/_{E_o} = 4.13 \text{ (see table 519.2-IB)}$$

$$r/_{r_o} = 70/_{100} = .7$$

$$n/_{n_o} = 1/_1 = 1$$

$$G_{os} = 2000 \, g^2 (4.13)(.7)(1)(1) = 5782 \, g^2$$

select equation (2) or (2a)

$$G_{or} = \Gamma_r \, E/_{E_o} \, r/_{r_o} \, n/_{n_o}$$

$$\Gamma_r = 35 \, g^2/\text{Hz}$$

$$G_{or} = 35 \, g^2/\text{Hz} \; (4.13)(.7)(1)(1) = 101.19 \, g^2/\text{Hz}$$

7.1.1.1 Test level reduction, Δ_h, of G_{os} and G_{or} due to gun standoff parameter (h/c). Owing to the gun configuration of this aircraft (see figure 519.2-5 and 519.2-6), $\Delta_h = 0$ dB.

7.1.1.2 Test level reduction, Δ_M, of G_{os} and G_{or} due to free air configuration. This is a free air configuration (see 3.3.2.2 and figure 519.2-6); Δ_M = -6 dB.

7.1.1.3 Test level reduction, Δ_R, of G_{os} and G_{or} as a function of R_s. See figure 519.2-7. Since R_s = 0; Δ_R = 0 dB

7.1.1.4 Test level reduction, Δ_W, of G_{os} and G_{or} due to equipment mass loading. Refer to figure 519.2-9. Since the equipment weight (W) is 75 pounds G_{os} and G_{or} may be reduced 2.6 dB ($10 \log_{10}$); thus Δ_W = -2.6 dB.

7.1.2 Adjustments of G_{os}, G_{or} (primary structure). Refer to equations (5) and (6) of 3.3.2 and insert the dB reductions.

$$10 \log_{10} \frac{G^a_{os}}{\Gamma_s} = 10 \log_{10} \frac{G_{os}}{\Gamma_s} + (0) + (-6) + (0)\ (-2.6)$$

where: $G_{os} = 5782\ g^2$

$\Gamma_s = 2000\ g^2$

$$10 \log_{10} (2.891) - 8.6 \text{ db} = 4.6 \text{ dB} - 8.6 \text{ db} = -4 \text{ dB re. } 2000\ g^2$$

$$G^a_{os} = (2000)(.398) = 796\ g^2 = 28.21 \text{ grms} = 0 \text{ dB (figure 519.2-2)}$$

Also, the dB adjustments are the same for G_{or}, so using equation (6) of 3.3.2

$$10 \log_{10} \frac{G^a_{or}}{\Gamma_r} = 10 \log_{10} \frac{G_{or}}{\Gamma_r} - 8.6 \text{ dB}$$

where: $G_{or} = 101.19\ g^2/Hz$

$\Gamma_r = 35\ g^2/Hz$

$$10 \log_{10} 2.891 - 8.6 \text{ db} = 4.6 \text{ dB} - 8.6 \text{ dB} = -4 \text{ dB re. } 35\ g^2/Hz$$

$$G^a_{or} = (35)(.398) = 13.93\ g^2/Hz = 0 \text{ db (figure 519.2-3)}$$

7.1.3 Determination of the locator frequencies f_o and $f_{o'}$. From 3.3.4.2 select: f_o = 200 Hz for the sinusoidal surface, f_o = 300 Hz for the low frequency random surface and from figure 519.2-11 select (from the curve at W = 75 lbs): $f_{o'}$ = 900 Hz.

7.1.4 Determination of the sinusoidal surface, G_s. Refer to figure 519.2-2. It is useful to draw lines on the figure hence it is advantageous to make a copy. On the copy draw a line in the zero dB plane parallel to the constant D lines at D = 48 inches. Note that this line intersects the f/f_o parameter. From the intersections draw vertical lines down to the heavy, constant f/f_o lines of the prediction surface. These distances down are now transferred to the left hand dB scale (3.3.4). Recalling that f_o = 200 Hz for the sinusoidal surface arrange a table of values of G_s vs f/f_o as follows:

G^a_{os} = 796 g^2/28.2 grms

f/f_o	f	G_s (dB re. G^a_{os})
2.0	400	- 11.6 = 55.07 g^2 = 7.42 grms
1.6	320	- 12.3 = 46.86 g^2 = 6.85 grms
1.2	240	- 13.8 = 33.19 g^2 = 5.76 grms
1.0	200	- 15.5 = 22.43 g^2 = 4.74 grms
0.8	160	- 18.6 = 10.98 g^2 = 3.31 grms
0.6	120	- 20.5 = 7.09 g^2 = 2.66 grms
0.4	80	- 22.0 = 5.02 g^2 = 2.24 grms
0.2	40	- 23.0 = 3.98 g^2 = 1.99 grms

For plotting purposes it is convenient to express the values of G_s relative to G_s at f/f_o = 2.0; which is $G_{s\ max}$. This is done by subtracting $G_{s\ max}$ (-11.6 dB) from all of the values.

f/f_o	f	$G_s - G_{s\ max}$ (dB_s)
2.0	400	0 dB re. 55.07 g^2 = 7.42 grms
1.6	320	- 0.7
1.2	240	- 2.2
1.0	200	- 3.9
0.8	160	- 7.0
0.6	120	- 8.9
0.4	80	- 10.4
0.2	40	- 11.4

Before proceeding to the next step it is instructive to pause and observe that were we concerned with defining a test spectrum for secondary structure (3.4) it is now only necessary to attach the required dB_H column to the right of the present dB_S column and add the values to obtain the response, dB_{Y_S}.

7.1.4.1 Setting up the sine spectrum. Plot the envelope of G_S as a function of frequency (see 3.3.4.1) and designate the fundamental and harmonics as follows:

1. Set $r = f_1 = 70$ Hz, $f_2 = 2(70) = 140$ Hz,

   $f_3 = 3(70) = 210$ Hz and $f_4 = 4(70) = 280$ Hz

2. Pick off the four corresponding values of dB_s from the plot (re. 55.07 g^2 or 7.42 grms)

   @ 70 Hz G_{s1} = - 10.7 dB = 4.69 g^2 = 2.16 grms
   @ 140 Hz G_{s2} = - 8.1 dB = 8.53 g^2 = 2.92 grms
   @ 210 Hz G_{s3} = - 3.9 dB = 22.43 g^2 = 4.74 grms
   @ 280 Hz G_{s4} = - 1.3 dB = 40.82 g^2 = 6.39 grms

3. Establish the cycling range for each sinusoid.

$f_1 = \pm .2(f_1) = \pm .2(70) = 56$ to 84 Hz

$f_2 = \pm .2(f_2) = \pm .2(140) = 112$ to 168 Hz

$f_3 = \pm .2(f_3) = \pm .2(210) = 168$ to 252 Hz

$f_4 = \pm .2(f_4) = \pm .2(280) = 224$ to 336 Hz

Note that the low end of the cycling range ($f_1 - .2f_1$) is 56 Hz and is also the low end of the low frequency random spectrum (see 3.3.4.3 and figure 519.2-11).

7.1.5 Determination of the high frequency random surface, G_r. Refer to figure 519.2-3 and at the intersections of $f/f_{o'}$ and D = 48 inches record the following values of G_r. Note that $f_{o'}$ = 900 Hz (see 3.3.4.2).

$f/f_{o'}$	f	G_r (dB re. G^a_{or})	$G^a_{or} = 13.93\ g^2/Hz$
.7	630	- 13.7 = .594 g^2/Hz	
.89	800	- 16.2 = .334 g^2/Hz	
1.0	900	- 18.2 = .205 g^2/Hz	
1.11	1000	- 20.1 = .135 g^2/Hz	
1.39	1250	- 24.0 = .060 g^2/Hz	
1.78	1600	- 29.2 = .056 g^2/Hz	
2.22	2000	- 33.5 = .006 g^2/Hz	

Make $G_{r\ max}$ the reference value by subtracting it from all the values of G_r.

f/f_o	f	$G_r - G_{r\,max}$ (dB_r)
.7	630	0 dB re. .594 g^2/Hz
.89	800	- 2.5
1.0	900	- 4.5
1.11	1000	- 6.4
1.39	1250	-10.3
1.78	1600	-15.5
2.22	2000	-19.8

Plot G_r vs f or f/f_o, as desired.

7.1.6 Determination of the low frequency random spectrum, G_r. Refer to *figure 519.2-4. The maximum value* ($G_{r\,max}$) occurs at f/f_o = 2.0 and D = 48 inches. Set $G_{r\,max}$ equals $G_{r\,max}$ of the high frequency random, that is, $G_{r\,max}$ = .594 g2/Hz. Measure, as in the previous steps, the values of G_r, noting that $G_{r\,max}$ measures - 11.3 db down from 0 dB of the figure. Define the values of G_r relative to $G_{r\,max}$ by subtracting from all values of G_r. Note, finally, that f_o = 300 Hz (see 3.3.4.2).

f/f_o	f	$G_r - G_{r\,max}$ (dB_r)
2.0	600	0 db re. .594 g^2/Hz
1.6	480	- 0.7
1.2	360	- 2.5
1.0	300	- 4.7
0.8	240	- 8.3
0.6	180	- 11.1
0.4	120	- 12.8
0.2	60	- 13.8

The final test spectrum is shown in figure 519.2-1.

7.1.7 Determination of overall RMS(OARMS). Refer to 3.3.6 and figure 519.2-13. Using equation (8)

$$OARMS = [G_{s1} + G_{s2} + G_{s3} + G_{s4} + OAMS_R]^{1/2}$$

7.1.7.1 Determination of mean squared sines ($G_{s1} + G_{s2} + G_{s3} + G_{s4}$).

Sum the squares of the four sines

$$G_{s1} + G_{s2} + G_{s3} + G_{s4} = 4.69 + 8.53 + 22.43 + 40.83$$

$$= 76.5 \ g^2$$

7.1.7.2 Determination of overall mean squared random noise spectrum ($OAMS_R$)

Using equation (9)

$$OAMS_R = A_1 + A_a^b + A_c^d$$

$$A_1 = G_{r\ max} [f_c - f_b]$$

where: $f_c = 0.7 f_{o'} = 630$ Hz

$f_b = 600$ Hz (see figure 519.2.13)

$$A_1 = .594(30) = 17.82 \ g^2$$

$A_a^b = f_o G_{r\ max}[I_b - I_a]$ (see figure 519.2-13)

where: $f_o = 300$ Hz

$G_{r\ max} = .594 \ g^2/Hz$

$$A_a^b = 178.2[I_b - I_a]$$

and, $A_c^d = f_{o'} G_{r\ max}[I_d - I_c]$

where: $f_{o'} = 900$ KHz

$G_{r\ max} = .594 \ g^2/Hz$

$$A_c^d = 534.6[I_d - I_c]$$

7.1.7.3 <u>Determination of $[I_b - I_a]$ and $[I_d - I_c]$</u>

From figure 519.2-16 select at D = 48 inches; a $\beta_f = .300$

From figure 519.2-15 select at $\beta_f = .300$ and $f/_{f_o} = a = f_{1/}{}_{f_o} = .233$; a value of $I_a = .041$

At $f/_{f_o} = b = 2.0$ select a value of $I_b = 1.053$

$[I_b - I_a] = 1.012$

substituting in eq. (11)

$A_a^b = 178.2\ [1.012] = 180.3\ g^2$

From figure 519.2-17 select at D = 48 inches; a $\beta_{f'} = .511$

From figure 519.2-24 select at $\beta_{f'} = .511$ and $f/_{f_o} = c = .7$; a value of $I_c = 0$

At $f/_{f_o} = d = .222$ select a value of $I_d = .435$

Substituting in eq. (12)

$A_c^d = 534.6\ [.435] = 232.6\ g^2$

Add random noise

$A_1 + A_a^b + A_c^d = 17.82\ g^2 + 180.3\ g^2 + 232.6\ g^2$

$= 430.7\ g^2$

Add sines: $430.7\ g^2 + 76.5\ g^2 = 507.2\ g^2$

Take the square root:

OARMS $= (507.2)^{1/2} = 22.5$ grms

7.2 An A-7D utilizes a 20 mm (M61) cannon with a firing rate of 100 Hz. The instrument panel is shock mounted (45 Hz), weighs 75 pounds and the vector distance, D, is determined to be 49.6 inches from the nearest mount of the panel. R_S is equal to 2 inches and the gun standoff distance is zero. Determine the gunfire vibration spectrum of an altimeter indicator rigidly mounted to the instrument panel.

7.2.1 Determination of G_{os} and G_{or}. From equations (1) and (2)

$$G_{os} = 2000\ (1/_1)\ (1/_1)\ (1/_1) = 2000\ g^2$$

$$G_{or} = 35\ (1/_1)\ (1/_1)\ (1/_1) = 35\ g^2/Hz$$

7.2.2 Determination of G^a_{os} and G^a_{or}.

Δ_h = 0 dB (see 3.3.2.1)

Δ_M = 0 dB (see 3.3.2.2)

Δ_{R_s} = -0.2 dB (see 3.3.2.3)

Δ_W = 0 dB (see 3.3.2.4)

Using equations (4) and (5)

$$10 \log_{10} \frac{G^a_{os}}{\Gamma_{os}} = 10 \log_{10} \frac{G_{os}}{\Gamma_{os}} - 0.2 \text{ dB}$$

$$= -\ 0.2 \text{ dB re. } 2000\ g^2$$

$$G^a_{os} = (.9550)(2000) = 1910\ g^2 = 0 \text{ dB}$$

$$G^a_{or} = (.9559)(35) = 33.43\ g^2/Hz = 0 \text{ dB}$$

7.2.3 Determination of dB_s, dB_H and dB_{Y_s}. Utilizing the procedures detailed in 7.1 we assemble the following table. From 3.3.4.2, f_o is set at 250 Hz.

Sinusoidal Spectrum

$G^a_{os} = 1910\ g^2$

$f_o = 250$ Hz

f/f_o	f	G_s (re. G^a_{os})	dB_s (re. $G^s_{s\ max}$)	+ dB_H	= dB_{Y_s}	g^2/grms
2.0	500	-14.7	0.0	-13.0	-13.0	3.24/1.80
1.6	400	-15.2	-0.5	-11.8	-12.3	3.80/1.95
1.2	300	-16.8	-2.1	-10.0	-12.1	4.00/2.00
1.0	250	-18.6	-3.9	- 8.6	-12.5	3.65/1.91
0.8	200	-21.1	-6.4	- 6.8	-13.2	3.10/1.76
0.6	150	-23.0	-8.3	- 3.7	-12.0	4.00/2.00
0.4	100	-24.0	-9.3	+ 1.8	- 7.5	11.6/3.40
0.32	80	-24.4	-9.7	+ 4.0	- 5.7	17.39/4.17

The transfer function dB_H appears as a column that, in frequency correspondence, is added to dB_s. The details of this derivation now follow.

From 3.4 note equations (15) and (16). Go to table 519.2-II, Category II(a). The block, concerning a known f_{n_1}, requires that κ (figure 519.2-18) be set at 2.0; independent of equipment weight. From figure 519.2-18 insert κ = 2 as indicated in the f/f_{n_1} parameter. Also insert f_{n_1} = 45 Hz. This step establishes the low frequency scale. Note that each octave of frequency is divided into three bands. This scale is, therefore, 1/3 octave. To obtain the frequency in the upper adjacent 1/3 octave it is only necessary to multiply the preceding frequency by 1.26.

Establish frequencies corresponding to the sinusoidal surface (G_s), previously developed. Measure dB_H values (preferrably with dividers) and enter in the column designated dB_H. In accordance with equation (15) add dB_H to dB_s to obtain dB_{Y_s}; the desired spectrum. Remember that dB_{Y_s} is referenced to $G_{s\ max}$ which is - 14.7 dB relative to G^a_{os}. Thus, $G_{s\ max}$ = (.03388)(1910 G^2) = 64.7 g^2 = 8.04 grms.

Plot the sinusoidal spectrum.

7.2.4 Determination of dB_r, dB_H and dBY_r (High frequency random). Following the steps detailed in 6.1 for the high frequency random curve and making use of figure 519.2-11 to obtain $f_o' = 920$ Hz the following table is constructed.

High Frequency Random

$G^a_{or} = 33.43\ g^2/Hz$

$f_o' = 920$ Hz

f/f_o'	f	G_r (re. G^a_{or})	dB_r (re. $G_{r\ max}$)	+ dB_H	= dB_{Y_r}	g^2/Hz
0.7	644	-14.3	0.0	-12.2	-12.2	.075
0.89	818	-17.0	-2.7	-12.0	-14.7	.042
1.0	920	-18.5	-4.2	-12.3	-16.5	.028
1.11	1021	-20.6	-6.3	-12.1	-18.4	.019
1.39	1279	-24.5	-10.2	-12.4	-22.6	.007
1.78	1638	-29.1	-14.8	-12.7	-27.5	.002
2.22	2042	-33.6	-19.3	-13.2	-32.5	.001

Again, note that $G_{r\ max}$ is -14.3 dB down from G^a_{or} or $G_{r\ max}$ = (.03715) (33.43) = 1.241 g^2/Hz. In turn, dBY_r is referenced to $G_{r\ max}$ and represents the high frequency test spectrum for the altimeter. The final right hand column is the vibration spectrum in units of g^2/Hz. The high frequency spectrum may now be plotted.

7.2.5 Determination of dB_r, dB_H and dBY_r (Low frequency random). Repeating the past procedures of 7.1 and noting from 3.3.4.2 that f_o = 300 Hz the following table is constructed.

Low Frequency Random

$G_{r\,max} = 1.241\ g^2/Hz$
$f_o = 300$ Hz

f/f_o	f	G_r (re. 0 dB)	dB_r (re. $G_{r\,max}$)	+ dB_H	= dBY_r	g^2/Hz
2.0	600	-12.0	0.0	-12.2	-12.2	.075
1.6	480	-12.6	- 0.6	-12.4	-13.0	.063
1.2	360	-13.8	- 1.6	-12.7	-14.3	.047
1.0	300	-16.6	- 4.6	-12.9	-17.5	.023
0.8	240	-19.8	- 7.8	-13.3	-21.1	.009
0.6	180	-22.8	-10.8	-14.1	-24.9	.005
0.4	120	-24.2	-12.2	-15.0	-27.2	.002
0.27	80	-24.9	-12.9	-16.0	-28.9	.002

Note that G_r is measured relative to the 0 dB of figure 519.2-4; not relative to G^a_{0r}, as was done in 7.2.3 and 7.2.4. Following this, G_r at f/f_o = 2.0, is subtracted from the G_r column to obtain dB_r which now has a 0 dB level at f/f_o = 2.0. This level (0 dB) is then set to correspond to $G_{r\,max}$ = 1.241 g^2/Hz and dBY_r then is referenced to $G_{r\,max}$. The last column on the right indicated the spectral values in g^2/Hz.

The low frequency random spectrum may be plotted. The complete test spectrum is shown in figure 519.2-24.

7.2.6 The OAMS. The overall $(RMS)^2$ is determined for the primary structur spectrum only. This value is always greater than the spectrum for the secondary structure and, therefore, provides a conservative estimate of the overall force requirements of the shaker.

7.2.7 Determination of the blast energy, E. To illustrate the application of the blast energy equation (3) an example is presented for the reference gun (M-61).

$$E_o = f(W^c)/.3 - m_o v_o^2/2$$

where: $f = 330 \times 10^3$ ft-lbs/lb

$W_o^c = 600$ grains $= .086$ lb

$W_p = .223$ lb/rd

$V_o = 3380$ ft/sec

$g = 32.17$ ft/sec^2

$$E_o = \frac{330 \times 10^3(.086)}{.3} - \frac{.223(3380)^2}{32.17(2)}$$

$$E_o = 94{,}600 - 39{,}600 = 55{,}000 \text{ ft/lb/gun}$$

TABLE 519.2-IA. Typical gun configurations associated with aircraft classes

Gun Configuration	Aircraft	Installation (Typical)	Gun Caliber (mm)	(in)
M61	F-104 F-105 F-111 F-4 F-100 B-58 B-52 A-7	Various Fixed (Forward Bomb Bay) SUU-16, on racks, tail turrets	20	.79
M39	F-5 F-100 F-101 B-57 B-52	2 or 4 in nose or back of nose or tail turret	20	.79
MK11	A-4 F-4 A-7 A-6	MK4 C.L. POD inboard wing, etc.	20	.79
MK12	A-4	1 at each wing root	20	.79
M3	A-1E	2 each wing	20	.79
M24	B-52 F-86	Tail turret 4 or 6 nose	20	.79
M3	B-52 B-26 B-57 F-86 HH-53 A-1	Tail turret up to 6 in nose	12.7	.50

TABLE 519.2-IA. (Continued)

Gun Configuration	Aircraft	Installation (Typical)	Gun Caliber (mm)	Gun Caliber (in)
GAU-2B/A	OH-6A AC-47 AC-130 A-37 UH-1 CH-3 AH-1	side-looking, nose, and up to 8 PODS	7.62	.30
GAU-4/A	F-4	POD, inboard, wing	20	.79
GAU-8/A	A-10	nose	30	1.18

TABLE 519.2-IB. Ballistic tables for typical gun configurations (English units)

Gun	Gun Caliber (mm)	Gun Caliber (in)	Propellant Weight W^c (gr)	Propellant Weight W^c (lbs)	Propellant S. Impetus f (ft-lbs/lb)	Propellant Chg. Energy E^c (ft-lbs)	Firing Rate r rds/min	Firing Rate r rds/sec	Projectile weight W_p (gr)	Projectile weight W_p (lbs)	Muzzle Vel. v (ft/sec)	Muzzle Energy $W_p v^2/2g$ (ft-lbs)	Blast Energy E (ft-lbs)	E/E_o
M61 (note 1)	20	.79	600 (nom) 590 to 610	.086	330×10^3	94.6×10^3	6,000 (nom) 1,000 (min)	100 (max) 17 (min)	1,560 (avg)	.223 (avg)	3,380 (nom) 3,250 to 3,450	39,600	55,000	1.0
M39	20	.79	See M61	See M61		See M61	1,500	25	1,560 (avg)	.223 (avg)	3,380 (nom) 3,250 to 3,450	39,600	55,000	1.0
MK11	20	.79	665 (nom) 680 to 650	.095		105×10^3	4,000 (max) 750 (min)	67 (max) 12.5 (min)	1,700	.243	3,300	41,200	63,800	1.16
MK12	20	.79	See MK11	See MK11		See MK11	1,000	16.68	1,700	.243	3,300	41,200	63,800	1.16
M3	20	.79	600 (nom)	.086		See M61	800	13.33	2,000	.286	2,700	33,400	61,200	1.11
M24	20	.79	590 (nom)	.084		92,730	800	13.33	2,000	.286	2,700	33,400	59,330	1.08
M3	12.7	.50	237	.034		37,400	1,200 (nom)	20	709	.114	3,400	18,196	19,304	.351

Note 1: Reference gun, where v_o = 3380 ft/sec, r_o = 100 Hz, and n_o = 1

TABLE 519.2-IB. (Continued)

Gun	Gun Caliber		Propellant				Firing Rate F		Projectile weight W_p		Muzzle Vel. v	Muzzle Energy $W_p v^2/2g$	Blast Energy E	E/E_o
			Weight W_C		S. Impetus f	Chg. Energy E^C								
	(mm)	(in)	(gr)	(lbs)	(ft-lbs/lb)	(ft-lbs)	rds/min	rds/sec	(gr)	(lbs)	(ft/sec)	(ft-lbs)	(ft-lbs)	
GAU-2B/A	7.62	.30	47	.0067	330×10^3	7.38×10^3	6,000 (nom) 1,500 (min)	100 25 (min)	150	.021	2,750	2,468	4,810	.087
GAU-4/A	20	.79	600	.086		See M61	6,000 (nom) 1,000 (min)	100 (max) 17 (min)	1,560 (avg)	.223 (avg)	3,380 (nom) 3,250 to 3,450	39,600	55,000	1.0
GAU-8/A	30	1.18	2,390	.341		375,100	4,200 (max) 2,100 (min)	70 (max) 35 (min)	5,800	.825	3,400	148,200	227,000	4.12

TABLE 519.2-IC. Ballistic tables for typical gun configurations
(Metric units)

Gun	Gun Caliber		Propellant				Firing Rate r		Projectile weight W_p		Muzzle Vel. v	Muzzle Energy $W_p v^2/2g$	Blast Energy E	E/E_o
			Weight W^c		S. Impetus f	Chg. E^c Energy								
	(mm)	(in)	(gr)	(kg)	(m-kg/kg)	(n-m)	rds/min	rds/sec	(gr)	(kg)	(m/sec)	(n-m)	(n-m)	-
M61 (Note 1)	20	.79	600	.039	45,639	128,300	6,000 (nom) 1,000 (min)	100 (max) 17 (min)	1,560 (avg)	.101 (avg)	1,030	53,700	74,600	1.0
M39	20	.79	600	.039		128,300	1,500	25	1,560 (avg)	.101 (avg)	1,030	53,700	74,600	1.0
MK11	20	.79	665	.043		142,400	4,000 (max) 750 (min)	67 (max) 12.5 (min)	1,700	.110	1,006	55,867	86,500	1.16
MK12	20	.79	665	.043		142,400	1,000	16.68	1,700	.110	1,006	55,867	86,500	1.16
M3	20	.79	600	.039		128,300	800	13.33	2,000	.130	823	45,300	83,000	1.11
M24	20	.79	590	.038		125,700	800	13.33	2,000	.130	823	45,300		1.08
M3	12.7	.50	237	.015		50,700	1,200 (nom)	20	709	.046	1,036	24,700	26,000	.351

Note 1: Reference gun, where; v_o = 1030 m/sec, r_o = 100 Hz and n_o = 1

TABLE 519.2-IC. (Continued)

Gun	Gun Caliber		Propellant				Firing Rate r		Projectile weight W_p		Muzzle Vel. v	Muzzle Energy $W_p v^2/2g$	Blast Energy E	E/E_o
			Weight W^c		S. Impetus f	Chg. Energy E^c								
	(mm)	(in)	(gr)	(kg)	(m-kg/kg)	(n-m)	rds/min	rds/sec	(gr)	(kg)	(m/sec)	(n-m)	(n-m)	
GAU-2B/A	7.62	.30	47	.003	45,639	10,000	6,000 (nom) 1,500 (min)	100 25 (min)	150	.010	838	3,414	6,685	.087
GAU-4/A	20	.79	600	.039		128,300	6,000 (nom) 1,000 (min)	100 (max) 17 (min)	1,560 (avg)	.101	1,030	53,700	74,600	1.0
GAU-8/A	30	1.18	2,340	.155		508,500	4,200 (max) 2,100 (min)	70 (max) 35 (min)	5,800	.376	1,036	201,000	307,500	4.12

TABLE 519.2-ID. Conversion table - English to Metric units

lbs x (0.4536)	= kg
grams x (10^{-3})	= kg
grains x (6.480×10^{-5})	= kg
inches x (25.4)	= mm
feet x (0.3048)	= meters
feet/sec x (0.3048)	= meters/sec
feet-lbs x (.1383)	= m - kgf
kgf x (9.807)	= newtons
newton x meter	= joule

TABLE 519.2-II Secondary structure transfer functions associated with equipment categories

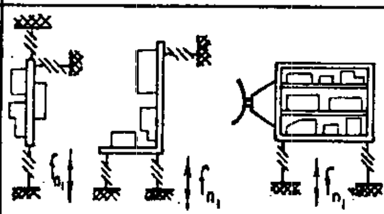
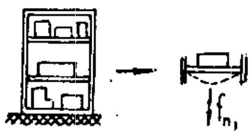
Equipment Category	Examples	Remarks	$\|H(f)\|^2$ if f_{n_1} is known	$\|H(f)\|^2$ if f_{n_1} is unknown	$\|H(f)\|^2$ f_{n_2}
I(a)		f_{n_1} is the lowest vertical translation frequency of the isolated systems	see Fig 519.2-18	see Fig 519.2-18 select: f_{n_1} = 45 Hz	see Fig 519.2-18
I(b)			see Fig 519.2-19	see Fig 519.2-19 select: f_{n_1} = 60 Hz	see Fig 519.2-19
II(a)		For instr. panels only D is measured from the gun muzzle to the nearest panel mount or attach point.	see Fig 519.2-18 select: κ = 2.0	see Fig 519.2-18 select: κ = 2.0 f_{n_1} = 60 Hz	see Fig 519.2-18

TABLE 519.2-II (continued)

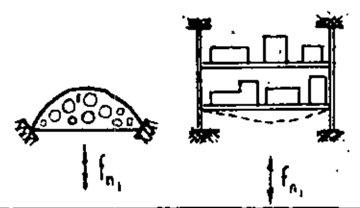
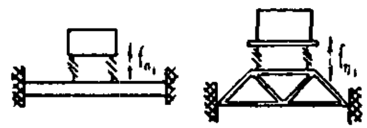
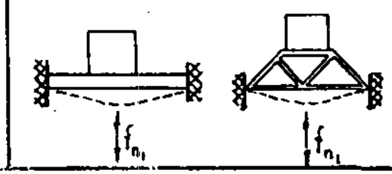
Equipment Category	Examples	Remarks	$\lvert H(f)\rvert^2$ if f_{n_1} is known	$\lvert H(f)\rvert^2$ if f_{n_1} is unknown	f_{n_2}
II(b)		If 3 or more sides of the shelves are attached (other than at the corners) to the walls, bulkheads or outer structural surfaces (frames, stringers, etc.) use the criteria of 3.2.1. (Instr. panels only see II (b)	see I(b)		see Fig 519.2-19
III(a)			see I(a)		see Fig 519.2-18
III(b)			see I(b)		see Fig 519.2-19

TABLE 519.2-III Gunfire test tolerances

	Sine	Random
W < 10 lbs	A	A
$G_{r\ max} < .1\ g^2/Hz$	A	A
W ≥ 10 lbs	A	A+C
$G_{r\ max} \geq .1\ g^2/Hz$	A	A+B
$G_{r\ max} \geq .1\ g^2/Hz$ and W ≥ 10 lbs	A	A+B+C

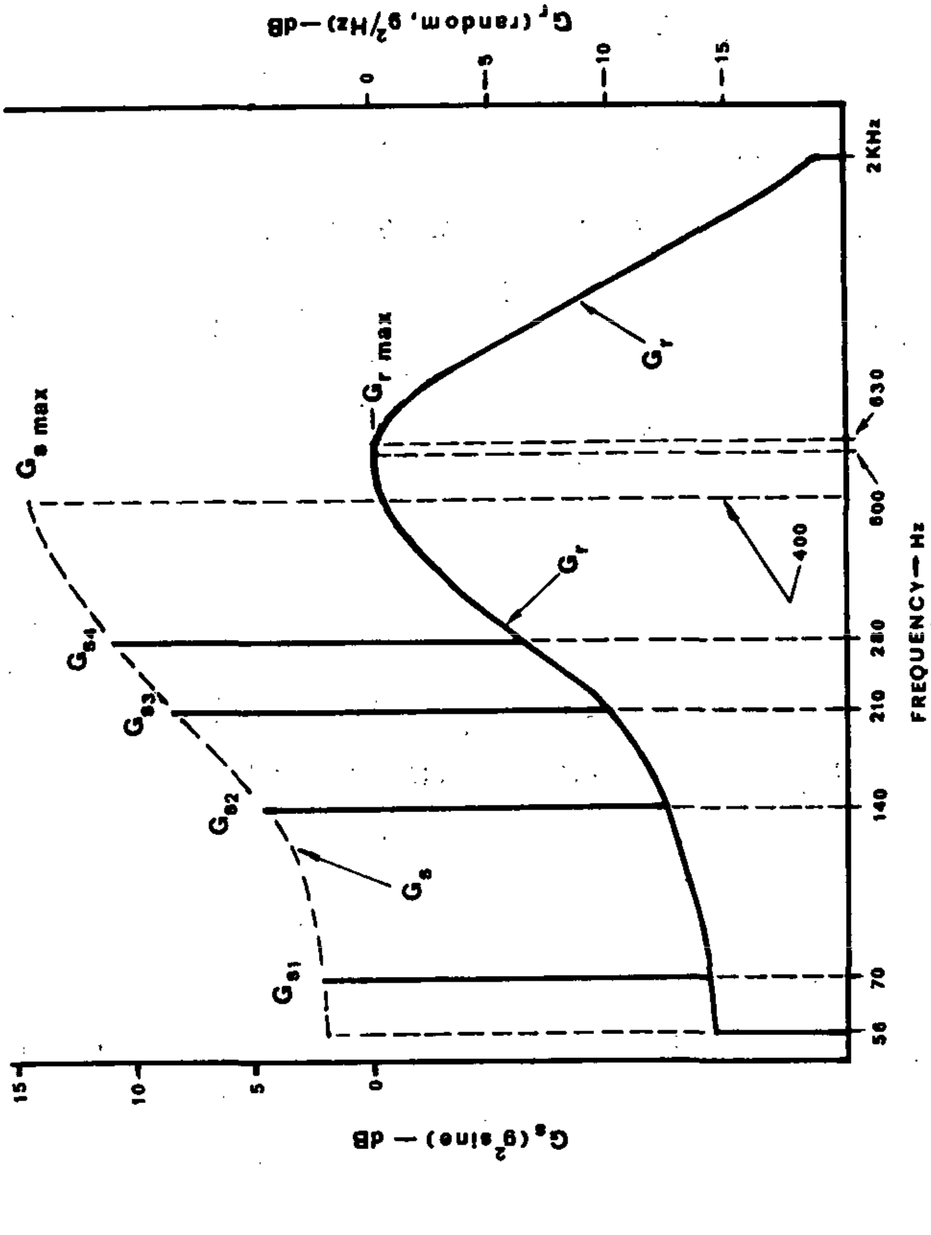


FIGURE 519.2-1. Low frequency sinusoidals superimposed on random vibration

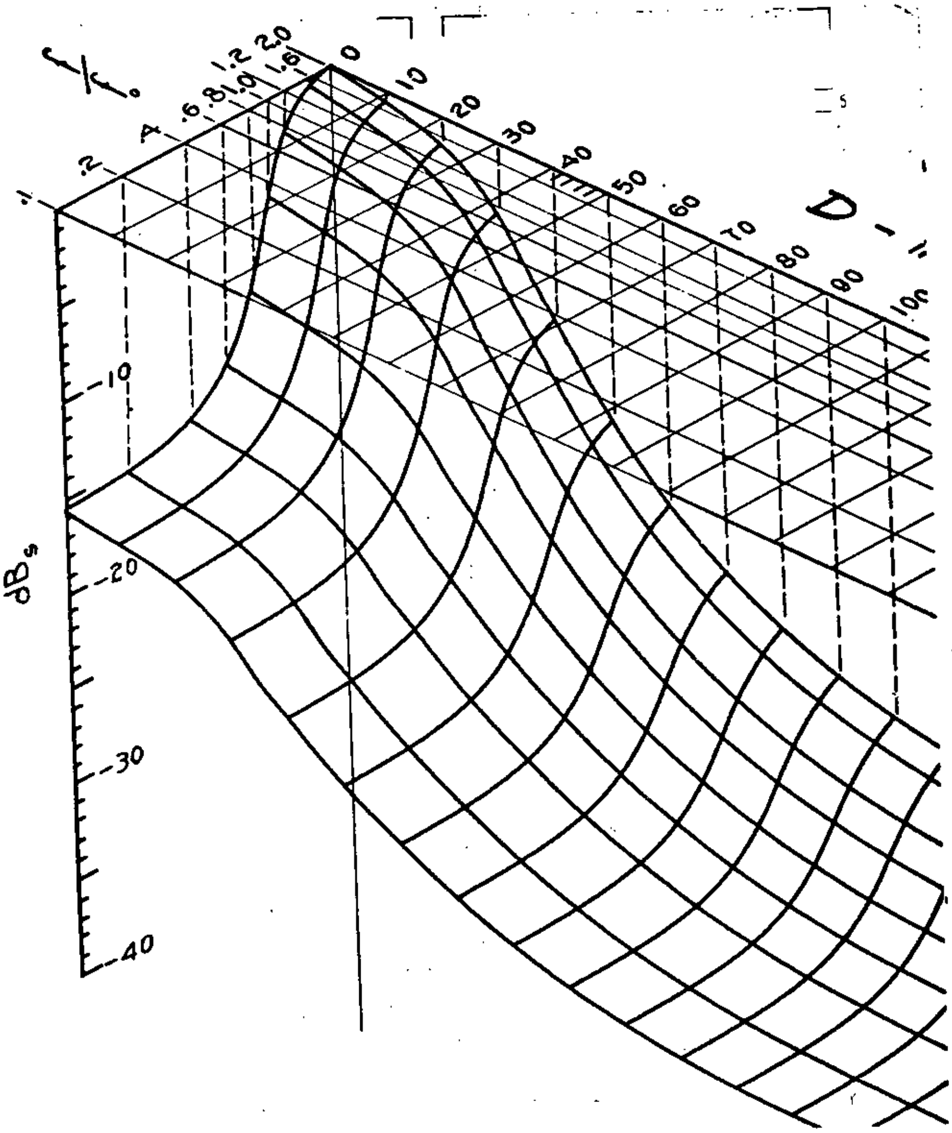


FIGURE 519.2-2. Sinusoidal vibration prediction surface

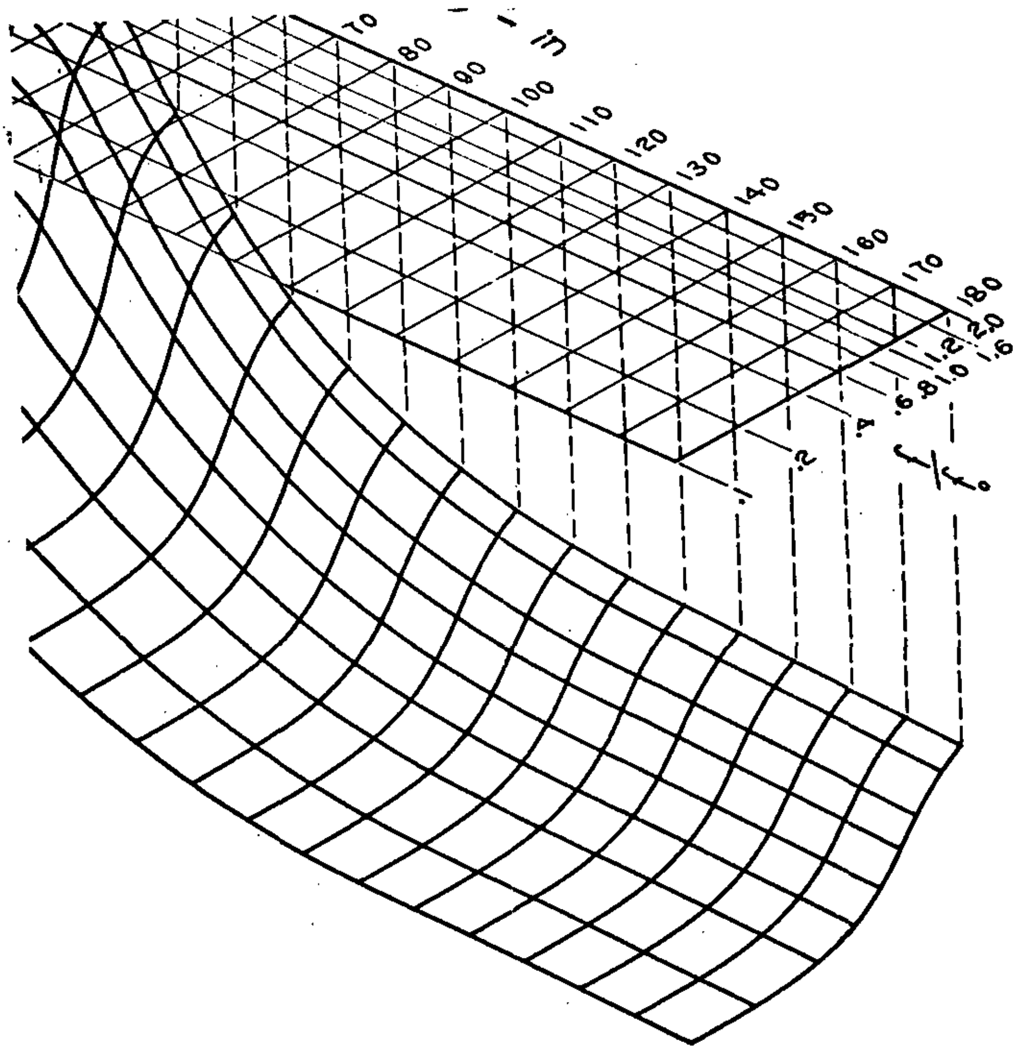


FIGURE 519.2-2. Sinusoidal vibration prediction surface (Cont'd)

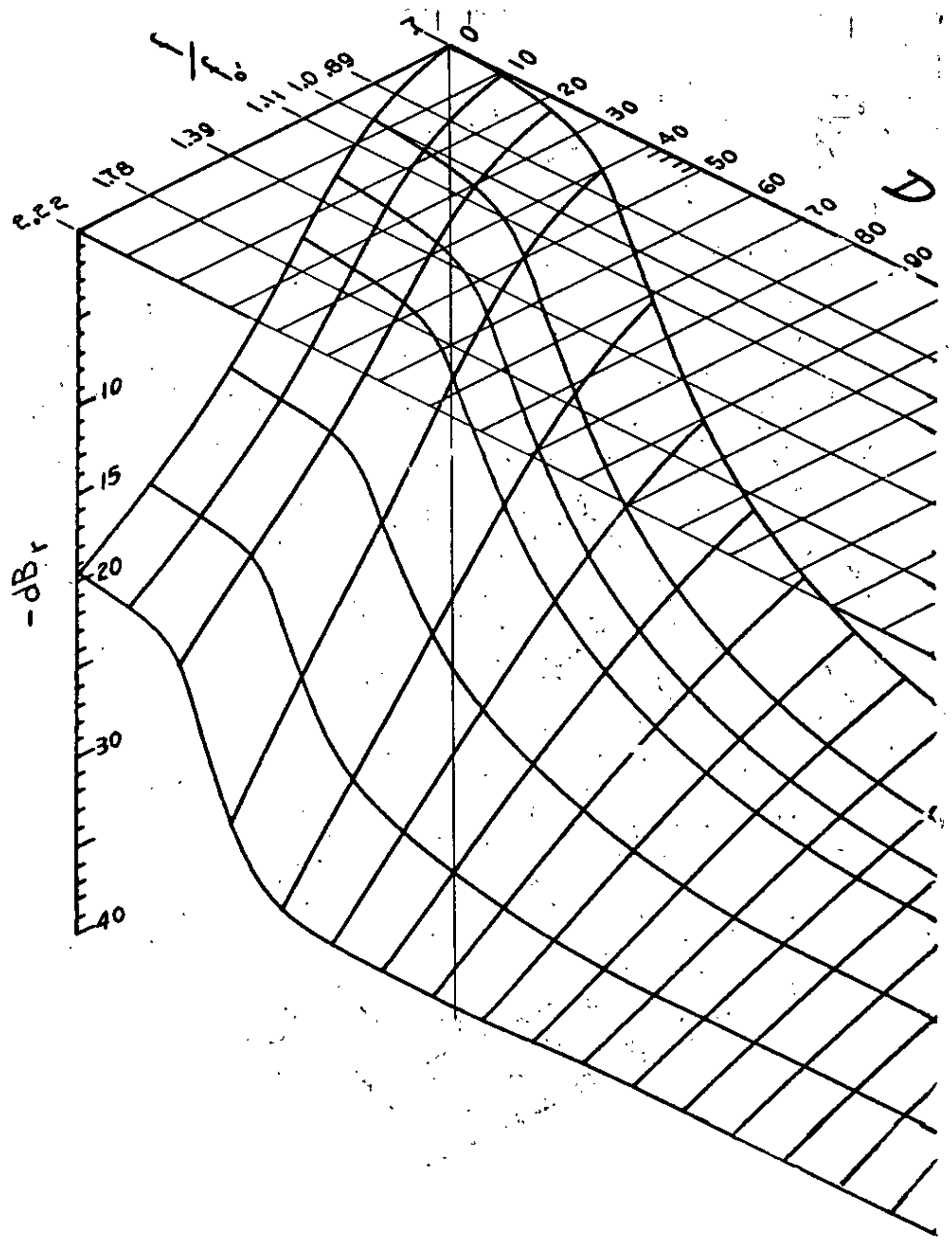


FIGURE 519.2-3. Random vibration prediction surface, high frequency

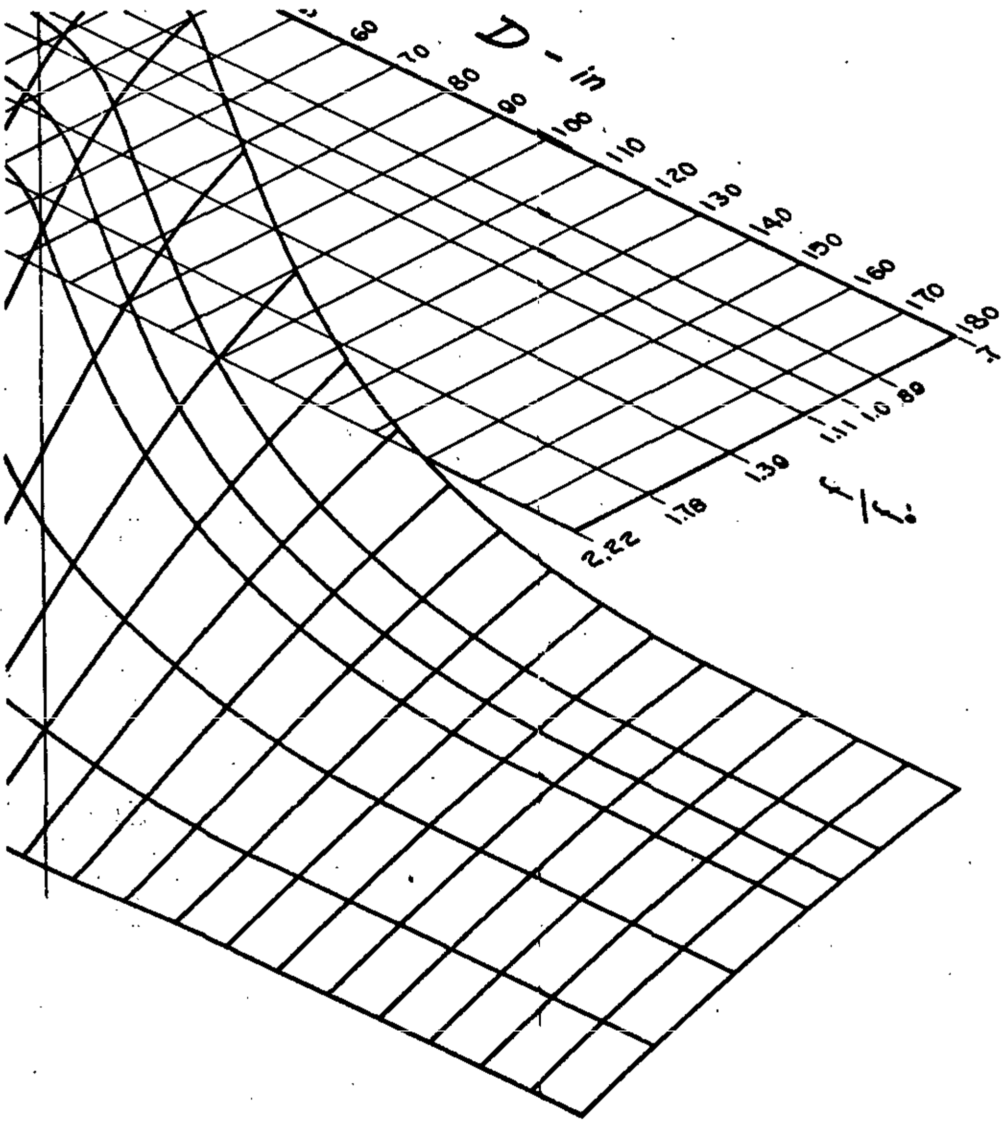


FIGURE 519.2-3. Random vibration prediction surface, high frequency (Cont'd)

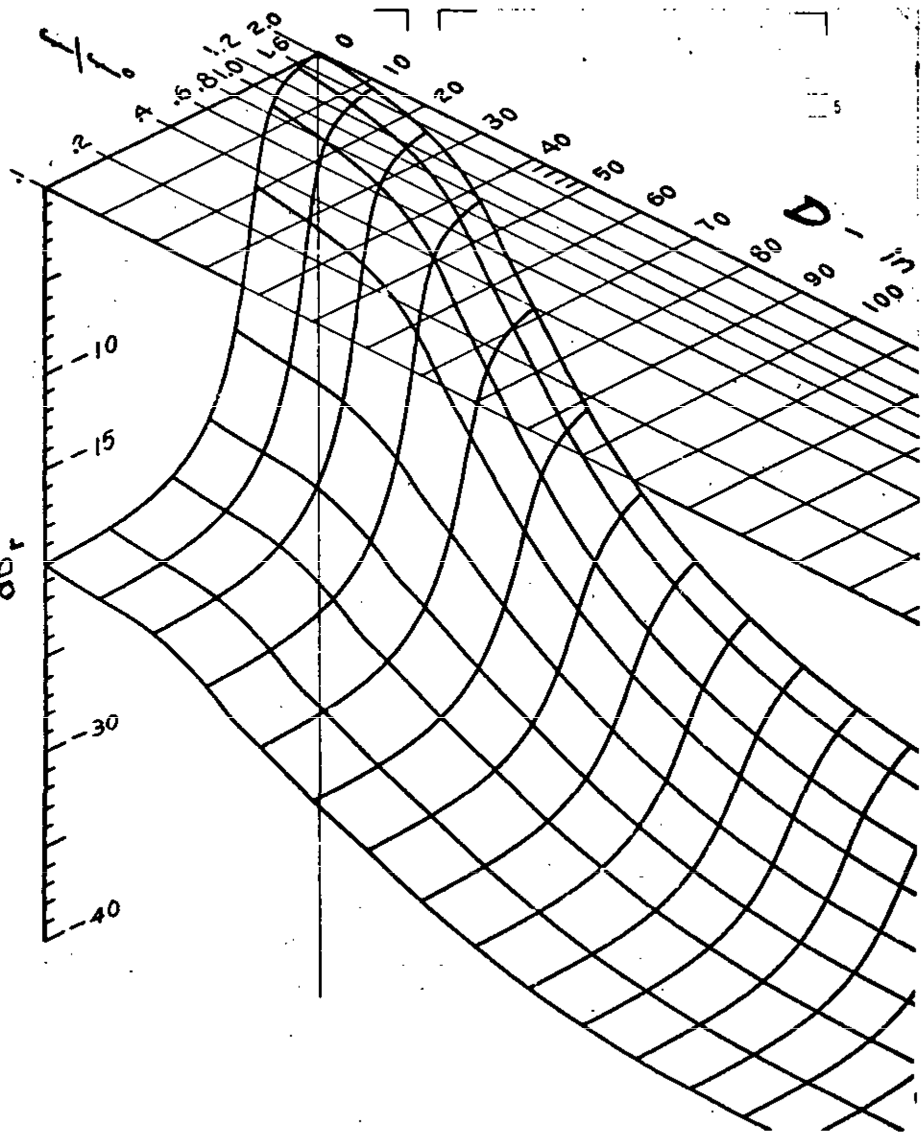


FIGURE 519.2-4. Random vibration prediction surface, low frequency

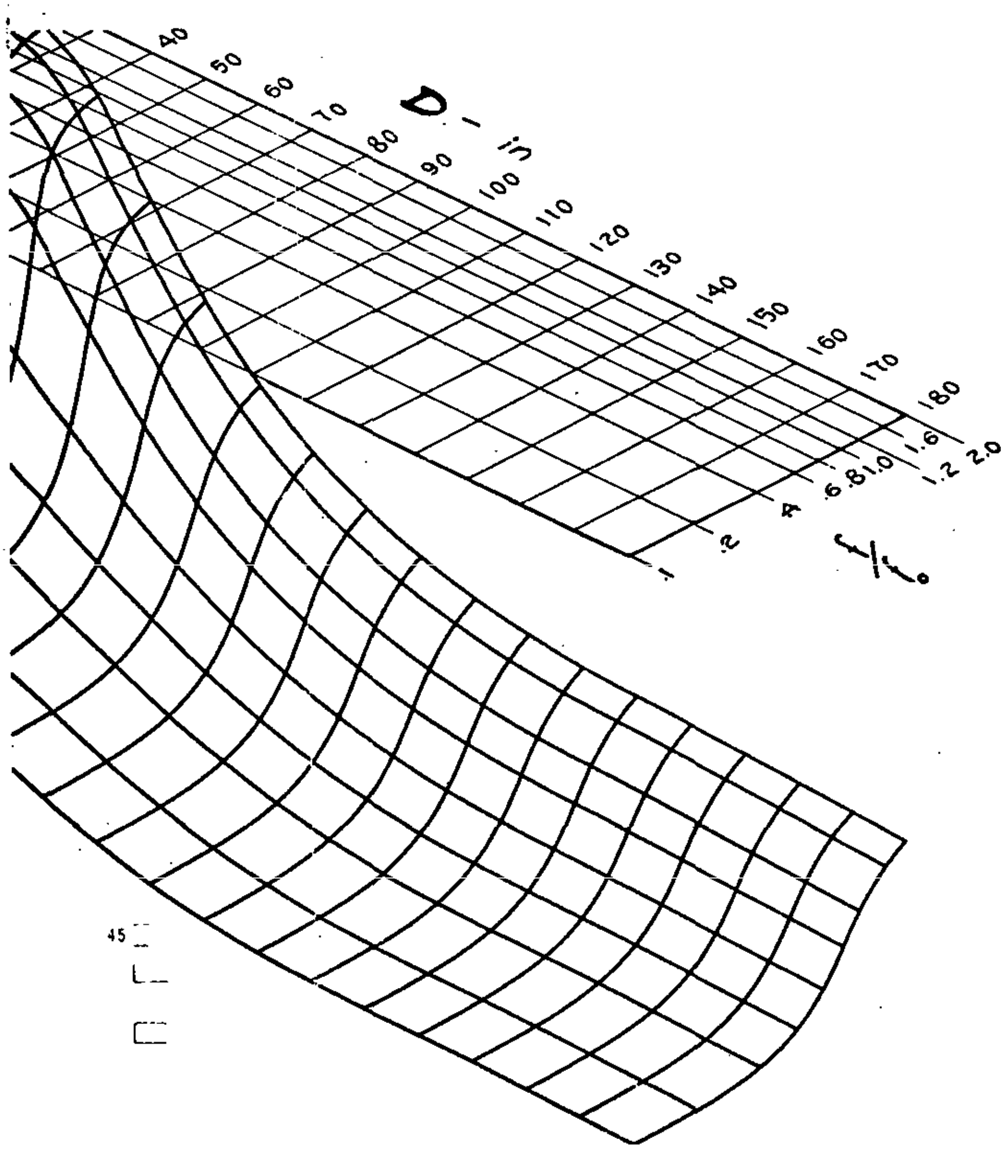


FIGURE 519.2-4. Random vibration prediction surface, low frequency (Cont'd)

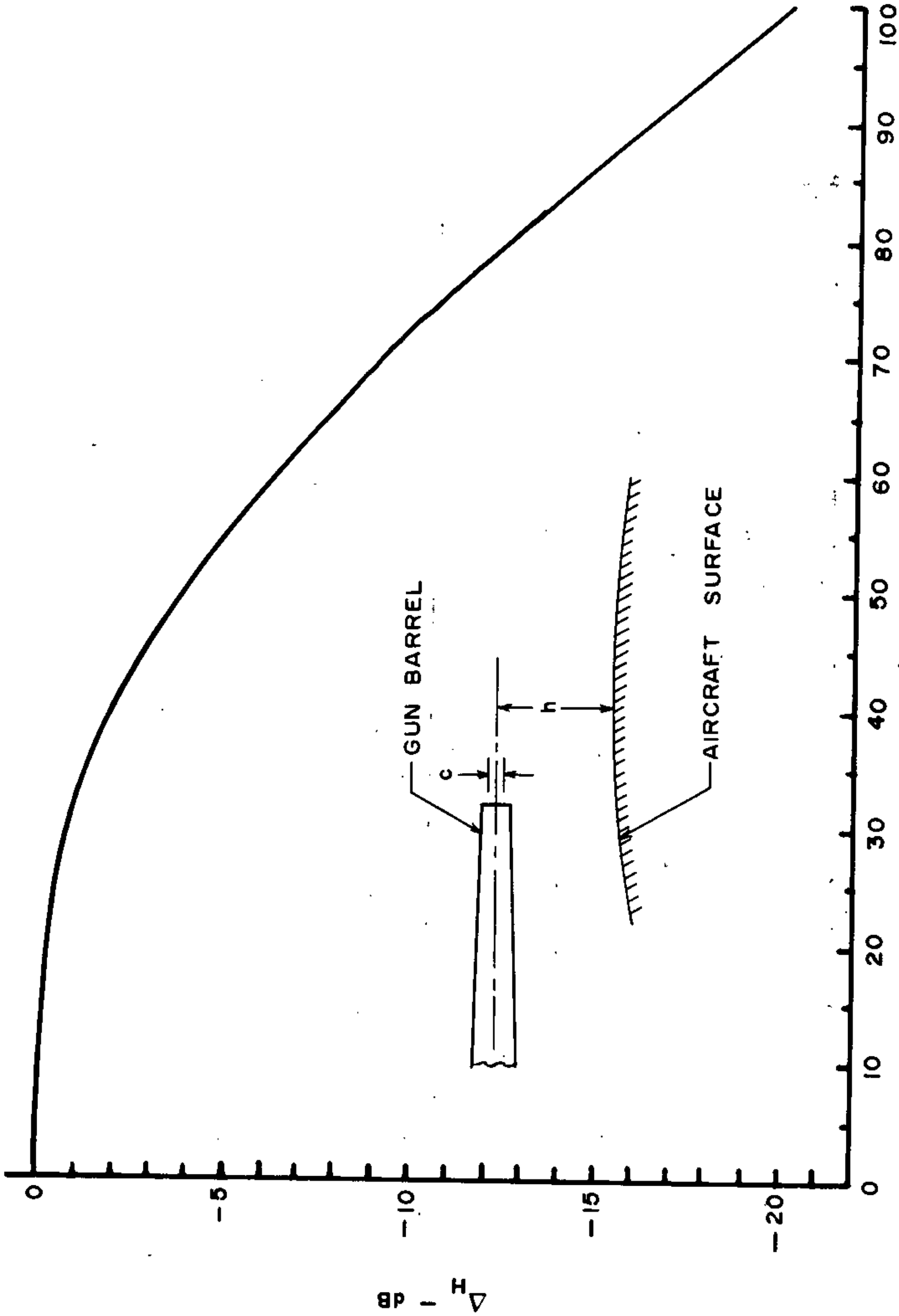


FIGURE 519.2-5. Test level reduction, Δ_H, due to gun standoff parameter, h/c

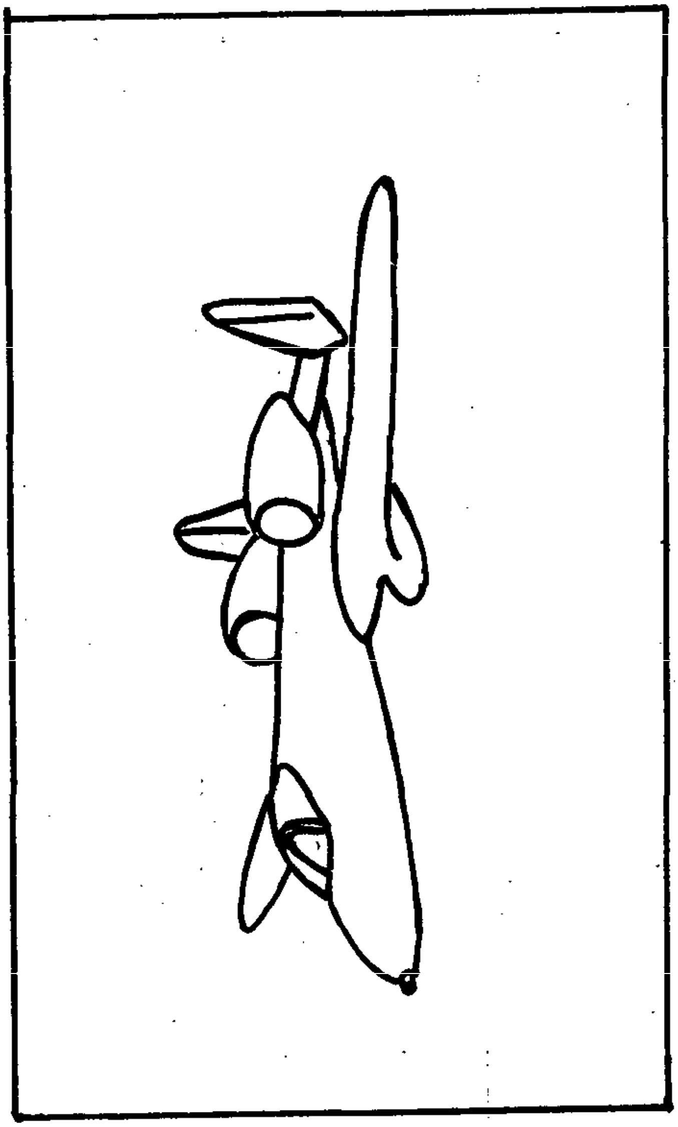


FIGURE 519.2-6. Example of gun configuration, free air

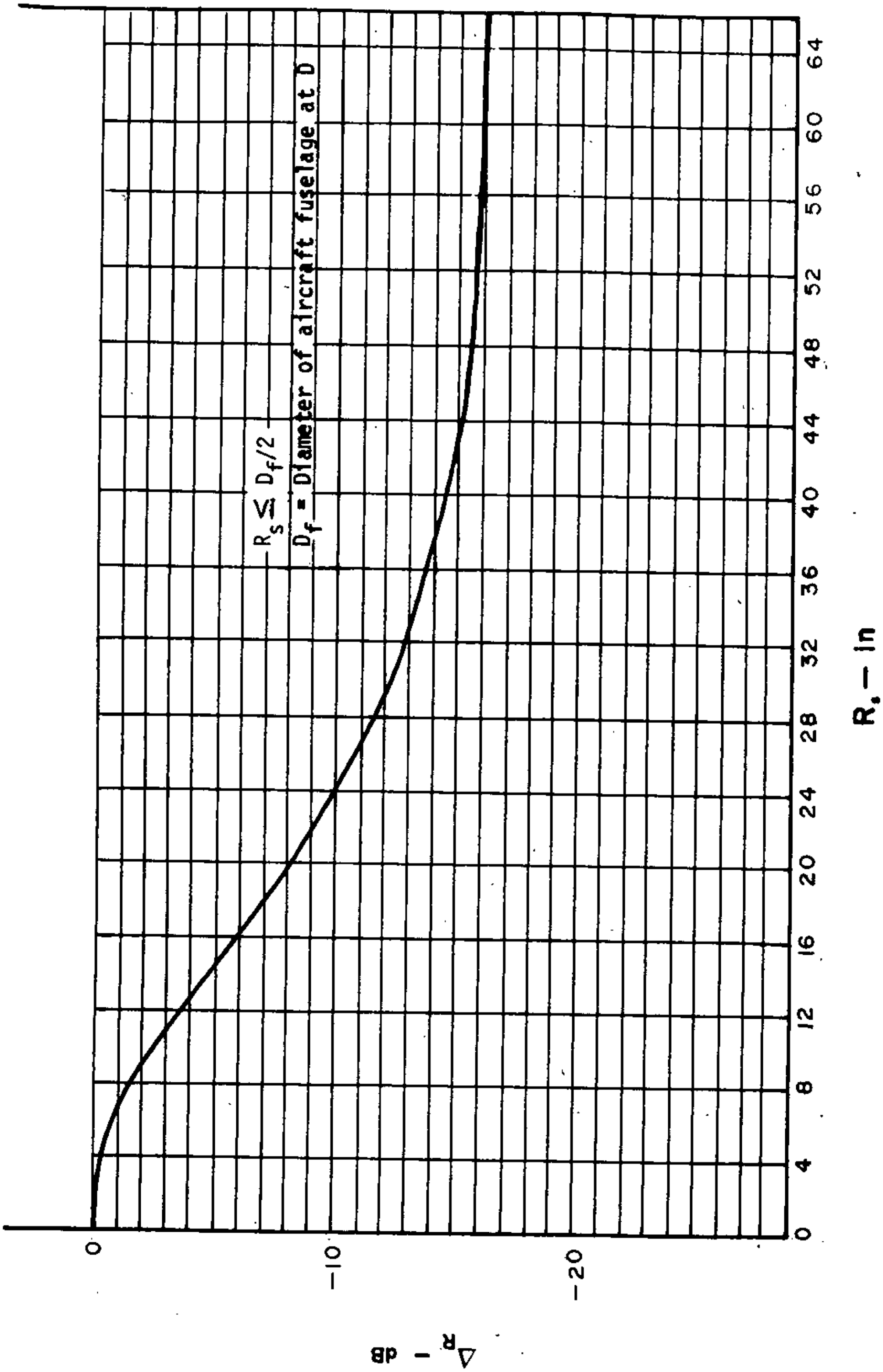


FIGURE 519.2-7. Test level reduction, Δ_R, due to depth parameter R_s.

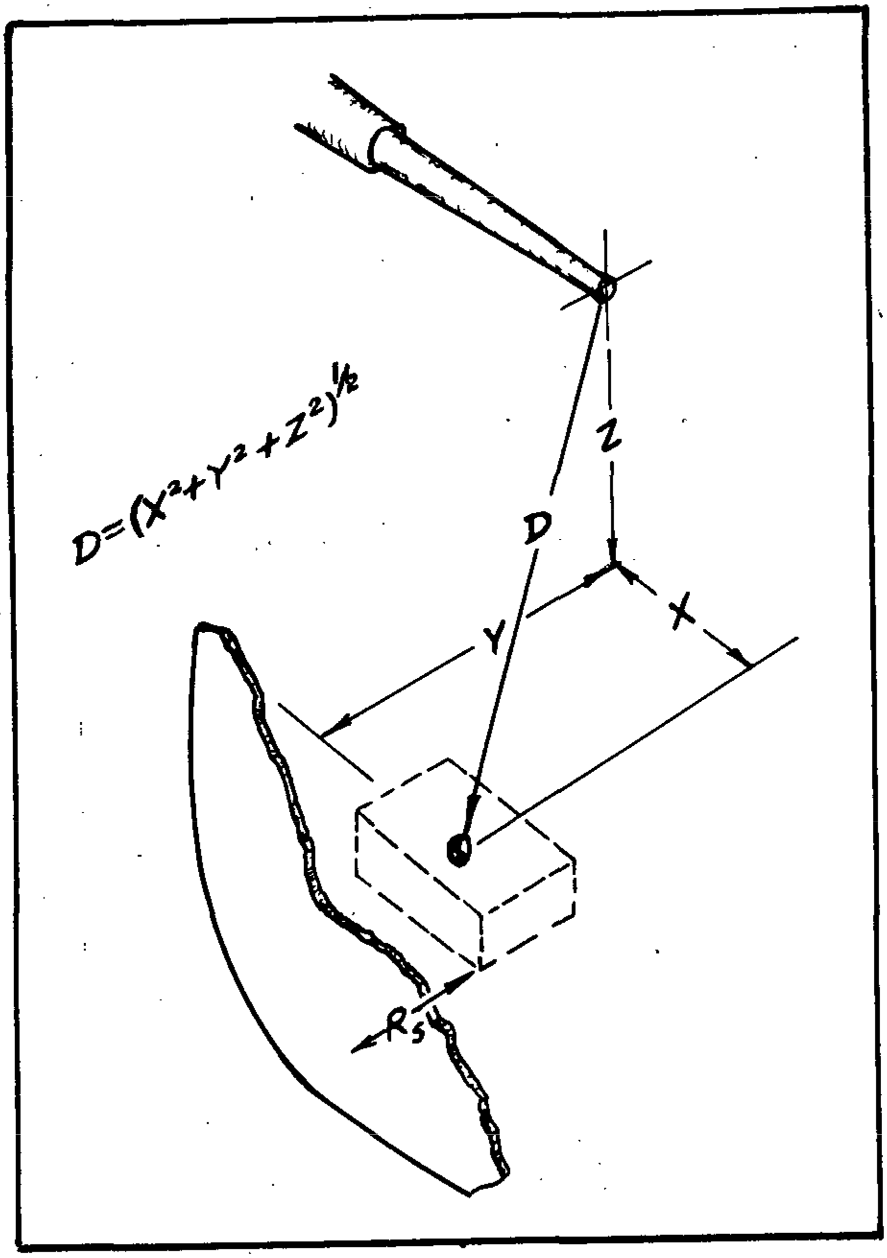


FIGURE 519.2-8. The distance parameter, D, and the depth parameter, R_s

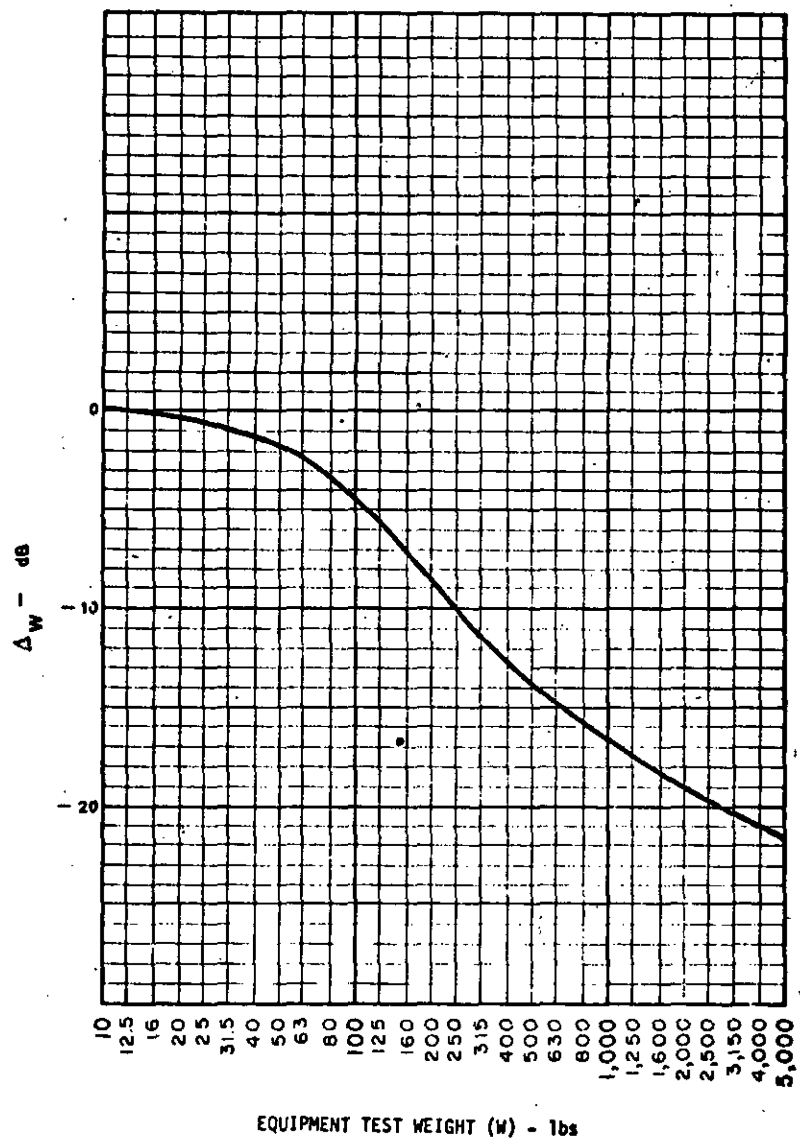


FIGURE 519.2-9. Test level reduction, Δ_W, due to equipment mass loading

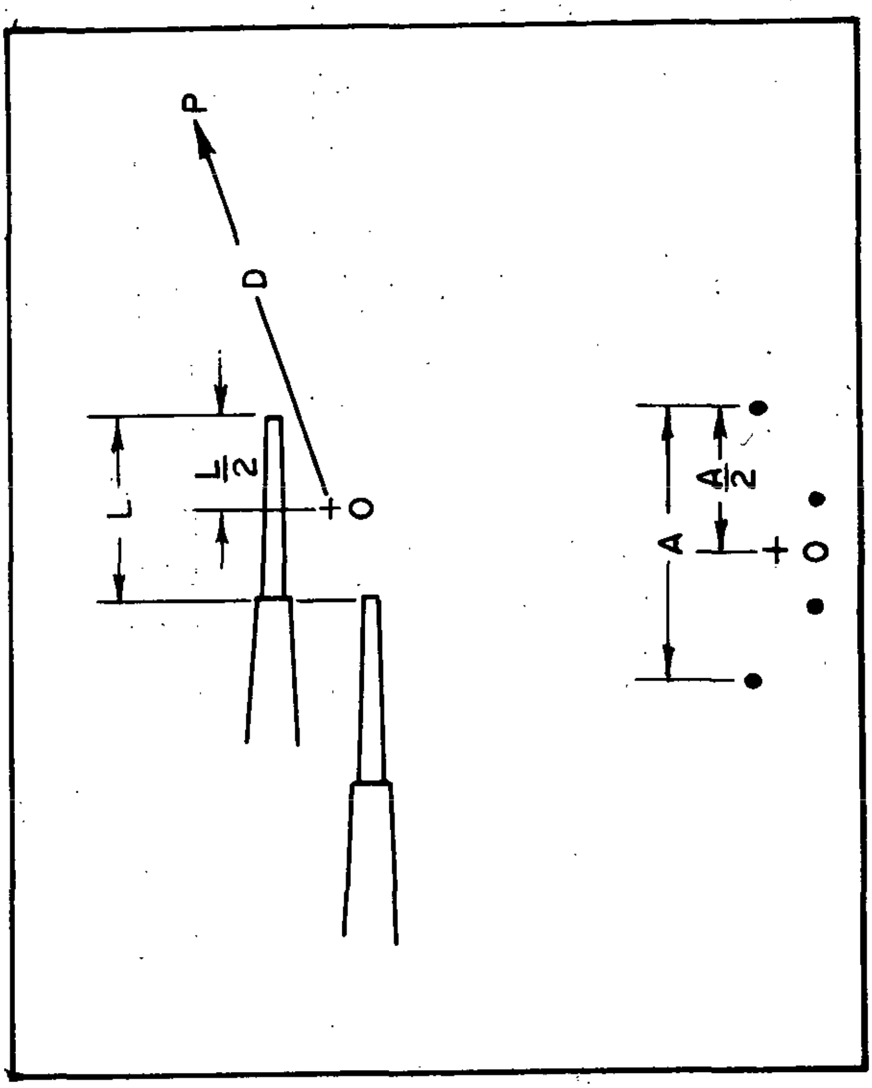


FIGURE 519.2-10. Multiple guns, closely grouped

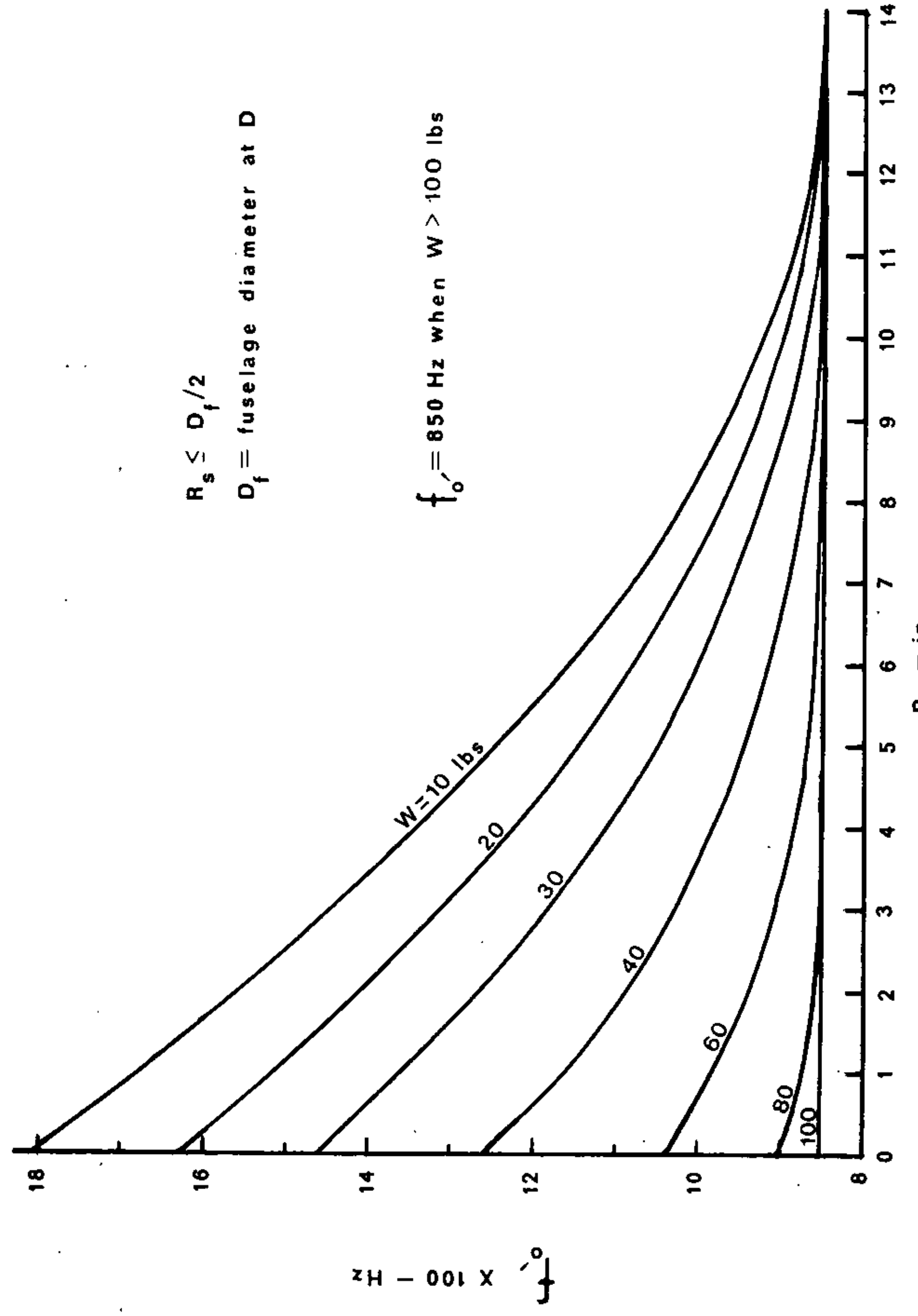


FIGURE 519.2-11. Locator frequency, f_o, for high frequency random prediction surface

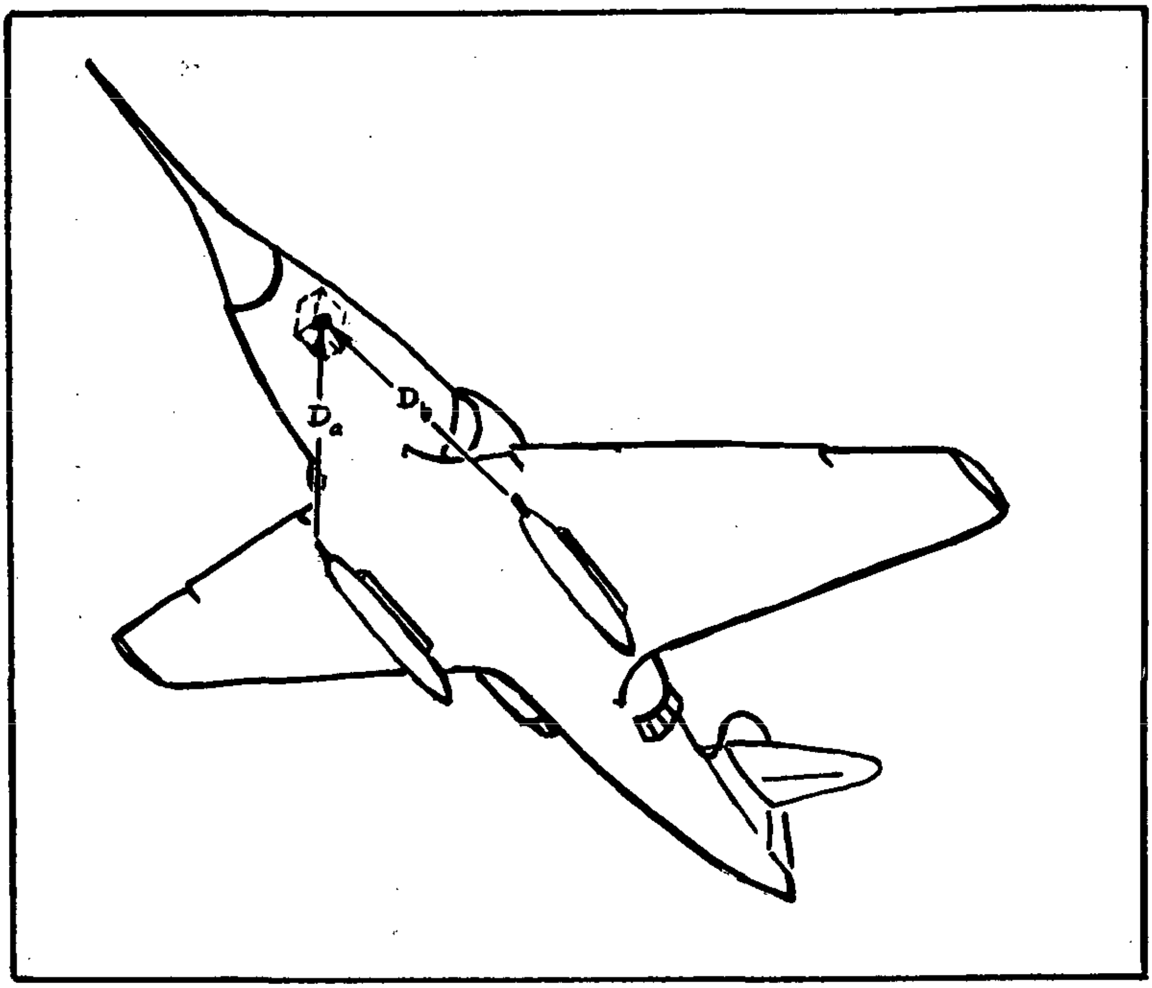
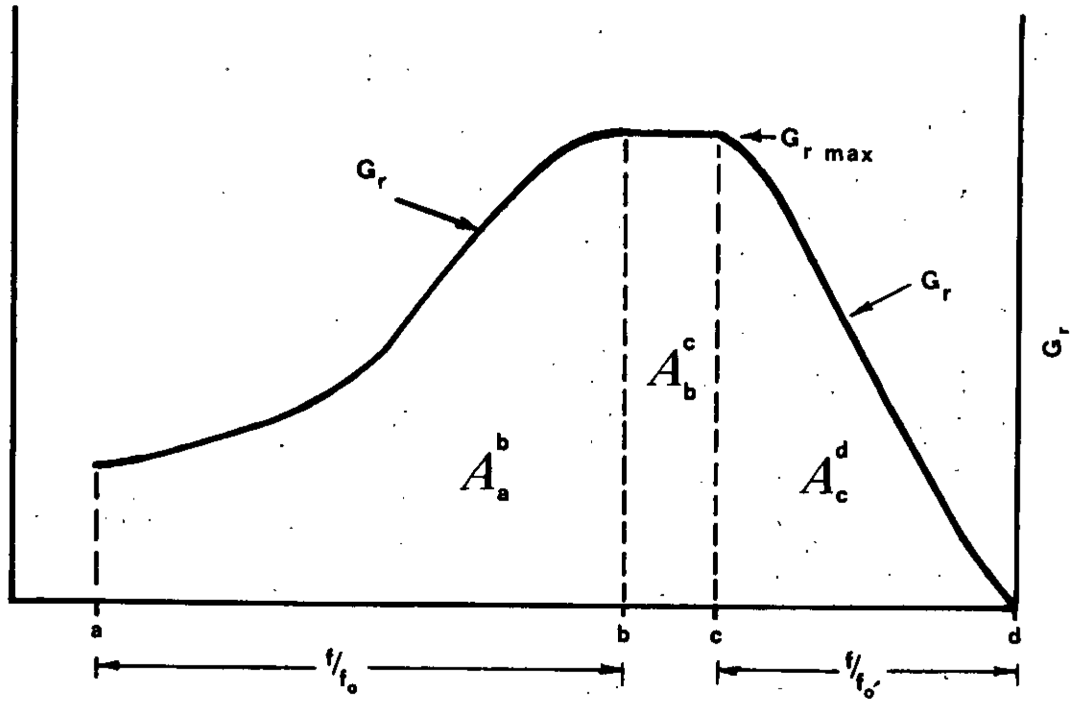


FIGURE 519.2-12. Multiple guns, dispersed



$A_a^b = G_{r\ max}\ f_o[I_b - I_a]$

$[I_b - I_a]$ = see Fig 519.2-14 and 3.3.7.1.1

where: f_o = 300 Hz

$a = 0.8\ f_1/f_o$

$b = f_b/f_o = 2.0$

$A_b^c = G_{r\ max}\ [f_c - f_b]$

where: $f_{o'}$ = see Fig 519.2-11

$c = f_c/f_{o'} = 0.7$

$A_c^d = G_{r\ max}\ f_{o'}[I_d - I_c]$

$[I_d - I_c]$ = see Fig 519.2-15 and 3.3.7.1.1

where: $d = f_d/f_{o'}$

f_d = 2 KHz

FIGURE 519.2-13. Determining the OAMS from the random test curves

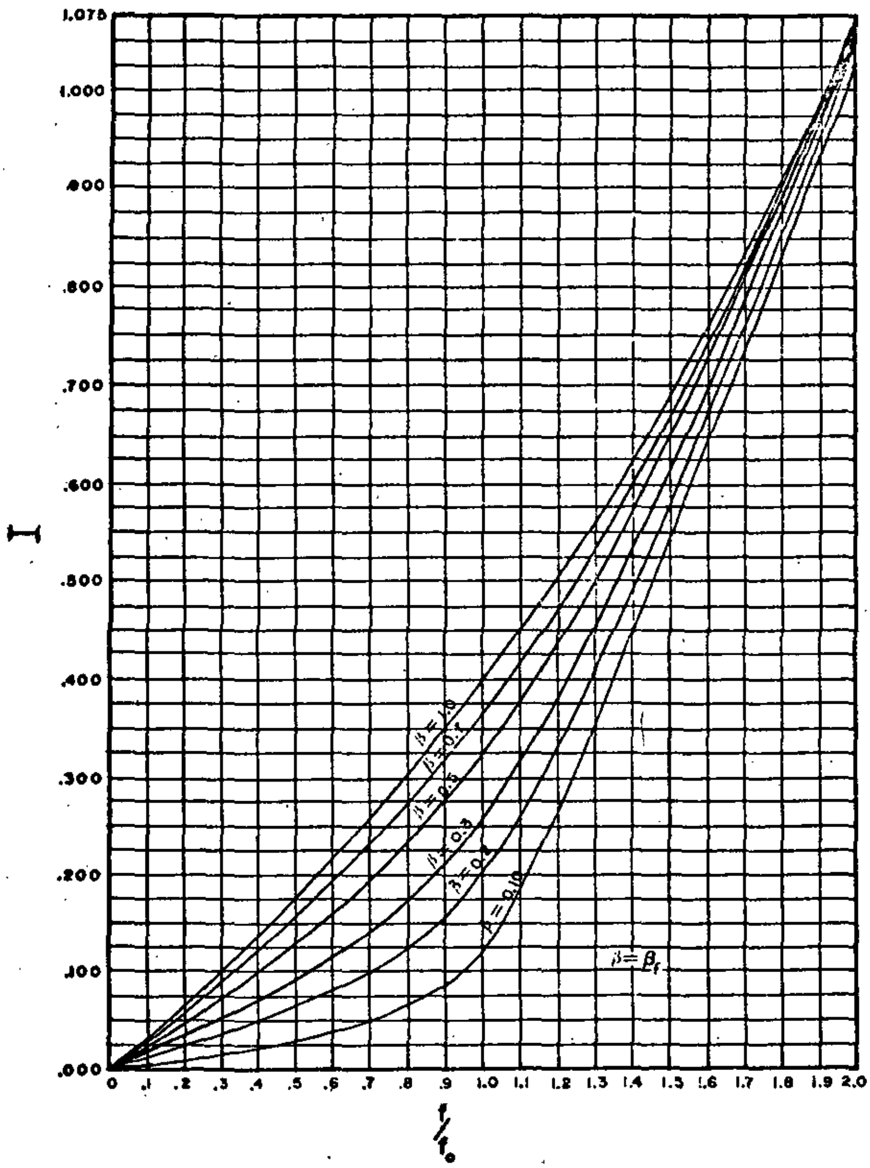


FIGURE 519.2-14. Normalized area under the low frequency random curve as a function of f/f_o and β_f

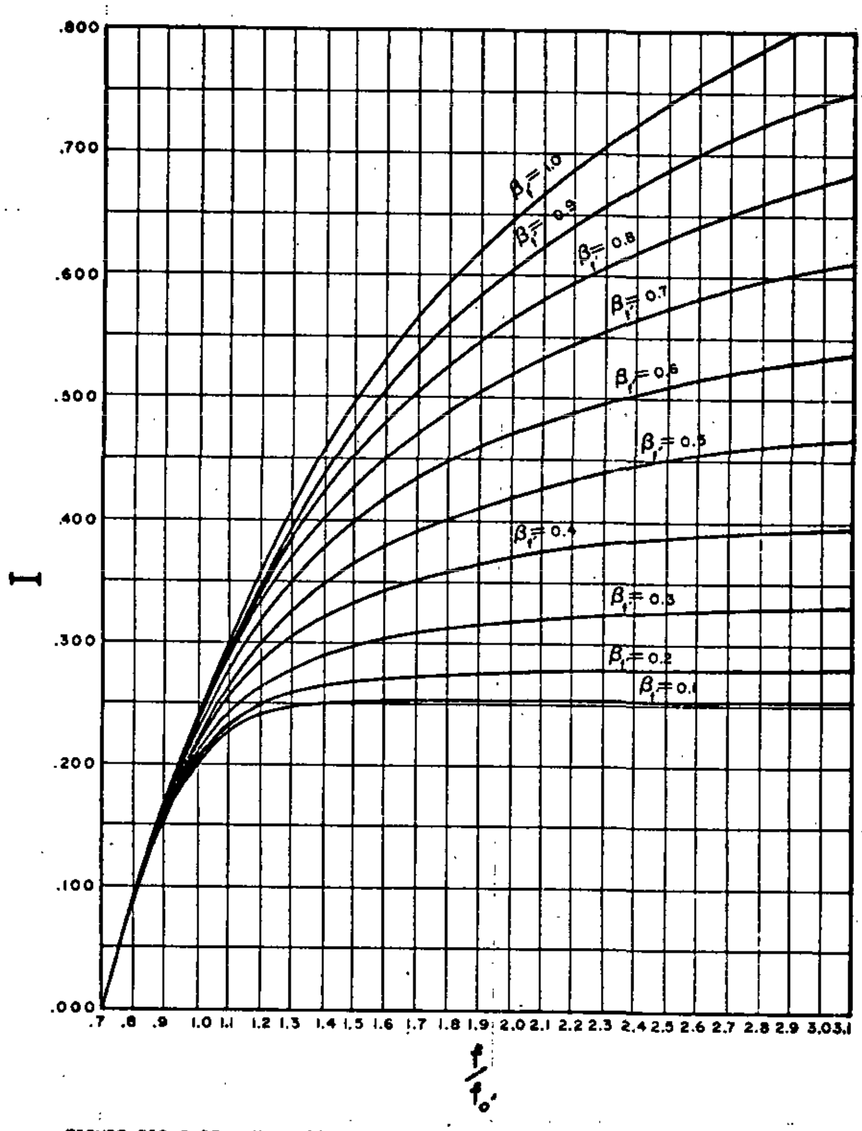


FIGURE 519.2-15. Normalized area under the high frequency random curve as a function of f/f_o, and β_f.

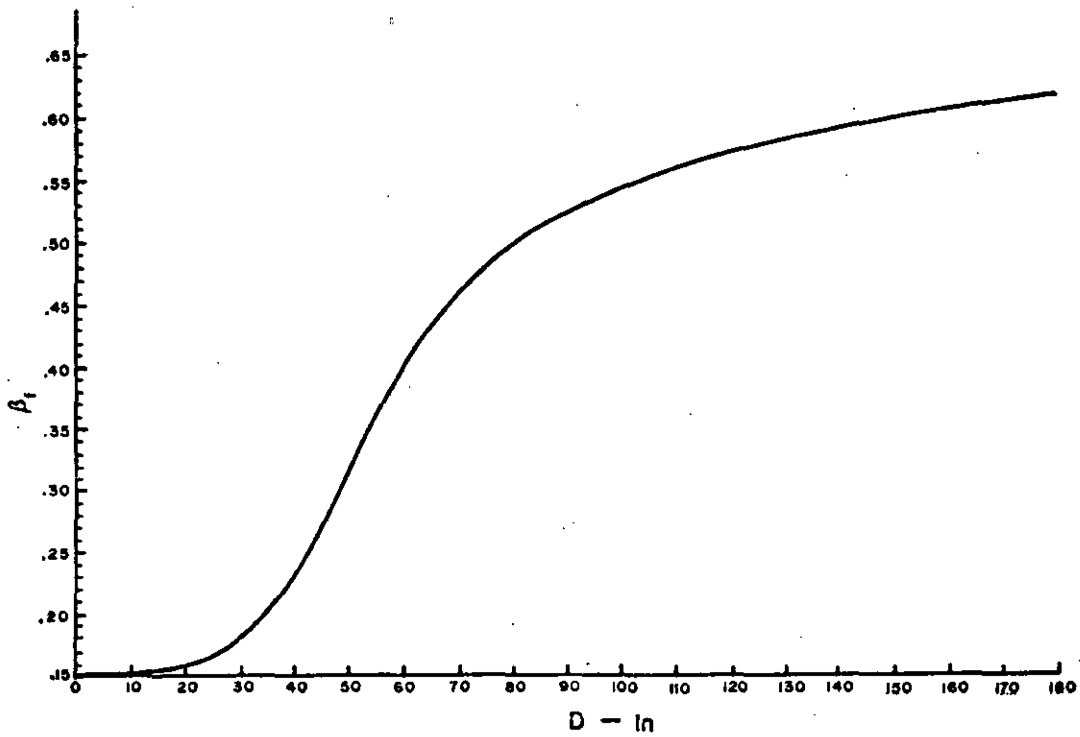


FIGURE 519.2-16. Slope factor, β_f, for the low frequency random surface

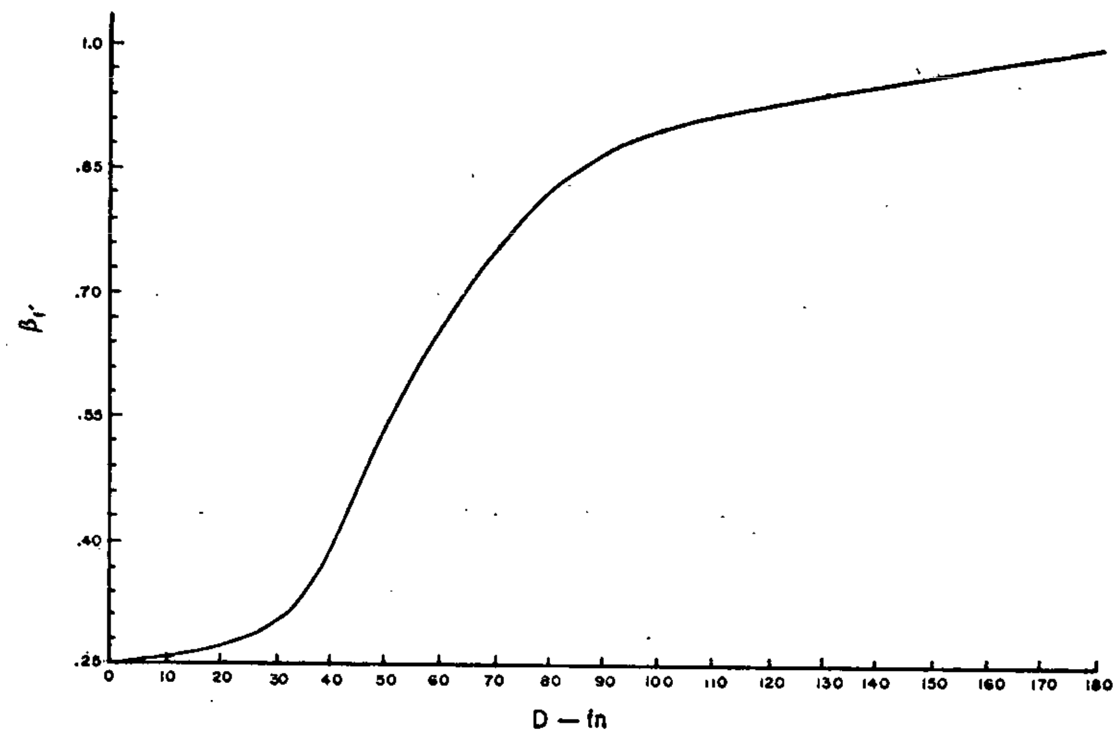


FIGURE 519.2-17. Slope factor, $\beta_{f'}$, for the high frequency random surface

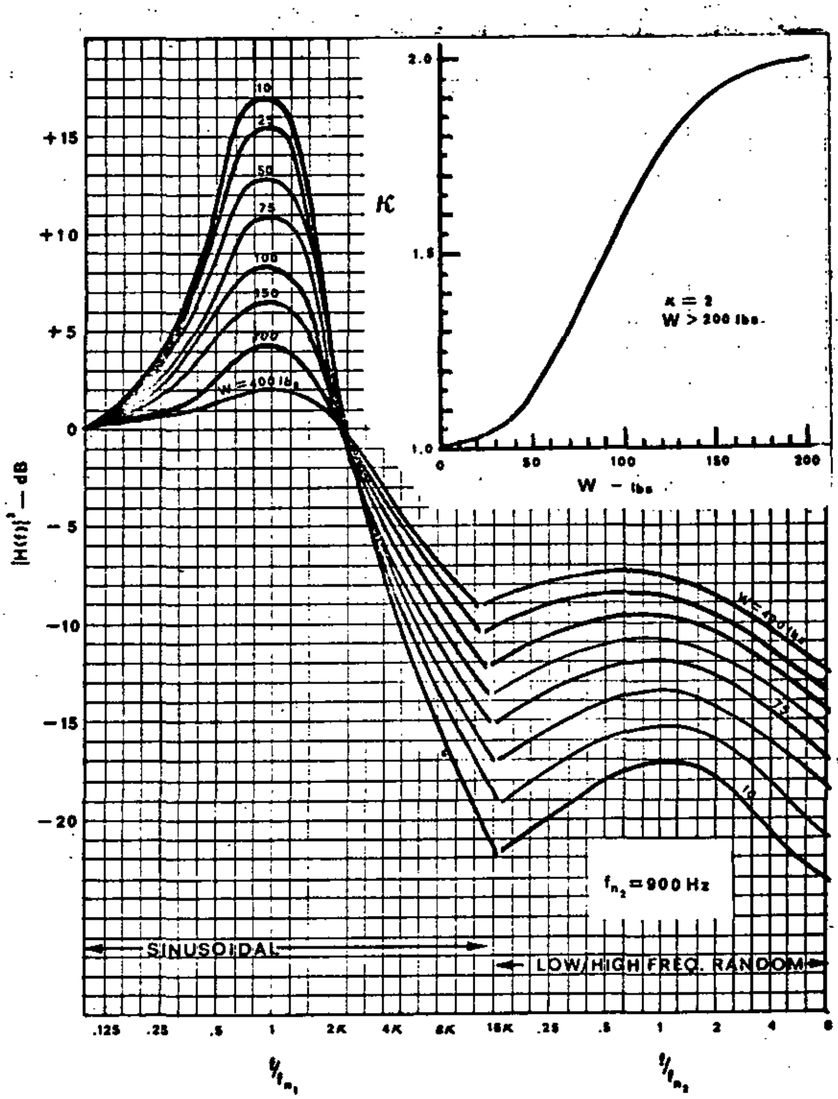


FIGURE 519.2-18 Transfer function for isolated equipments

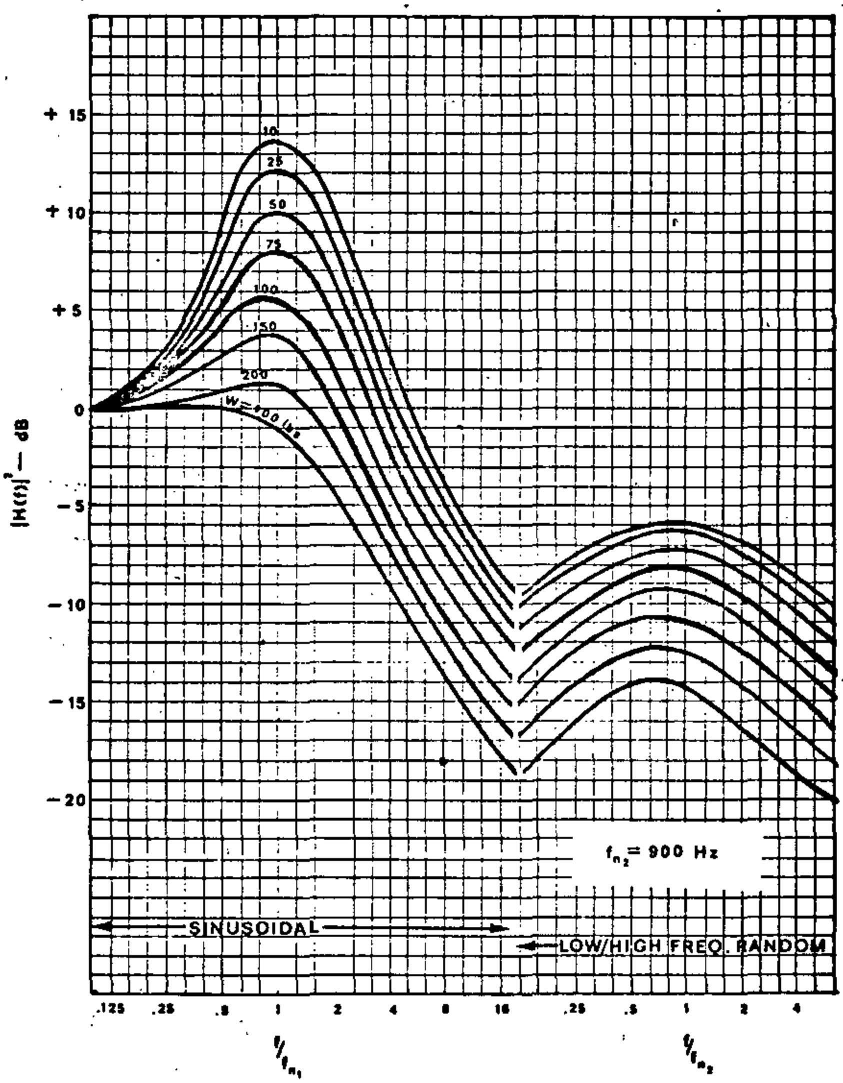


FIGURE 519.2-19 Transfer functions for non-isolated equipments

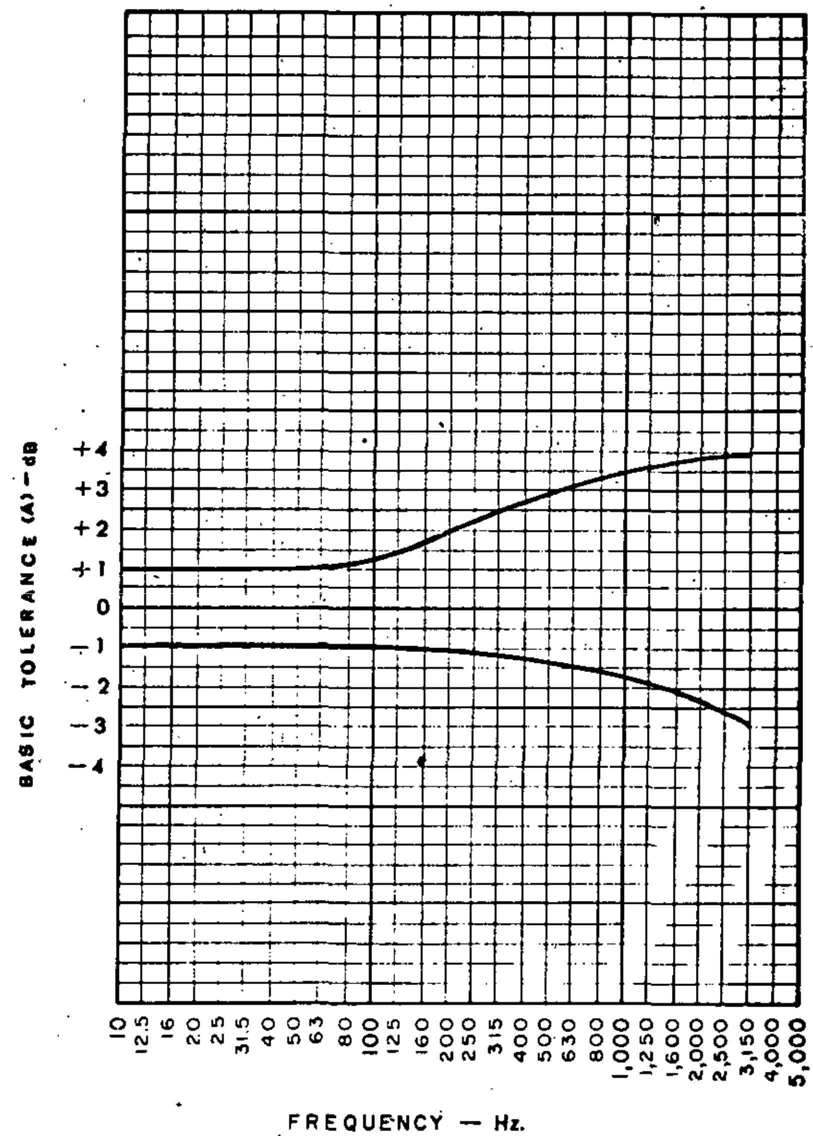


FIGURE 519.2-20 Basic test tolerance (A) for gunfire spectrum (W < 10 lbs)

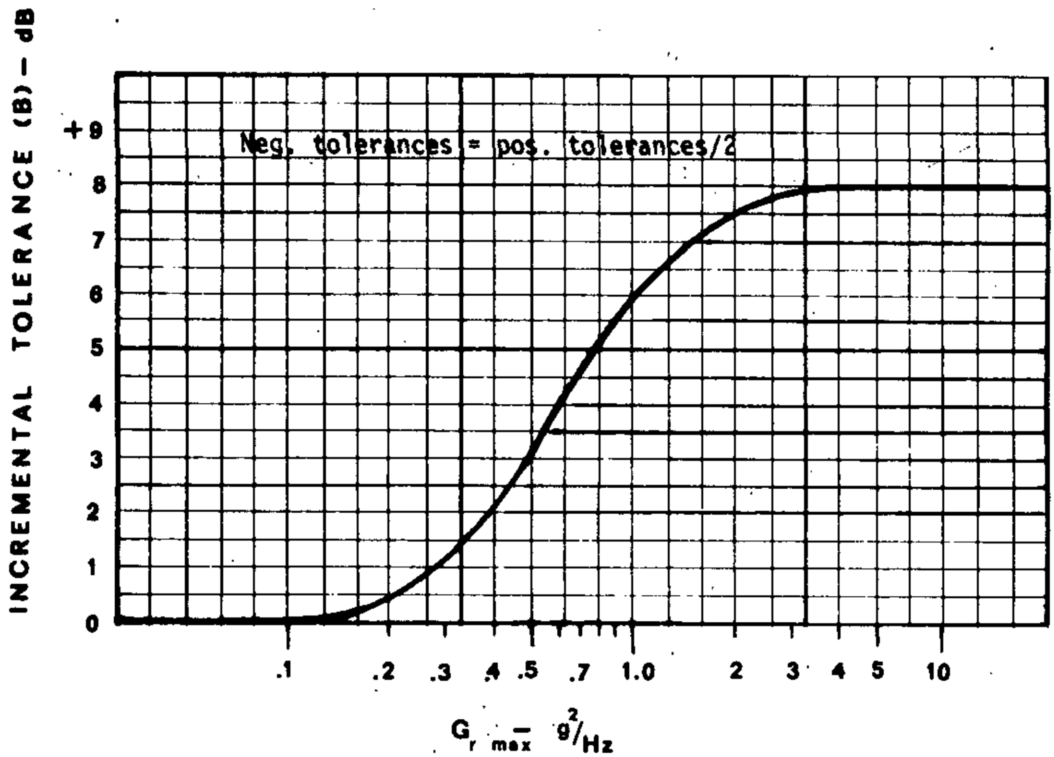


FIGURE 519.2-21 Gunfire test tolerance (B) for $G_{r\ max} \geq 0.1\ g^2/Hz$

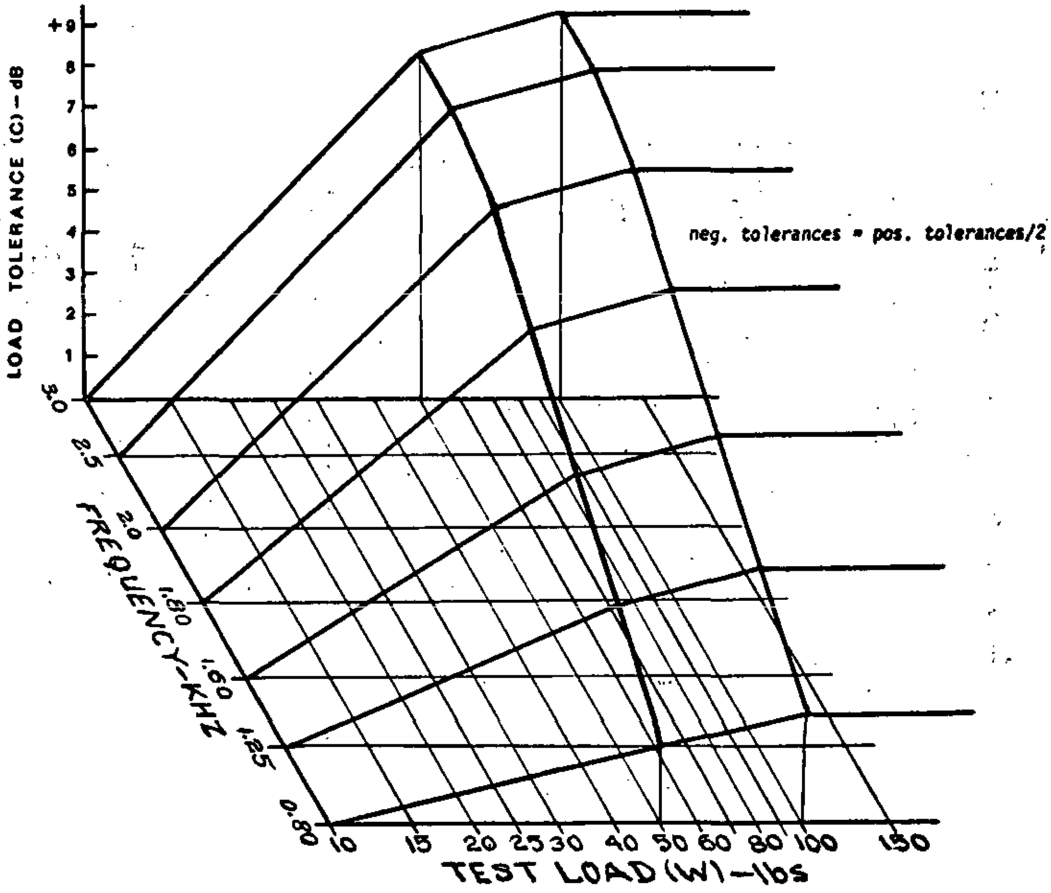


FIGURE 519.2-22 Gunfire test tolerance (C) for W ≥ 10 lbs

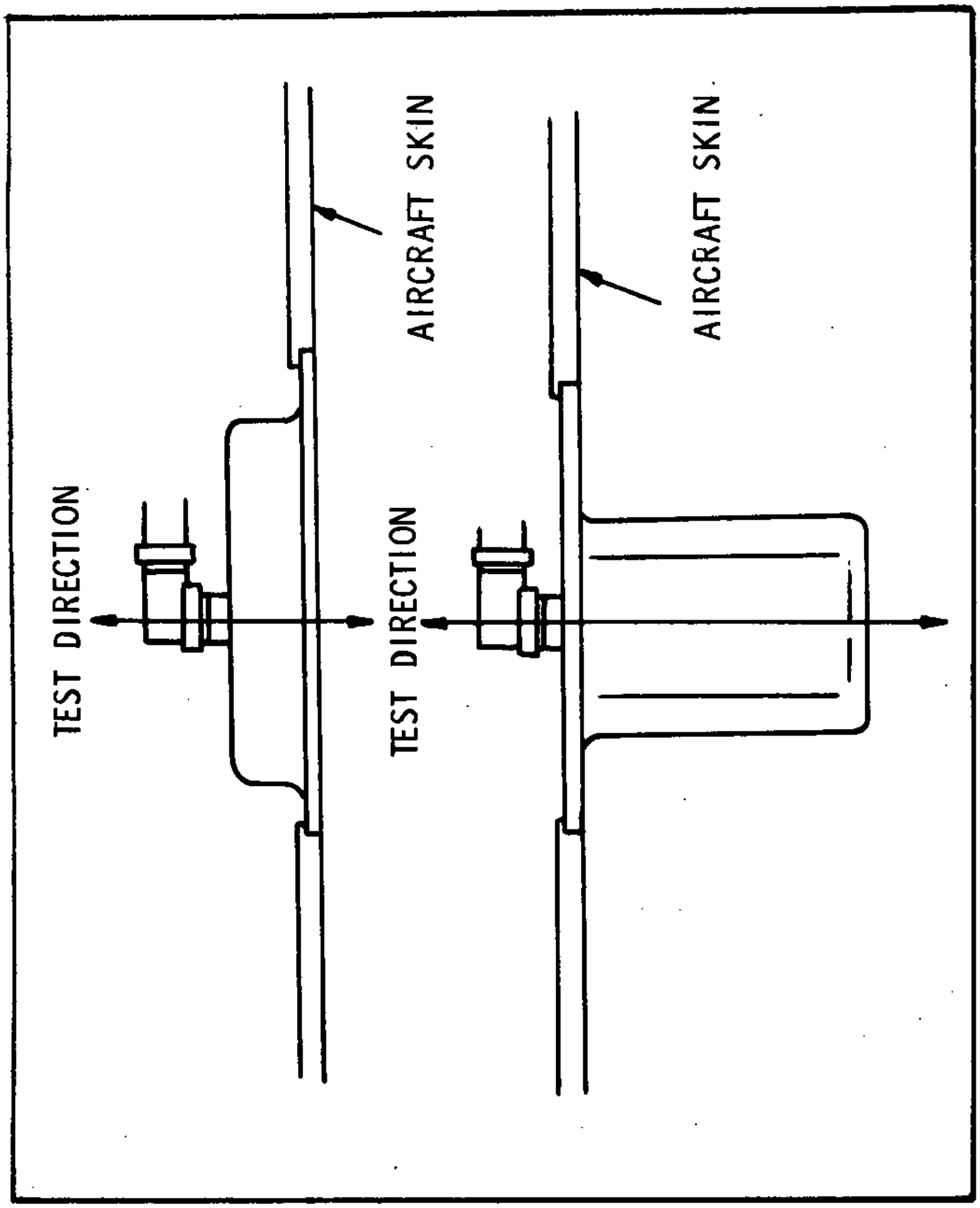


FIGURE 519.2-23 Single direction example

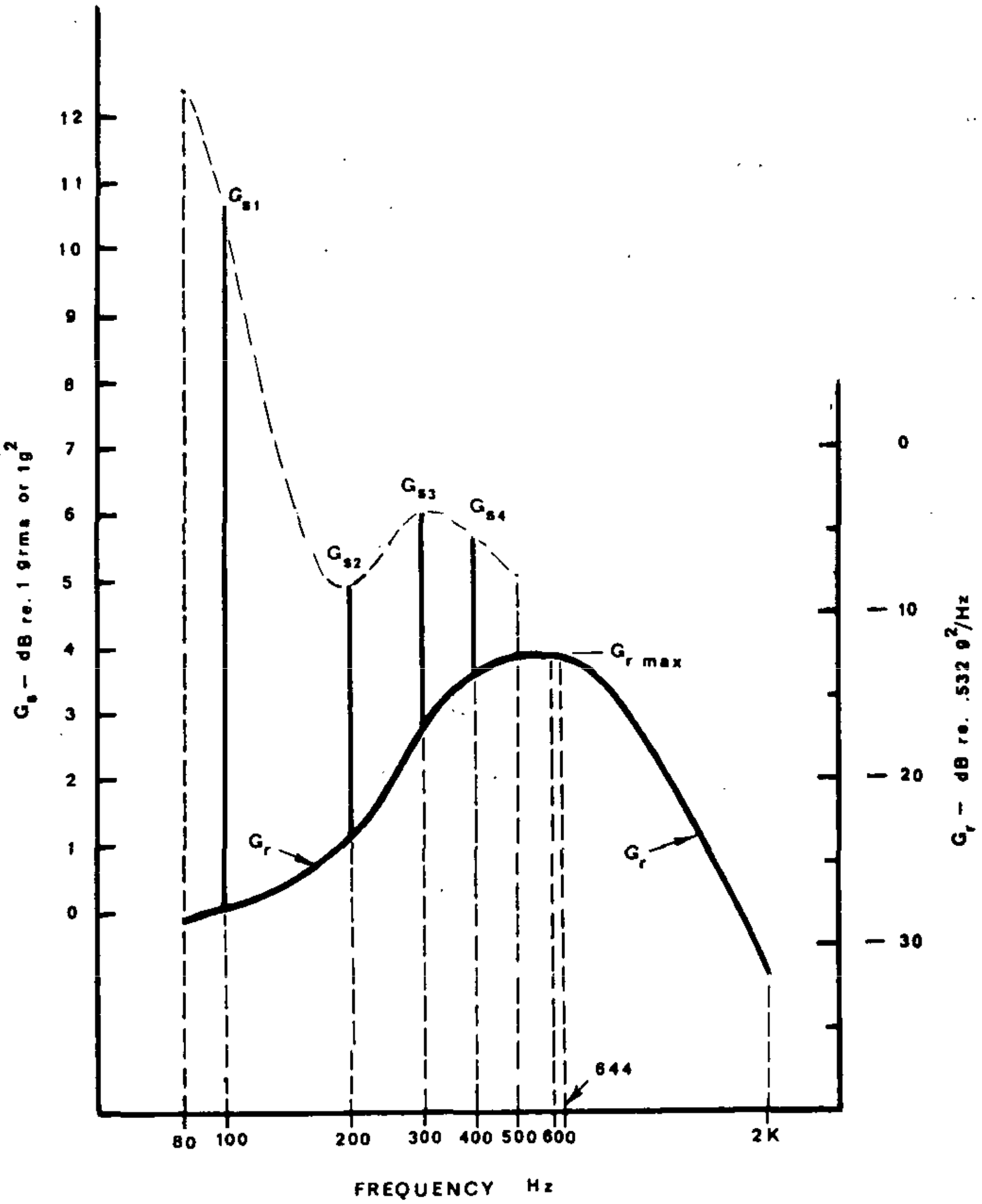


FIGURE 519.2-24 Example of test spectrum for secondary structure (instr. panel)

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