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MILITARY STANDARD

ENVIRONMENTAL TEST METHODS

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

FSC MISC

1. This standard has been approved by the Department of Defense and is published to establish environmental test methods for equipment.

2. Use of this standard by activities, departments, and agencies of the Department of Defense shall be mandatory effective on date of issue.

3. Recommended corrections, additions, or deletions should be addressed to:

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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. The test methods contained herein are intended:

(a) To specify environmental conditions obtainable in the laboratory, such that if an item is exposed to these conditions and continues to operate in a satisfactory manner, a high degree of confidence will have been established that the item could survive the field environment during its expected service life. The tests described herein are not to be interpreted as an exact and conclusive representation of actual service operation.

(b) To describe in one standard (1) all of the test methods of a similar character which appeared in the various joint or single service specifications, (2) those newly-developed test methods which are feasible for use by more than one service, and (3) the recognized extreme environments, particularly temperatures, barometic pressures, etc., at which equipment will be tested under some of the presently standardized testing procedures. By so consolidating, these methods may be kept uniform and thus result in conservation of equipment, man-hours, and testing facilities. In achieving these objectives, it is necessary to make each of the general test methods adaptable to a broad range of equipment.

(c) To standardize environmental tests in order to obtain, as much as possible, reproducible test results.

1.2 Application of test methods. Test methods contained in this standard apply broadly to all items of equipment and generally represent the extreme conditions which usually constitute the minimum acceptable conditions. 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 a 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 and the details as specified in the summary paragraph.

2. REFERENCED 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-S-901 — Shock Tests, H.I. (High - Impact), Shipboard Machinery, Equipment and Systems, Requirements for

MIL-E-2036 — Enclosure for Electric and Electronic Equipment, Naval Shipboard

MIL-G-5572 — Gasoline, Aviation, Grades 80/87, 100/-130, 115/145

MIL-C-9435 — Chamber, Explosion-Proof Testing

MIL-C-45662 — Calibration of Standards

STANDARDS

Military

MIL-STD-167 — Mechanical Vibrations of Shipboard Equipment

(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 Geophysics Union

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

(Copies of the above publication may be obtained from the American Geophysics Union, 1145 - 19th Street, N.W., Washington, D. C. 20036.)

United States of America Standards Institute

Acoustical Terminology (Including Mechanical Shock and Vibration) S1.1-1960

(Copies of the above publication may be obtained from the United States of American Standards Institute, 10 East 40th Street, New York, N. Y. 10016.)

U.S. Committee on Extension to the Standard Atmosphere

U.S. Standard Atmosphere, 1962

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

3. GENERAL REQUIREMENTS

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

Temperature	23° ± 10° C (73° ± 18° F)
Relative humidity	50 percent ± 30 percent
Atmospheric pressure	725^{+50}_{-115} mm. of mercury ($28.5^{+2.0}_{-4.5}$ in. of mercury)

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

Temperature	23° ± 1.4° C (73° ± 2.5° F)
Relative humidity	50 percent ± 5 percent
Atmospheric pressure	$725\ ^{+50}_{-75}$ mm. of mercury ($28.5\ ^{+2.0}_{-3.0}$ in. of mercury)

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) Tolerances for use with test chamber:

(1) Air temperature at the control sensor: ±1.4° C (2.5° F). 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.

(2) Pressure: When measured by devices such as manometers, ±5 percent or ±1.5 mm. (0.059 inches) of mercury, whichever provides the greatest accuracy. When measured by devices such as ion gages, ±10 percent to 10—5 Torr.

(3) Relative humidity at the control sensor: ±5 percent.

(b) Other tolerances:

(1) Vibration amplitude: Sinusoidal, ±10 percent.

(2) Vibration frequency: ±2 percent, or±½ cps below 20 cps.

(3) Acceleration: ±10 percent.

3.1.3 *Accuracy of test apparatus.* The accuracy of instruments and test equipment used to control or monitor the test parameters, whether located at a Government testing laboratory or at the contractor's plant shall be verified periodically (at least every 12 months, preferably once every 6 months, unless contractor procedures prepared to satisfy the requirements of MIL–C–45662 for calibration cycle of specific instruments specify otherwise) 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.

(c) Be appropriate for measuring the test parameters.

3.1.4 *Stabilization of test temperature.* 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 does not change more than 2.0° C (3.6° F) per hour.

3.1.5 *Reference conditions.* The equivalent pressure corresponding to altitude can be obtained from U.S. Standard Atmosphere, 1962.

3.2 Performance of test.

3.2.1 *Pretest performance record.* Prior to proceeding with any of the test methods, the test item shall be operated under standard ambient conditions (see 3.1) and a record made of all data necessary to determine compliance with required performance. These data shall provide the criteria for checking satisfactory performance of the test item either during, or at the conclusion of the test, or both, as required. Certification by signature and date block is required as specified in 3.4.

3.2.2 *Installation of test item in test facility.* 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 or immediately following exposure to the specified test.

3.2.3 *Performance check during test.* When operation of the test item is required during the test exposure, the operation and performance checks shall be of sufficient duration or shall be repeated at appropriate intervals to insure a record of comprehensive comparative data for comparison with data recorded under standard ambient conditions specified in 3.2.1.

3.2.4 *Visual inspection and failure criteria.* When specified herein, the test item shall be visually inspected and a record made of any damage or deterioration resulting from the test. If a test chamber is used for the test, perform a visual inspection of the test item within the chamber at test conditions, when possible. Upon completion of the test, visually inspect the test item again after the test item has been returned to standard ambient conditions. 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 shall provide reason to consider the test item as having failed to withstand the conditions of the test.

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 test conditions.

3.3.1.2 *Heat source.* The heat source of the test facility shall be so located that radiant heat 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 centrally located within the test chamber where possible, or in the return air stream and shall be baffled, or otherwise protected against direct impingement of supply air and against radiation effects.

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 The selection of environmental test methods should be based on a consideration of the environments which the equipment will experience. When more than one method has been selected, a sequence of testing should be specified. Table I provides advisory information on the applicability of the various test methods and recommended test sequences.

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	Altitude	1	1	1	3	3	4	2^1	2	2	2	3	4	3	2	3
501	High temperature	2	2	2	2	2	1	1	1	3	1	1	1	1	1	2
502	Low temperature	4	4	3	1	1	2	3^1	3	1	4	2	3	2	3	1
503	Temperature shock	5^1	5^1	5^1	5^1	5^1	$3^{1,3}$	$5^{1,3}$	$5^{1,3}$	$5^{1,3}$	$3^{1,3}$	$5^{1,3}$	2	4	$5^{1,3}$	$5^{1,3}$
504	Temperature-altitude	—	—	—	—	—	5^5	4^5	4^5	4^5	$5^{1,3,5}$	4^5	5^5	5^5	4^5	4^3
505	Sunshine	3^1	3^1	4^1	4^1	4^1	—	—	—	—	—	—	6^3	—	—	—
506	Rain	8^1	8	7	11^1	11	—	7^1	7^1	8^1	$7^{1,3}$	—	—	$7^{1,3}$	—	—
507	Humidity	9	9	8	12	12	8	8^1	8	9	8	7	9	8	7^1	12
508	Fungus	10	10	9	13	13	9	9^1	9	10	$9^{1,3}$	8	10	9	$8^{1,3}$	13
509	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	Dust	7^1	7	11	7^1	7	7	11^3	11^3	7	11	10	8	11	10^3	7
511	Explosive atmosphere	—	—	12	8^1	8^1	12^3	—	—	13^3	—	12^3	13^3	13	$12^{1,3}$	$9^{1,3}$
512	Leakage (immersion)	6	6	6	6	6	6	6	6	6	6	6	7	6	6	6
513	Acceleration	—	—	—	—	—	11	12	12	12	12	11	12	12	11	8
514	Vibration	13	13	14	10	10	14	14	14	15	14	14	14	15	14	11
515	Acoustical noise	—	—	—	—	—	$15^{1,4}$	$15^{1,4}$	$15^{1,4}$	16	15	15	16^1	16	15	15
516	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
T517	Space simulation^1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
518	Temperature-humidity-altitude	—	—	—	—	—	16^1	16^1	16^1	17^1	16^1	16^1	17^1	17^1	16^1	16^1

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 for guidance in testing satellites and space vehicles.

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

Custodians:

Army—EL

Navy—AS

Air Force—11

Reviewer activities:

Army—EL, MI, MU, ME, AV, GL

Navy—AS, SH, OS, YD

Air Force—11

Preparing activity:

Air Force—11

Project No. MISC-0290

METHOD 500

ALTITUDE

1. **Purpose.** The altitude test is conducted to determine the effects of reduced pressure on equipment. Damaging effects of low pressure include leakage of gases or fluids from gasket-sealed enclosures and rupture of pressurized containers. Under low pressure conditions, low density materials change their physical and chemical properties. Damage due to low pressure may be augmented or accelerated by the contraction, embrittlement, and fluid congealing induced by low temperature. Erratic operation or malfunction of equipment may result from arcing or corona. Greatly decreased efficiency of convection and conduction as heat transfer mechanisms under low pressure conditions is encountered. This test method is composed of two procedures:

1.1 Procedure I is applicable to equipment of group I in section 4, table I, for the purpose of determining the ability of such equipment to withstand the reduced pressure encountered during shipment by air and for satisfactory operation under those pressure conditions found at high ground elevations.

1.2 Procedure II is applicable to equipment of group II in section 4, table I, for the purpose of determining the ability of equipment to operate satisfactorily during and following exposure to both reduced pressure and temperature conditions encountered during flight.

2. **Apparatus.** Temperature-altitude chamber or altitude chamber for procedure I and temperature-altitude chamber for procedure II.

3. Procedures.

3.1 Procedure I.

Step 1—Place the test item in the test chamber in accordance with section 3, paragraph 3.2.2, and maintain standard ambient temperature during the entire test.

Step 2—Reduce the chamber internal pressure to 87.5 mm of Hg (3.44 in. of Hg or 50,000 ft. above sea level). The rate of pressure change may be the maximum attainable by the chamber. Maintain the chamber pressure for a period of not less than 1 hour.

Step 3—Increase the chamber pressure to 523 mm of Hg (20.6 in. of Hg or 10,000 ft. above sea level) and then operate the test item and compare the results with the data obtained in accordance with section 3, paragraph 3.2.1.

Step 4—With the test item not operating, return the chamber to standard ambient conditions.

Step 5—Operate the test item and compare the data obtained with the data obtained in accordance with section 3, paragraph 3.2.1.

Step 6—Inspect the test item as specified in section 3, paragraph 3.2.4.

3.2 Procedure II.

Step 1—Place the test item in the test chamber in accordance with section 3, paragraph 3.2.2.

Step 2—Reduce the chamber internal temperature to −54° C (−65° F), unless otherwise specified, and maintain until the test item is stabilized.

Step 3—Reduce the chamber internal pressure (The rate of pressure change may be the maximum obtainable by the chamber) to the lowest pressure condition for which the test item is designed to operate while maintaining the specified temperature.

Step 4—Maintain the above pressure and temperature for a period of not less than 1 hour.

Step 5—At the conclusion of the time period and while at the same pressure and temperature, operate the test item and compare the data with the data obtained in accordance with section 3, paragraph 3.2.1.

Step 6—With the test item still operating, increase the chamber internal pressure and temperature to standard ambient conditions, stabilize and compare the results with the data obtained in accordance with section 3, paragraph 3.2.1. During this period, special attention shall be given to electrical and electronic test items for erratic operation or malfunction resulting from arcing or corona.

Step 7—Inspect the test item as specified in section 3, paragraph 3.2.4.

Note: The rate of temperature change (steps 2 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 specified in the equipment specification:

(a) Procedure number.

(b) Pretest data required (section 3, paragraph 3.2.1).

(c) For procedure II (in addition to (a) and (b)).

  (1) Temperature, if other than −54° C (−65° F) (step 2).

  (2) Pressure (step 3).

(d) Length of time required for operation and measurements.

(e) Rate of pressure change, when required.

METHOD 501

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. In equipment, high temperature conditions may cause the permanent set of packings and gaskets. Binding of parts may also result in items of complex construction due to differential expansion of dissimilar metals. 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.

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

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

2. **Apparatus.** Temperature chamber.

3. **Procedures.**

3.1 **Procedure I.**

Step 1—Place the test item in the test chamber in accordance with section 3, paragraph 3.2.2.

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 not less than 48 hours while insuring the relative humidity is not in excess of 15 percent.

Step 4—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 5—Operate the test item until the item is stabilized or as specified in the equipment specification, and compare the results with the data obtained in accordance with section 3, paragraph 3.2.1.

Step 6—Return the test item, non-operating to standard ambient condition and stabilize.

Step 7—Operate the test item and compare the results with the data obtained in accordance with section 3, paragraph 3.2.1.

Step 8—Inspect the test item as specified in section 3, paragraph 3.2.4.

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.** (See note at end of procedure.)

Step 1—Place the test item in the test chamber in accordance with section 3, paragraph 3.2.2.

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 68° C (154°

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 compare the results with the data obtained in accordance with section 3, paragraph 3.2.1.

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

Step 10—Operate the test item and compare the results with the data obtained in accordance with section 3, paragraph 3.2.1.

Step 11—Inspect the test item as specified in section 3, paragraph 3.2.4.

Note: The rate of temperature change (steps 2, 4, 5, 7, and 9) shall be 20° ± 4° C (36° F) per hour.

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

(a) Procedure number.

(b) For procedure I:

  (1) Pretest data required (section 3, paragraph 3.2.1).

  (2) Internal chamber temperature desired, if other than 71° C (160° F) (step 2).

  (3) Highest operating temperature under which the test item is designed to operate (step 4).

  (4) Length of time required for operation and measurements.

(c) For procedure II:

  (1) Pretest data required (section 3, paragraph 3.2.1).

  (2) Highest operating temperature under which the test item is designed to operate (step 7).

  (3) Length of time required for operation and measurements.

METHOD 502

LOW TEMPERATURE

1. **Purpose.** The low temperature test is conducted to determine the effects of low temperature on equipment during storage (without protective packaging) or service use. Differential contraction of metal parts, loss of resiliency of packings and gaskets, and congealing of lubricants are a few of the difficulties associated with low temperatures.

2. **Apparatus.** Temperature chamber.

3. **Procedures.**

3.1 **Procedure I.**

Step 1—Place the test item in the test chamber in accordance with section 3, paragraph 3.2.2.

Step 2—Lower the internal chamber temperature to the storage temperature specified in the equipment specification and maintain for the time specified.

Step 3—Inspect the test item in accordance with section 3, paragraph 3.2.4.

Step 4—Adjust the internal chamber temperature to the lowest temperature under 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 and compare the results with the data obtained in accordance with section 3, paragraph 3.2.1.

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

Step 7—Operate the test item and compare the results with the data obtained in accordance with section 3, paragraph 3.2.1.

Step 8—Inspect the test item as specified in section 3, paragraph 3.2.4.

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 specified in the equipment specification:

(a) Pretest data required (section 3, paragraph 3.2.1).

(b) Storage temperature (step 2).

(c) Lowest operating temperature (step 4).

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

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

METHOD 503

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. Cracking or rupture of materials due to sudden dimensional changes by expansion or contraction are the principal difficulties to be anticipated. These 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. **Procedures.**

3.1. **Procedure I.**

Step 1—The test item shall be placed in the high temperature chamber in accordance with section 3, paragraph 3.2.2 and the internal chamber temperature raised to 71° C (160° F), and maintained for a period of not less than 4 hours.

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 −54° C (−65° F). (When authorized by the procuring activity, large or heavy test items shall be transferred from one chamber to the other in the minimum practical time.)

Step 3—The test item shall be exposed to this temperature for a period of not less than 4 hours.

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. (The test may, for convenience purposes, be interrupted during this step if desired. This is accomplished by returning the test item to ambient conditions after an exposure at high temperature of 1 hour minimum. To continue the following steps, it is required that step 1 first be repeated.)

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 the test item and compare the results with the data obtained in accordance with section 3, paragraph 3.2.1

Step 10—Inspect the test item as specified in section 3, paragraph 3.2.4.

4. **Summary.** The following details shall be specified in the equipment specification.

(a) Pretest data required (section 3, paragraph 3.2.1).

METHOD 504

TEMPERATURE-ALTITUDE

1. **Purpose.** The temperature-altitude test is intended primarily for electronic equipment installed in aircraft capable of operation from sea level to 100,000 feet. Before applying this test to other types of equipment, the test conditions and procedures specified in this test method should be carefully analyzed for applicability. Equipment installed in space vehicles, satellites, etc. should be tested in accordance with Method 517 of this standard. 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. 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.

3. **Procedures.**

3.1 **Environmental conditions.** The test procedures specified herein are designed to determine that equipment will operate satisfactorily under the environmental conditions outlined in table 504-I. The equipment class number, as used in this method, is determined by the required altitude operating range and the required sea level continuous operating temperature.

3.2 **Procedure I.** The test item shall be placed in the test chamber in accordance with section 3, paragraph 3.2.2, making connections and attaching instrumentation as necessary. In general, the testing schedule outlined in table 504-II shall be followed. However, each step in table 504-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-I, the alternate temperature-altitude conditions in figures 504-1, 504-2, 504-3, or 504-4 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-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 and 0.5 inch of mercury per second. Pressures for altitudes are contained in U.S. Standard Atmosphere, 1962.

Step 1—With the test item nonoperating, adjust the test chamber conditions to those specified for step 1 in table 504-II. The test item temperature shall be stabilized and maintained for at least 2 hours. Where it is possible without changing the temperature condition, a visual inspection of the test item shall be made to determine whether or not deterioration which would impair future operation has occurred.

Step 2—With the test item nonoperating, adjust the test chamber conditions to those specified in step 2 in table 504-II. After the test item temperature has stabilized, the test item shall be turned on at the lowest specified input voltage. The test item shall operate satisfactorily within the specified warmup time. The test item shall then be turned off and restabilized at the temperature specified for step 2 in table 504-II. The operation shall be repeated 2 more times (see notes (a) and (b). The chamber temperature shall be maintained at the temperature specified for step 2 in table 504-II.

Note (a): Satisfactory operation within the specified warmup time shall be determined by checking to see if the visual or aural presentations or other performance characteristics appear normal.

Note (b): 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-II and the operational check continued.

Step 3—With the test item nonoperating, permit the test item to stabilize at the temperature specified in step 3 of table 504-II. The test item shall then be turned on and the altitude adjusted to that specified. Upon reaching the specified altitude, an operational and performance check shall be made at the highest specified input voltage and the result recorded.

Step 4—With the test item nonoperating, adjust the chamber conditions to those specified for step 4 in table 504-II. After test item temperature has stabilized, the test chamber door shall be opened and frost permitted to form on the test item. The door shall remain open long enough for the frost to melt but not long enough to allow the moisture to evaporate. (See note (c)). The chamber door shall be closed and the test item turned on at the highest specified input voltage to see if it operates satisfactorily within the specified warmup time. The test item shall be turned on and off at least three times. (See notes (a) and (d).)

Note (c): 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.

Note (d): After completion of the cold test (steps 1, 2, 3, and 4), and prior to starting the high temperature tests, a reference run shall be made in accordance with section 3, paragraph 3.2.1. The reference run shall be made at the highest specified input voltages and data obtained compared with that of the reference run made prior to Step 1.

Step 5—With the test item nonoperating, adjust the chamber conditions to those specified for step 5 in table 504-II. The chamber temperature shall be stabilized and maintained for at least 16 hours. At the conclusion of this period the test item shall, when practicable, be visually inspected to determine the extent of any deterioration.

Step 6—With the test item nonoperating, adjust the chamber conditions to those specified for step 6 in table 504-II. After the test item temperature has stabilized, turn the test item on at the highest specified input voltage and permit it to operate continuously for 4 hours. Thermocouple readings of the test item shall be recorded every 30 minutes. At the end of the specified period of operation, and still at the specified chamber conditions, continue to operate the test item until it has been checked for satisfactory operation and results recorded.

Step 7—With the test item nonoperating, adjust the chamber conditions to those specified for step 1 in table 504-II. After the test item temperature has stabilized, the test item shall be operated for 30 minutes at the highest specified input voltage four times. Each of the four periods of operation shall be followed by a 15-minute off period. The test item shall be checked for satisfactory operation during each period of operation and results recorded. The thermocouple readings of the test item shall be recorded every 10 minutes.

Step 8—With the test item nonoperating, adjust the chamber conditions to those specified for step 8 in table 504-II. After the test item temperature has been stabilized, the test item shall be operated for 10 minutes at the highest specified input voltage four times. Each of the four periods of operation shall be followed by a 15-minute off period. The test item shall be checked for satisfactory operation during each period of operation and the results recorded. Thermocouple readings of the test item shall be recorded at the beginning and end of each operating period.

Step 9—With the test item nonoperating, adjust the chamber temperature to that specified for step 9 of table 504-II. The test item temperature shall then be stabilized. The test item shall then be turned on at the highest specified input voltage and the altitude shall be adjusted to that specified. Following altitude and test item temperature stabilization, the test item shall be operated at the highest specified input voltage for 4 hours. Thermocouple readings of the test item shall be recorded every 30 minutes. At the end of the specified operating period, continue to operate the test item until the equipment has been checked for satisfactory operation and results recorded.

Step 10—With the test item nonoperating, adjust the chamber temperature to that specified for step 10 in table 504-II. After the test item temperature has stabilized, operate the test item for 30 minutes at the highest specified input voltage four times. Each of the four periods of operation shall be followed by a 15-minute off period. The test item shall be checked for satisfactory operation during each period of operation and results recorded. Thermocouple readings of the test item shall be recorded for every 10 minutes of operation.

Step 11—With the test item nonoperating, adjust the chamber temperature to that specified for step 11 in table 504-II. Following chamber temperature adjustment, the test item shall be turned on and the altitude adjusted to that specified. After the chamber conditions have stabilized, permit the test item to operate at the highest specified input voltage for 4 hours. Thermocouple readings of the test item shall be recorded every 30 minutes. At the end of the specified operating period, continue to operate the test item at the specified conditions until an operational and performance check is made and the results recorded.

Step 12—With the test item nonoperating, stabilize the chamber and test item to those conditions specified for step 12 in table 504–II. After test item temperature has stabilized, operate the test item for 30 minutes at the highest specified input voltage four times. Each of the four periods of operation shall be followed by a 15-minute off period. The test item shall be checked for satisfactory operation during each period of operation and results recorded. Thermocouple readings of the test item shall be recorded for every 10 minutes of operation.

Step 13—With the test item nonoperating, stabilize the test time to those conditions specified for step 13 in table 504–II. Following stabilization, the test item shall be operated for 10 minutes at the highest specified input voltage four times. Each of the four periods of operation shall be followed by a 15-minute off period. The test item shall be checked for satisfactory operation and thermocouple readings of the test item recorded at the beginning and end of each operating period.

Step 14—With the test item operating, adjust the chamber conditions to standard ambient conditions. When the chamber conditions have stabilized, an operational and performance check shall be made on the test item and results compared with the data obtained in section 3, paragraph 3.2.1.

Note (e): In order to expedite the stabilization of test item temperatures, chamber temperatures other than those listed in table 504–II may be used.

Note (f): The steps listed herein include certain essential test points on the operational requirement curves of figures 504–1 through 504–4. These curves define the required temperature-altitude operational envelopes for the applicable classes of equipment. In addition to the essential test points listed any combination of conditions, in any sequence, within the design limitation envelopes as defined by the class of equipment or as modified by the equipment specification, may be chosen as additional operational test points.

Note (g): Following those steps where an increase in temperature at low pressure is specified, the pressure may be increased to ambient before raising the temperature and then returned to the specified altitude following temperature stabilization.

Note (h): The following guidelines are provided for consideration when determining location of thermal sensors used to monitor the test items:

(1) Temperature at several points inside each major unit. The number and location of the points to represent as nearly as possible the average ambient temperature inside the unit.

(2) Contact temperature on the 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.

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

- (a) Pretest data required (section 3, paragraph 3.2.1)
- (b) Length of time required for operation and measurements
- (c) Input voltage limits
- (d) Equipment class

TABLE 504-I. *Temperature range for various equipment classes*

Equipment class[1]		Equipment mode				Temperature
		Operating			Non-operating	
No.	Altitude range	Continuous	Intermittent	Short-time		
1	Sea level to 50,000 ft.	X				— 54 to 55° C
			X			55 to 71° C
					X	— 62 to 85° C
1A	Sea level to 30,000 ft.	X				— 54 to 55° C
			X			55 to 71° C
					X	— 62 to 85° C
1B	Sea level to 15,000 ft.	X				— 40 to 55° C
			X			55 to 71° C
					X	— 54 to 85° C
2	Sea level to 70,000 ft.	X				— 54 to 71° C
			X			71 to 95° C
					X	— 62 to 95° C
3	Sea level to 100,000 ft. (95° C continuous sea level operation)	X				— 54 to 95° C
			X			95 to 125° C
				X		125 to 150° C
					X	— 62 to 125° C
4	Sea level to 100,000 ft. (125° C continuous sea level operation)	X				— 54 to 125° C
			X			125 to 150° C
				X		150 to 260° C
					X	— 62 to 150° C

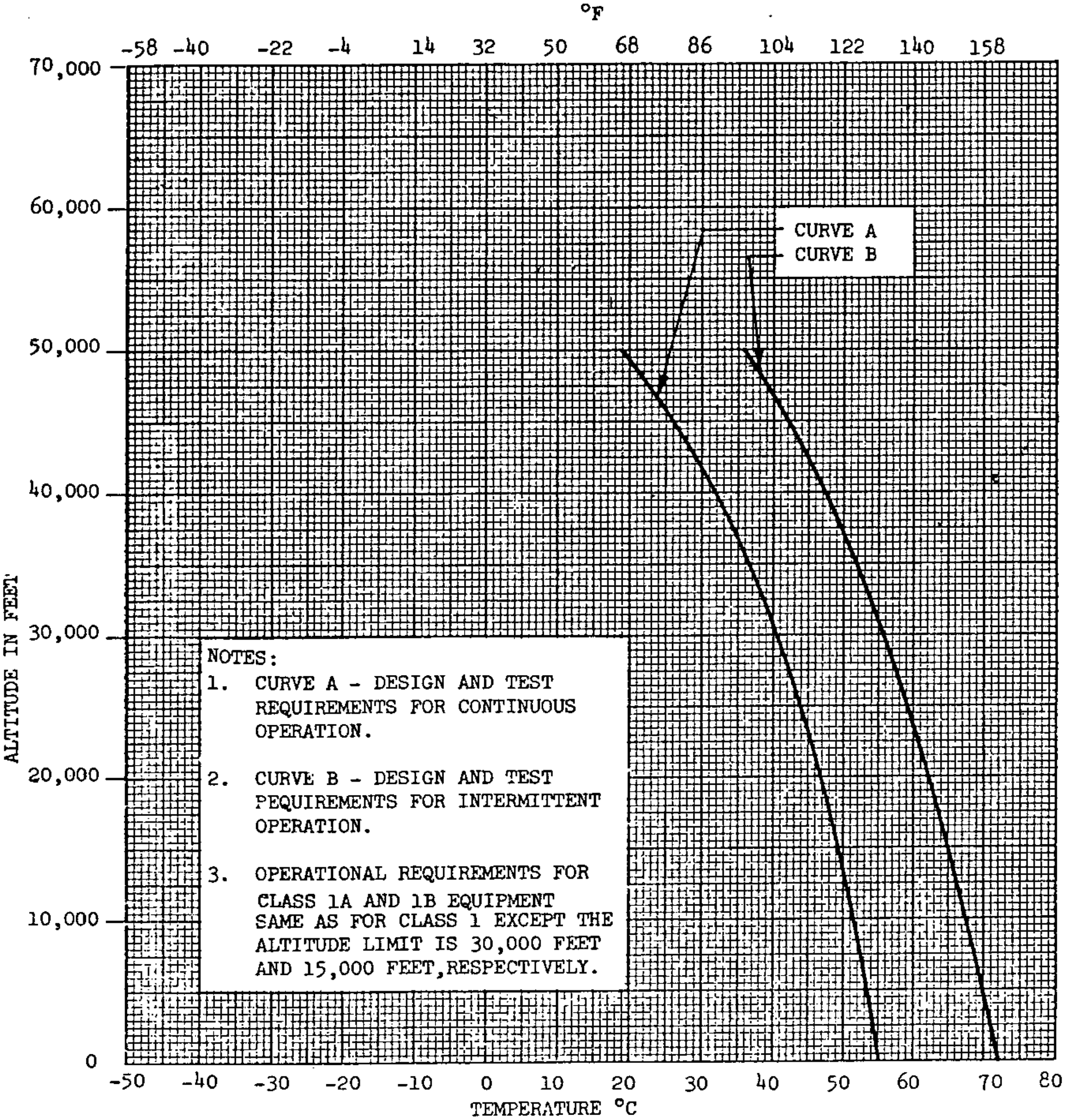
[1] Equipment classes as used in this test method are established for illustrating the equipment operating mode vs. the temperature-altitude relationship and are not intended to be analogous to equipment categories used elsewhere in this standard.

TABLE 504-II. *Test chamber conditions for temperature-altitude tests*

Class[1]	Step	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Temp. (°C)	—62	—54	—54	—10	85	55	71	Omit	30	47	20	35	Omit	[2]
	Alt. (feet)	[2]	[2]	50,000	[2]	[2]	[2]	[2]		40,000	40,000	50,000	50,000		
1A	Temp. (°C)	—62	—54	—54	—10	68	55	68	Omit	48	64	40	57	Omit	[2]
	Alt. (feet)	[2]	[2]	30,000	[2]	[2]	[2]	[2]		20,000	20,000	30,000	30,000		
1B	Temp. (°C)	—54	—40	—40	—10	68	55	68	Omit	52	68	49	66	Omit	[2]
	Alt. (feet)	[2]	[2]	15,000	[2]	[2]	[2]	[2]		10,000	10,000	15,000	15,000		
2	Temp. (°C)	—62	—54	—54	—10	95	71	95	Omit	36	60	10	35	Omit	[2]
	Alt. (feet)	[2]	[2]	70,000	[2]	[2]	[2]	[2]		50,000	50,000	70,000	70,000		
3	Temp. (°C)	—62	—54	—54	—10	125	95	125	150	60	90	—10	20	45	[2]
	Alt. (feet)	[2]	[2]	80,000	[2]	[2]	[2]	[2]	[2]	50,000	50,000	100,000	100,000	100,000	
4	Temp. (°C)	—62	—54	—54	—15	150	125	150	260	90	115	25	50	155	[2]
	Alt. (feet)	[2]	[2]	80,000	[2]	[2]	[2]	[2]	[2]	50,000	50,000	100,000	100,000	100,000	

[1] For class of equipment see figures 504-1 through 504-4 and table 504-I.

[2] Standard ambient.



NOTES:
1. CURVE A - DESIGN AND TEST REQUIREMENTS FOR CONTINUOUS OPERATION.
2. CURVE B - DESIGN AND TEST PEQUIREMENTS FOR INTERMITTENT OPERATION.
3. OPERATIONAL REQUIREMENTS FOR CLASS 1A AND 1B EQUIPMENT SAME AS FOR CLASS 1 EXCEPT THE ALTITUDE LIMIT IS 30,000 FEET AND 15,000 FEET, RESPECTIVELY.

FIGURE 504–1. *Operational requirements for class 1, 1A, and 1B aerospace equipment. Temperature vs. altitude.*

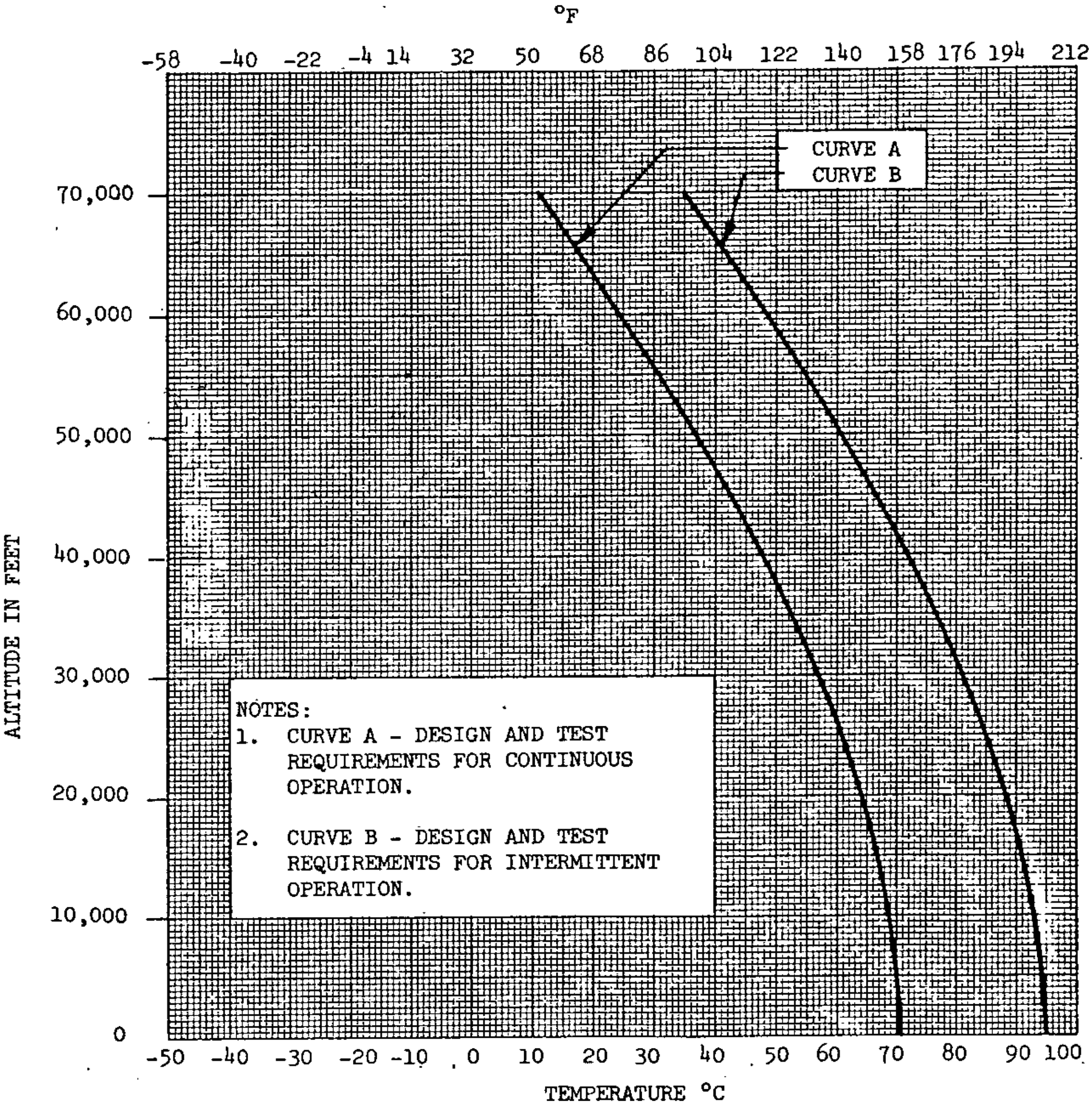
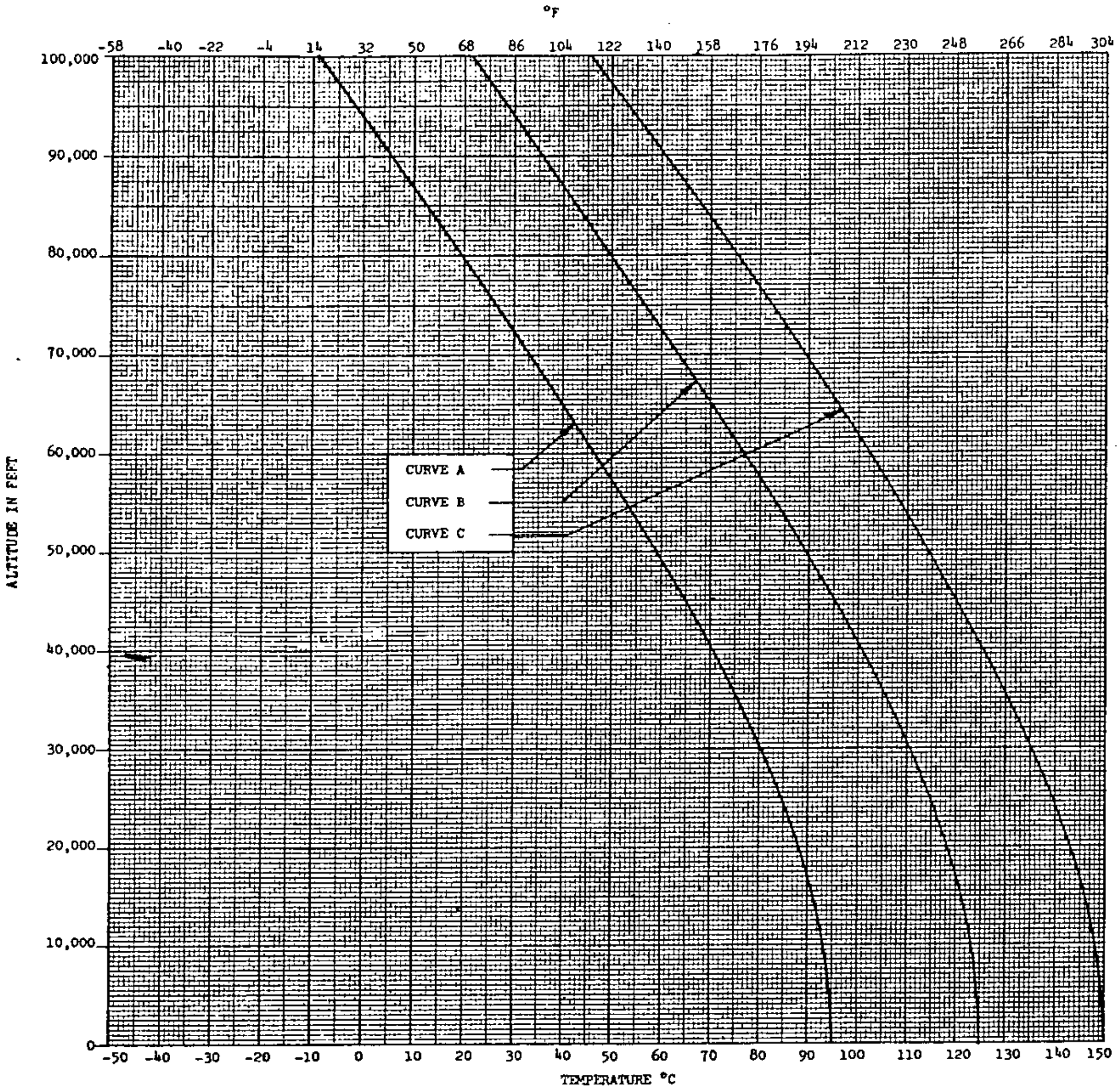


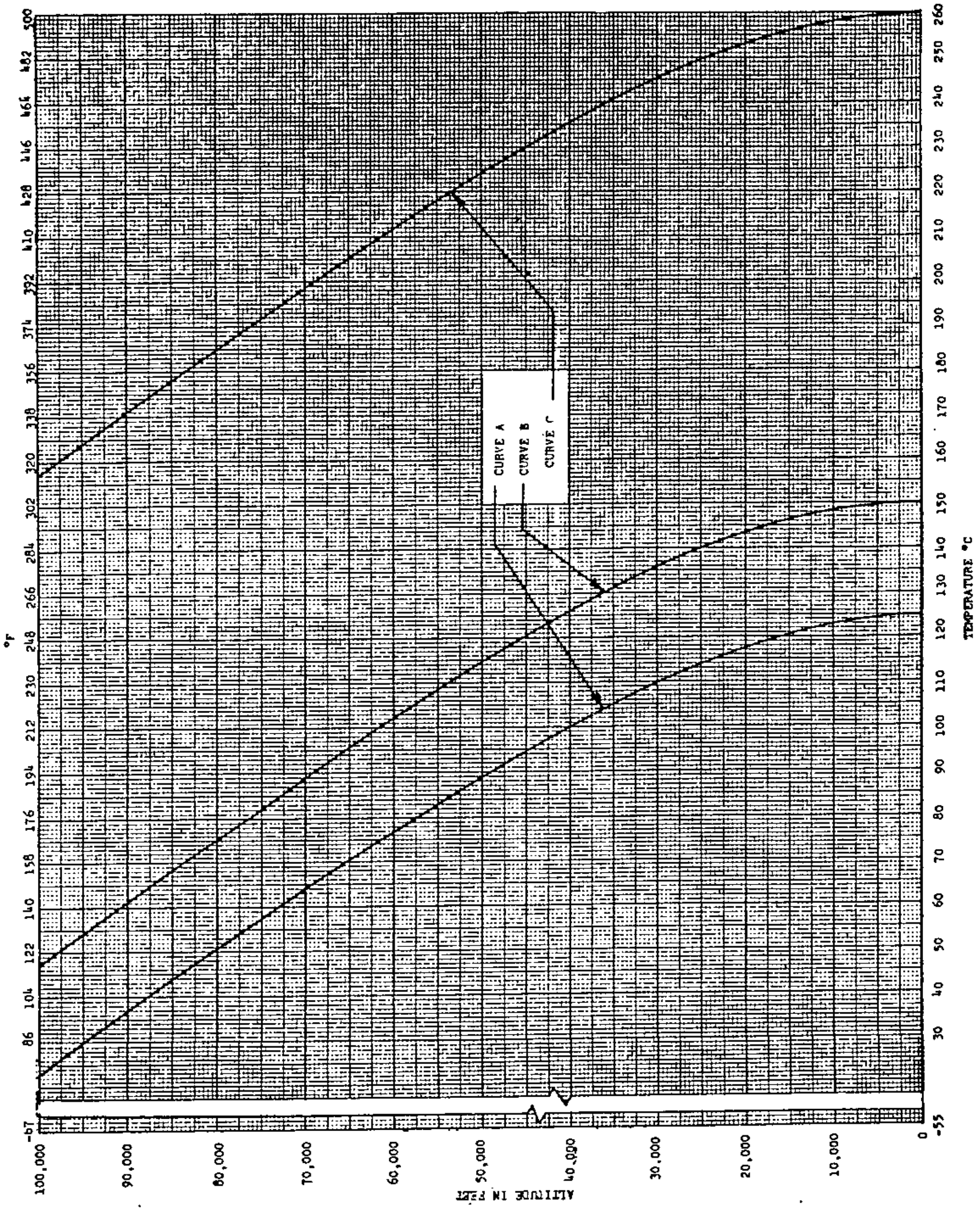
FIGURE 504-2. *Operational requirements for Class 2 aerospace equipment. Temperature vs. altitude.*



NOTES:

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

FIGURE 504-3. *Operational requirements for class 3 aerospace electronic equipment. Temperature vs. altitude.*



NOTES:

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

FIGURE 504-4. *Operational requirements for class 4 aerospace electronic equipment. Temperature vs. altitude.*

SUNSHINE

METHOD 505

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. Sunshine causes heating of equipment and photo-degradation, such as fading of fabric colors, checking of paints, and deterioration of natural rubber and plastics. 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.

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 build-up within the test item, may use one of the following acceptable radiation sources: (1) Mercury vapor lamps (internal reflector type only), (2) combination of incandescent spot lamps (including infrared filters) together with tubular type mercury vapor lamps with external reflector, (3) combination of incandescent spot lamps (including infrared filters) together with mercury vapor lamps with internal reflectors (with filters as required), (4) carbon arc lamps with suitable reflectors, or (5) mercury-xenon arc lamps with suitable reflectors (with filters as required).

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

3. **Procedures.**

3.1 **Procedure I. Accelerated steady state, solar radiation test, nonoperating.** The test item shall be placed in the test chamber in accordance with section 3, paragraph 3.2.2, and exposed to radiant energy at the rate of 100 to 120 watts per square foot or as specified in the equipment specification. The period of the test shall not be less than 48 hours, during which time the chamber temperature shall be maintained at 45° ±3° C (113° 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 compared with the data obtained in accordance with section 3, paragraph 3.2.1. The test item shall then be returned to room temperature and inspected in accordance with section 3, paragraph 3.2.4.

3.2 Procedure II. Simulated cycling temperature and solar radiation test, operating. The test item shall be placed in the test chamber in accordance with section 3, paragraph 3.3.2, and a performance pretest shall be conducted as specified in section 3, paragraph 3.2.1. The test item shall then be exposed to five continuous 24-hour cycles of controlled simulated solar radiation and dry bulb temperature as indicated in figure 505-1 or as specified in the equipment specification. Tolerances for control of radiation shall be ±10 watts/ft.^{2}. Tolerances for air temperature control shall be ±3° C. Standard ambient conditions shall be maintained within the test chamber at the beginning and end of each test cycle except that the chamber relative humidity (uncontrolled) shall be a maximum of 40 percent (equivalent to 50 grains moisture/lb. dry air) at standard ambient temperature. The air velocity in the chamber shall be maintained within 3 to 6 knots (300 to 600 ft./min.). At the conclusion of the last exposure, the test item shall be removed from the chamber and operated and the results compared with the data obtained in the pretest in accordance with section 3, paragraph 3.2.1. The test item shall then be returned to room ambient and inspected in accordance with section 3, paragraph 3.2.4.

Note: The test item may or may not be operated during the test at the option of the equipment specification.

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

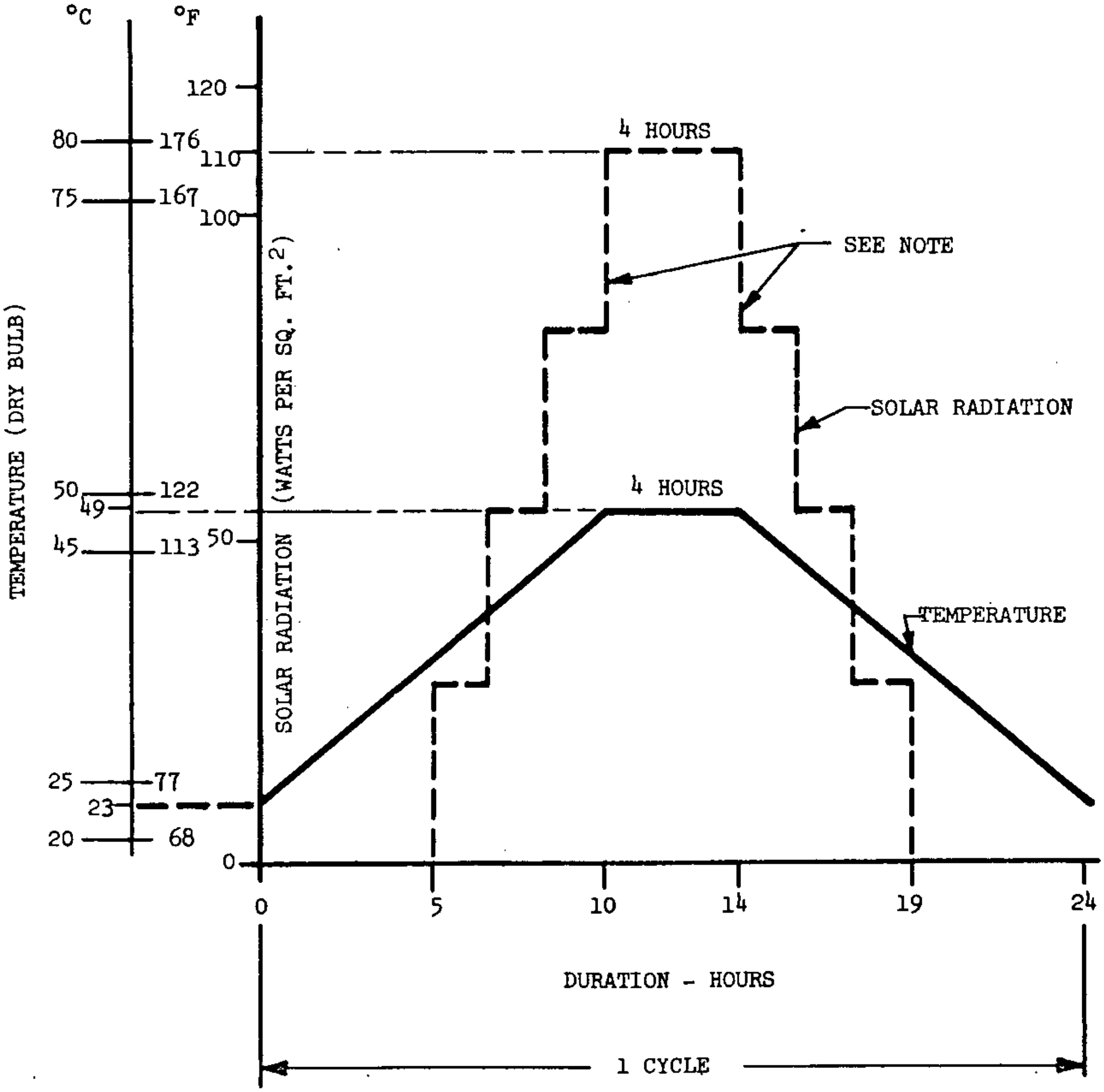
(a) Pretest data required (section 3, paragraph 3.2.1).

(b) Procedure number.

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

(d) Indicate purpose of test (degradation and deterioration, or heat build-up, or both).

(e) 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.



NOTE:

Use a minimum of three intermediate equal steps for increase or decrease of simulated solar radiation intensity.

FIGURE 505–1. *Simulated solar radiation cycle (Procedure II)*

RAIN

METHOD 506

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. Rain chamber with wind source.

2.1 Chamber. The rain chamber shall have the capability of producing falling rain and 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 1 and 4 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 over the test area within the limits specified below. The wind source shall be so positioned with respect to the equipment that it will cause the rain to beat directly and uniformly against one side of the equipment. 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.

((The 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 Geophysics Union, Part II, pps 452 to 459,-1943.))

3. Procedures.

3.1 Procedure I. The test item shall be placed in the chamber in its normal operating position in accordance with section 3, paragraph 3.2.2. The test item shall be exposed to a simulated rain at a rate of 5 ±1 inches per hour for 10 minutes. The rate of rainfall shall then be raised to 12 ±1 inches per hour and held at this rate for 5 minutes. The rate shall then be reduced to 5 ±1 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 turned off. Note: If specified in the equipment specification, the equipment 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, and the results compared with those obtained in accordance with section 3, paragraph 3.2.1. The protective cover or case shall, where possible, then be removed and the test item inspected for compliance with section 3, paragraph 3.2.4, with particular attention to evidence of water penetration, such as free water, swelling of material, or other deterioration.

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

(a) Pretest data required (section 3, paragraph 3.2.1).

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

METHOD 507

HUMIDITY

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

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 test chamber area 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.**

Step 1—Place the test item in the test chamber in accordance with section 3, paragraph 3.2.2. 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 71° C (160° F) and the relative humidity to 95 percent over a period of 2 hours.

Step 3—Maintain condition 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 28° ±10° C (82° F).

Step 5—Repeat steps 2, 3, and 4 for 10 cycles (not less than 240 hours). Figure 507-1 is an outline of the humidity cycle for this procedure.

Step 6—Remove the test item from chamber and allow the test item to return to 28° ±10° C (82° F).

Step 7—Operate the test item and compare results with the data obtained in accordance with section 3, paragraph 3.2.1. Prior to measurements excess moisture may be removed from the exterior surfaces of the test item by turning the test item upside down or by wiping external surfaces only.

Step 8—Inspect the test item in accordance with section 3, paragraph 3.2.4 within 1 hour.

3.2 Procedure II.

Step 1—Place the test item in the test chamber in accordance with section 3, paragraph 3.2.2.

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 section 3, paragraph 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 only be operated when specified test measurements are being performed.

Step 5—Raise the internal chamber temperature to 30° C (86° F).

Step 6—Subject the test item to 5 continuous 48-hour cycles in accordance with figure 507-2. Take measurements in accordance with section 3, paragraph 3.2.3 at the periods 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 section 3, paragraph 3.2.4 within an hour.

3.3 Procedure III. For sealed equipment (other than hermetic sealed).

Step 1 —Place the test item in the test chamber in accordance with section 3, paragraph 3.2.2.

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 section 3, paragraph 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 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).

Step 6 —Subject the test item to 5 continuous 48-hour cycles in accordance with figure 507-2. Take measurements in accordance with section 3, paragraph 3.2.3 at the periods 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. 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 the test item, and compare results with the data obtained in step 4.

Step 12—Inspect the test item in accordance with section 3, paragraph 3.2.4 within 1 hour.

3.4 Procedure IV.

Step 1—Place the test item in the test chamber in accordance with section 3, paragraph 3.2.2.

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° F) and 50 percent relative humidity for 24 hours.

Step 4—Take initial measurements as specified in the equipment specification in accordance with section 3, paragraph 3.2.1.

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 5 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 507-3. A 24-hour cycle consists of 16 hours at 60° ±5° C (140° F) and approximately 8 hours at 30° ±5° C (86° F) (includes transition times). A relative humidity shall be maintained at 95 percent, or greater, at both temperatures. Each transition time between 30° ±5° C (86° F) and 60° ±5° C (140° F) shall be not greater than 1-½ 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° F) immediately prior to decreasing to 30° ±5° C (86° F).

The test item shall only be energized a sufficient time to allow the required warm-up 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° 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).

Step 7—Condition the test item at 25° ±5° C (77° 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° 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.)

3.5 Procedure V.

Step 1—Place the test item in the test chamber in accordance with section 3, paragraph 3.2.2.

Step 2—Gradually raise the internal chamber temperature to 40.5° C (105° F) and 95 percent relative humidity in 2 hours.

Step 3—Take initial measurements in accordance with section 3, paragraph 3.2.1.

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 only be operated when specified test measurements are being performed.

Step 4—Maintain the internal chamber temperature at 40.5° C (105° F) and the relative humidity at 90 percent for 16 hours.

Step 5—Gradually decrease the internal chamber temperature to 21° C (70° F) and increase the relative humidity to 95 percent in 2 hours.

Step 6—Maintain the internal chamber temperature at 21° C (70° F) and the relative humidity at 95 percent for 4 hours.

Step 7—Repeat steps 4 through 6 for 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.

Step 8—After completion of step 7 cycling, operate the test item adjusting for optimum performance only as permitted in step 3 note, and compare results with data obtained in step 3.

Step 9—Inspect the test item in accordance with section 3, paragraph 3.2.4 *within an hour.*

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

(a) Procedure number

(b) Pretest data required (section 3, paragraph 3.2.1)

(c) Periods at which measurements are to be taken.

(d) 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).

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

(f) Number of cycles if other than 20 (procedure V, step 7)

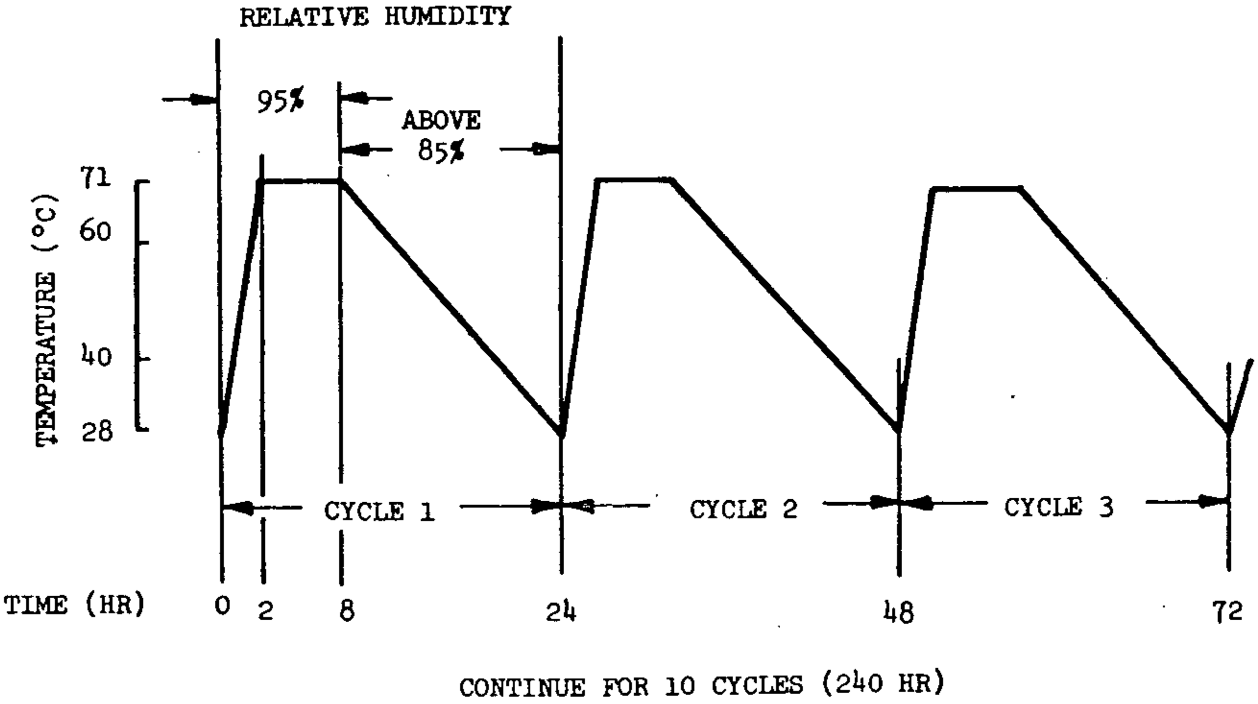
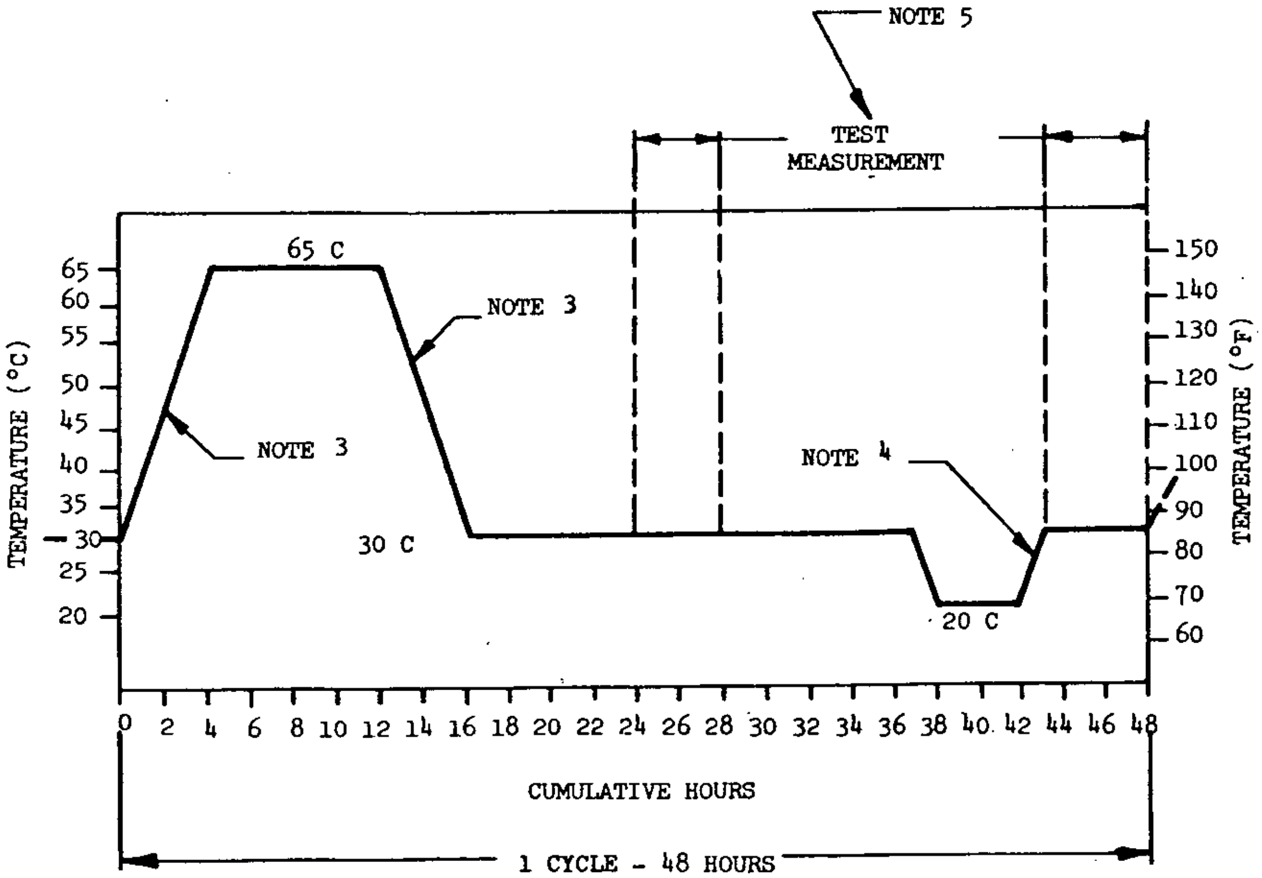


FIGURE 507-1. *Humidity cycle for Procedure I.*



NOTES:

1. Tolerance during temperature change shall not be greater than ± 3° C (5° F).
2. Relative humidity shall be maintained at 94 ± 4 percent at all times.
3. Rate of temperature change between 30° and 65° C shall not be less than 8° C per hour.
4. The measured increase in temperature from 20° C to 30° C shall not be less than 10° C.
5. Test measurements shall be taken only at the period specified in the applicable equipment or system specification.

FIGURE 507-2. *Humidity cycle — Procedures II and III.*

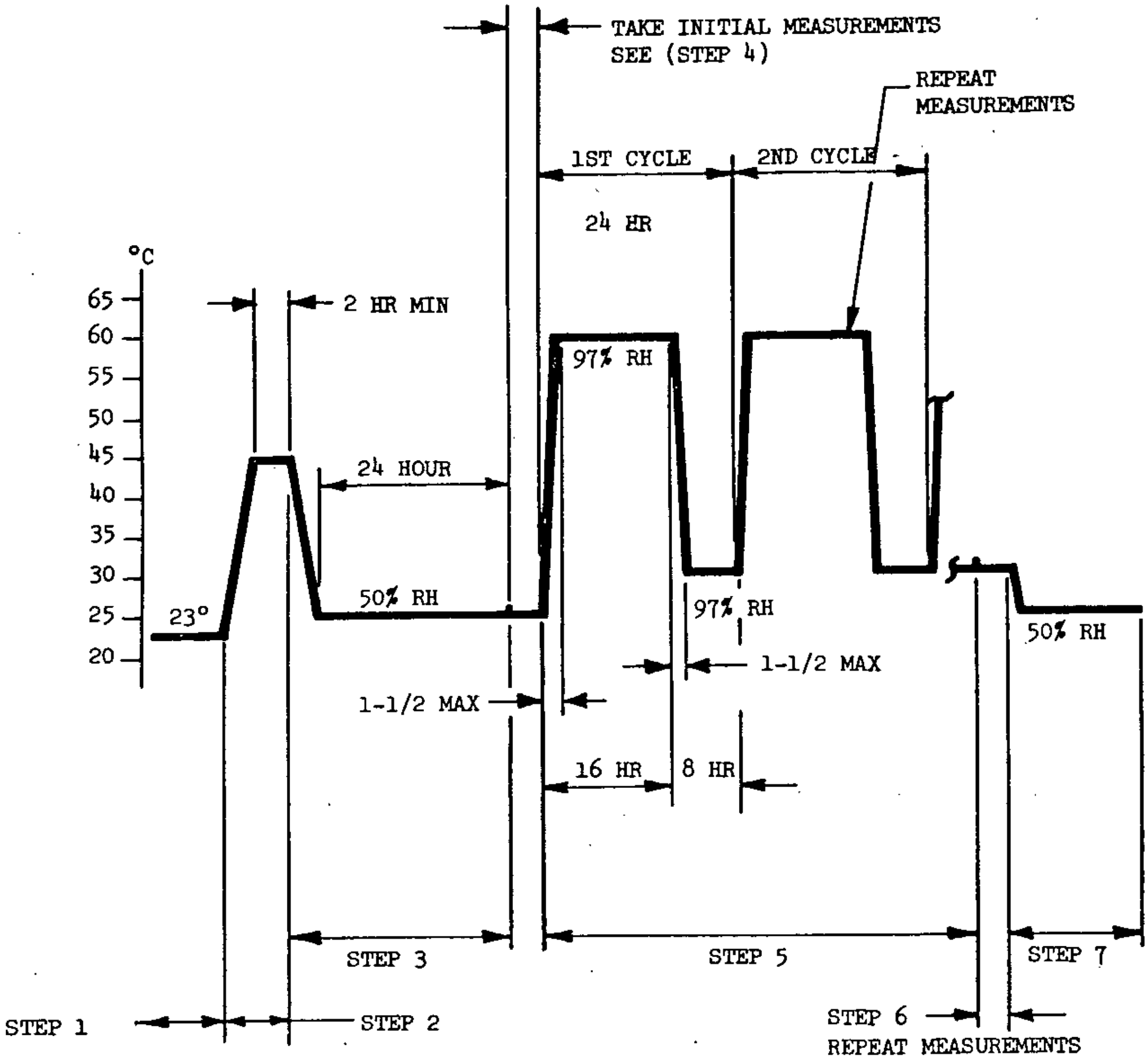


FIGURE 507-3. *Humidity cycle — Procedure IV.*

METHOD 508

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.

Typical materials which will support and are damaged by fungi are:

Cotton
Wood
Linen
Cellulose nitrate
Regenerated cellulose
Leather
Paper and cardboard
Cork
Hair and felts
Natural rubber
Plastic materials containing linen, cotton or wood flour as a filler
Vinyl films containing fungus susceptible plasticizers
Formulations of elastomers containing fungus susceptible catalysts, plasticizers or fillers

2. Apparatus. The aparatus 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 surface area of fixtures supporting the test item shall be kept to a minimum.

3. Procedures.

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 ($MgSO_4 \cdot 7H_2O$)	0.7 g
Ammonium nitrate (NH_4NO_3)	1.0 g
Sodium chloride ($NaCl$)	0.005 g
Ferrous sulfate ($FeSO_4 \cdot 7H_2O$)	0.002 g
Zinc sulfate ($ZnSO_4 \cdot 7H_2O$)	0.002 g
Manganous sulfate ($MnSO_4 \cdot 7H_2O$)	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 betwen 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 specifications 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]	*NLABS No.*[2]
Aspergillus niger	9642	386
Aspergillus flavus	9643	380
Aspergillus versicolor	11730	432
Penicillium funiculosum	9644	391
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 15.0 g of agar per liter.) The stock cultures may be kept for not more than 4 months at 6 ±4° C (43° F). Use subcultures incubated at 29° C (84° F) for 7 to 20 days in preparing the spore suspension.

Prepare a spore suspension of each of the five fungi by pouring into one subculture of each fungus a sterile 10-ml portion of water or of a sterile solution containing 0.05 g per liter of a nontoxic wetting agent such as sodium dioctyl sulfosuccinate. 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 10 to 15 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 shaken suspension through a thin layer of sterile glass wool in a glass funnel into a sterile flask in order to remove mycelial fragments.

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° F) for not more than 4 days.

3.1.3 *Viability of inoculum control.* With each daily group of tests place each of three pieces of sterilized filter paper, 1 in. 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] so that the entire surface is moistened with the spore suspension. Incubate these at 29° C (84° F) at a relative humidity not less than 85 percent and examine them after 14 days' incubation. There shall be copious growth on all three of the filter paper control specimens. Absence of such growth requires repetition of the test.

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[1] DeVilbiss No. 154 atomizer or equivalent has been found satisfactory for this purpose.

3.1.4 *Control items.* In addition to the viability of inoculum control, a number of 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 include three pieces each of preservative free vegetable tanned leather and protein-glue bonded cork.

3.1.5 *Inoculation of test and control items.*

(a) Mount the test and control items on

suitable fixtures or suspended from hangers.

(b) Precondition the chamber and its contents at 29° C (84° F) and 95 percent R.H. 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 the test and control items in the form of a fine mist from a previously sterilized atomizer or nebulizer until they are thoroughly wet with the spray. Incubation is to be started immediately following the inoculation.

3.1.6 *Incubation.*

(a) Maintain the test chamber at 29° C (84° F) and 95 percent R.H. (minimum) during the life of the test. Keep the test chamber closed during the incubation period except during inspection or for addition of other test items.

(b) After 14 days, inspect the control items. They should show an abundant growth of fungus. If the control items do not show an abundant 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 innoculation or as specified in the equipment specification.

3.7 **Criteria for passing test.** At the end of the incubation period, the test item shall be removed from the test chamber and inspected in accordance with section 3, paragraph 3.2.4. If so specified in the equipment specification, the test item shall be operated and the results compared with those obtained in accordance with section 3, paragraph 3.2.1.

4. **Summary.** The following details shall be designated in the equipment specification:

(a) Pretest data required (section 3, paragraph 3.2.1).

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

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

METHOD 509

SALT FOG

1. Purpose. The salt fog test is conducted to determine the resistance of equipment to the effects of a salt atmosphere. Damage to be expected from exposure to salt fog is primarily corrosion of metals, although in some instances salt deposits may result in clogging or binding of moving parts. In order to accelerate this test and thereby reduce testing time, 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 should be applied only after full recognition of its deficiencies and limitations which are as follows:

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 is highly doubtful 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 shows 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.)

1.1.2 *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 build-up 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 atomizers 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 heat 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 0.2 percent of total impurities. Unless otherwise specified, a 5 ±1 percent solution shall be prepared by dissolving 5 parts by weight of salt in 95 parts by weight of distilled water. The solution shall be adjusted to and maintained at a specific gravity between the limits shown on figure 509-1 by utilizing the measured temperature and density of the salt solution.

2.4.1 *Adjustment of pH.* The 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 dilute C.P. hydrochloric acid or C.P. sodium hydroxide shall be used to adjust the pH. 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 509-2 shall be provided in the supply line and immersed in the salt solution reservoir in a manner such as that illustrated in figure 509-3.

3.3 Procedures.

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 with 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 shieded 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 the 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.

3.1.4.3 *Time of measurements.* The measurement of both sodium chloride 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 section 3, paragraph 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, the test item shall be operated and the results compared with the data obtained in accordance with section 3, paragraph 3.2.1. The test item shall be inspected for corrosion in accordance with section 3, paragraph 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, the test item shall be again operated and the results compared with the data obtained in accordance with section 3, paragraph 3.2.1. The test item shall then be inspected in accordance with section 3, paragraph 3.2.4.

4. **Summary.** The following details shall be designated in the equipment specification:

(a) Pretest data required (section 3, paragraph 3.2.1).

(b) Applicable salt solution, if other than 5 percent is desired.

(c) Special mounting details, if applicable (see 3.1.5).

(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.

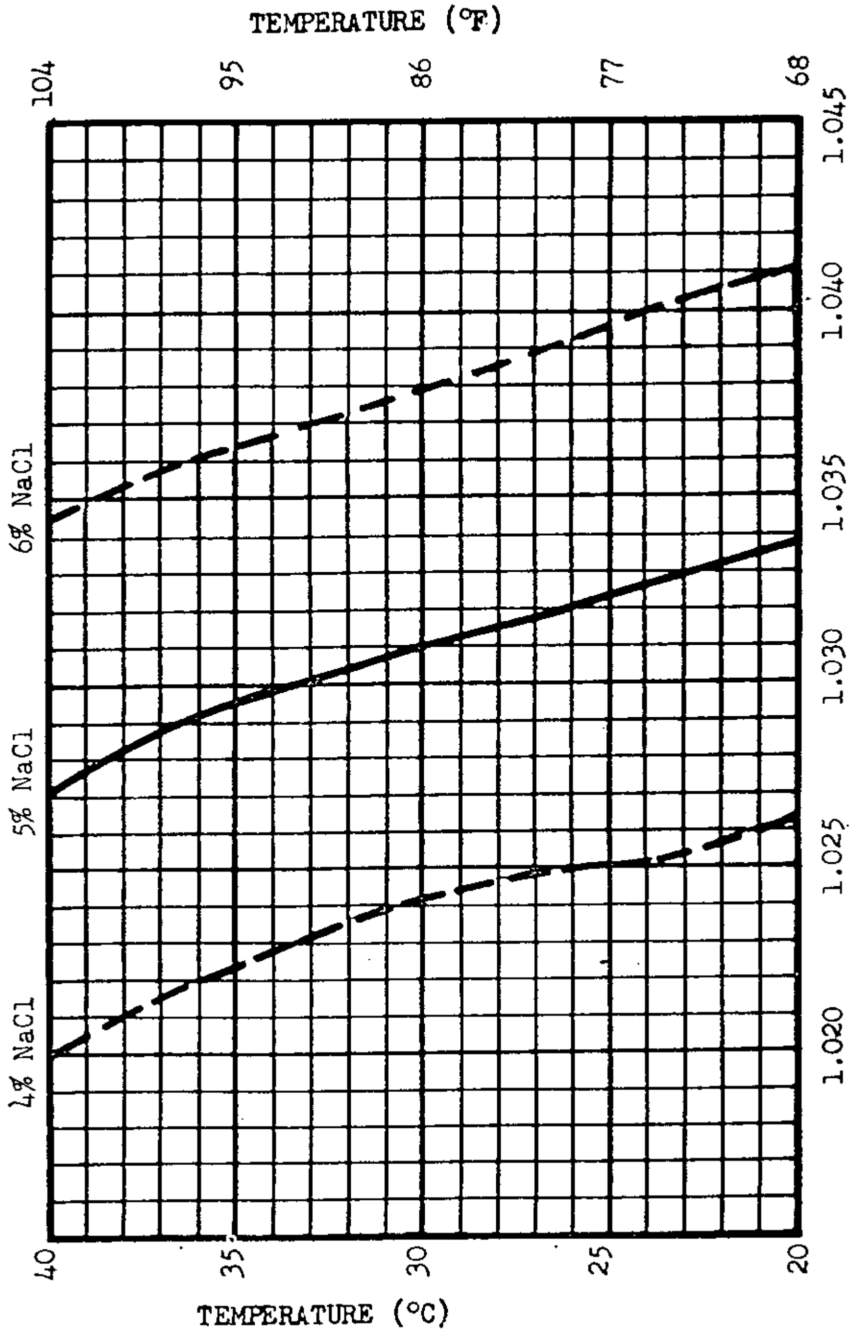


FIGURE 509-1. *Variations of specific gravity of salt (NaCl) solution with temperature*

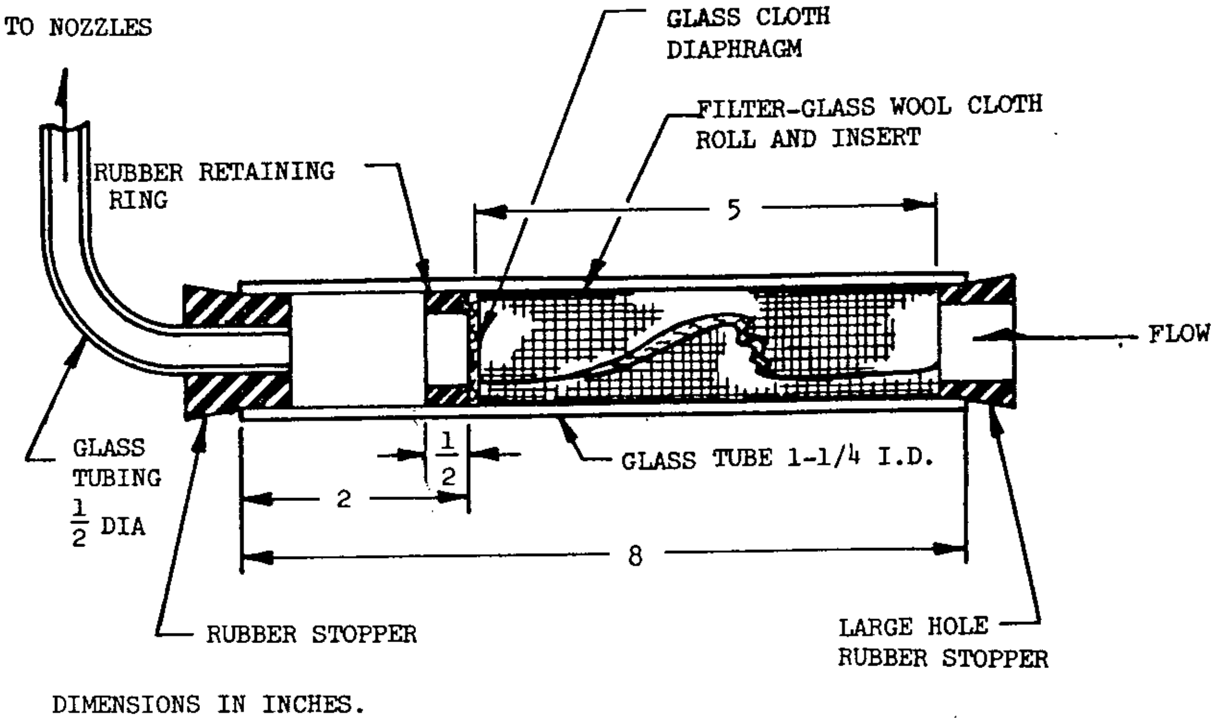


FIGURE 509–2. *Salt solution filter*

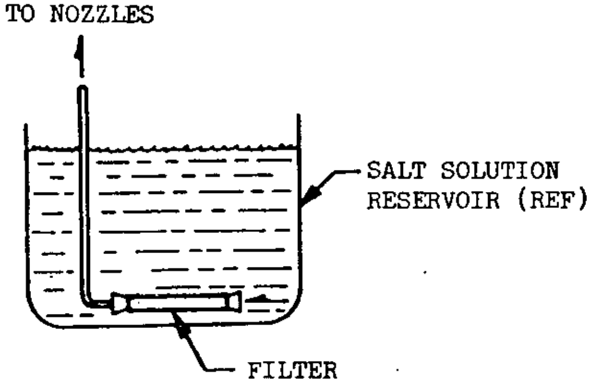


FIGURE 509–3. *Location of salt solution filler.*

METHOD 510

DUST

1. **Purpose.** The dust test is used during the development, test, and evaluation of equipment to ascertain their ability 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, and 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. 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.

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% 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.

"140-mesh silica flour" as produced by the Fenton Foundry Supply Company, Dayton, Ohio, and Ottawa Silica Company, Ottawa, Illinois, or equal, is satisfactory for use in the performance of these tests.

3. **Procedures.**

3.1 **Procedure I.** Place the test item in the chamber, positioned as near the center of the chamber as practicable, in accordance with section 3, paragraph 3.2.2. 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 than 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 gms. per cubic foot. With 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) and adjust humidity control to maintain a relative humidity of less than 10 percent. Hold these conditions overnight (approximately 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. 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. Under no circumstances, shall dust be removed by either air blast or vacuum cleaning.

Step 5—Operate the test item and compare the results with data obtained in accordance with section 3, paragraph 3.2.1.

Step 6—Inspect the test item as specified in section 3, paragraph 3.2.4. In the performance of this inspection, test items containing bearings, grease seals, lubricants, etc., shall be carefully examined for the presence of dust deposits.

Note: The test specimen may be operating during either or both of the 6-hour test periods (step 1 or 3) if so required by the equipment specification.

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

(a) Pretest data required (section 3, paragraph 3.2.1).

(b) Change in orientation during test, if required.

(c) Whether equipment is to operate during test and length of time required for operation and measurements.

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

METHOD 511

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 10,000 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.

2. **Apparatus (Procedures I, II).** An explosion-proof test chamber equal to that specified in MIL-C-9435 shall be used.

2.1 **Fuel.** Unless otherwise specified, the fuel used shall be gasoline, grade 100/130 conforming to MIL-G-5572.

2.1.1 *Calculation of fuel-air-vapor ratio.* 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 (80° F).

(b) Fuel temperature: 24° C (75° F).

(c) Specific gravity of fuel at 16° C (60° 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:

$$AAV = \frac{AV \text{ (desired)}}{1.04\left(\frac{P}{14.696}\right)-0.04} = \frac{13}{1.04\left(\frac{6.75}{14.696}\right)-0.04} = 29.68$$

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 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 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 511-2 to determine specific gravity at given temperature.

Step 4—Using figure 511-3, obtain correction factor K for the specific gravity determined during step 3. Apply factor to obtain weight of fuel corrected (W_{FC}).

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

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 installed in the test chamber in accordance with section 3, paragraph 3.2.2, 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.* The test shall be conducted as follows at simulated test altitudes of ground level to 5,000 feet, 10,000 feet (10,000 feet maximum for ground equipment), 20,000 feet, 30,000 feet, 40,000 feet, and 50,000 feet. (Pressures for altitudes are given in the U.S. Standard Atmosphere, 1962).

Step 1—The test chamber shall be sealed and the ambient temperature within shall be raised to 71° ± 3° C (160° F), or to the maximum temperature to which the test item is designed to operate (if lower than 71° C or 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 appriximately 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. (See 3.1.) 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 but not to exceed a pressure of 1 atmosphere. 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.

Step 4—If by the time the simulated altitude has been reduced to 5,000 feet below the test altitude, 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 item case or item enclosure.* When necessary, the test item case or item enclosures 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 as specified in section 3, paragraph 3.2.2.

3.2.2 *Performance of test.* The test shall be accomplished three times at altitudes between ground 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.** Procedure III shall be in accordance with the explosive proof test procedure of MIL-E-2036.

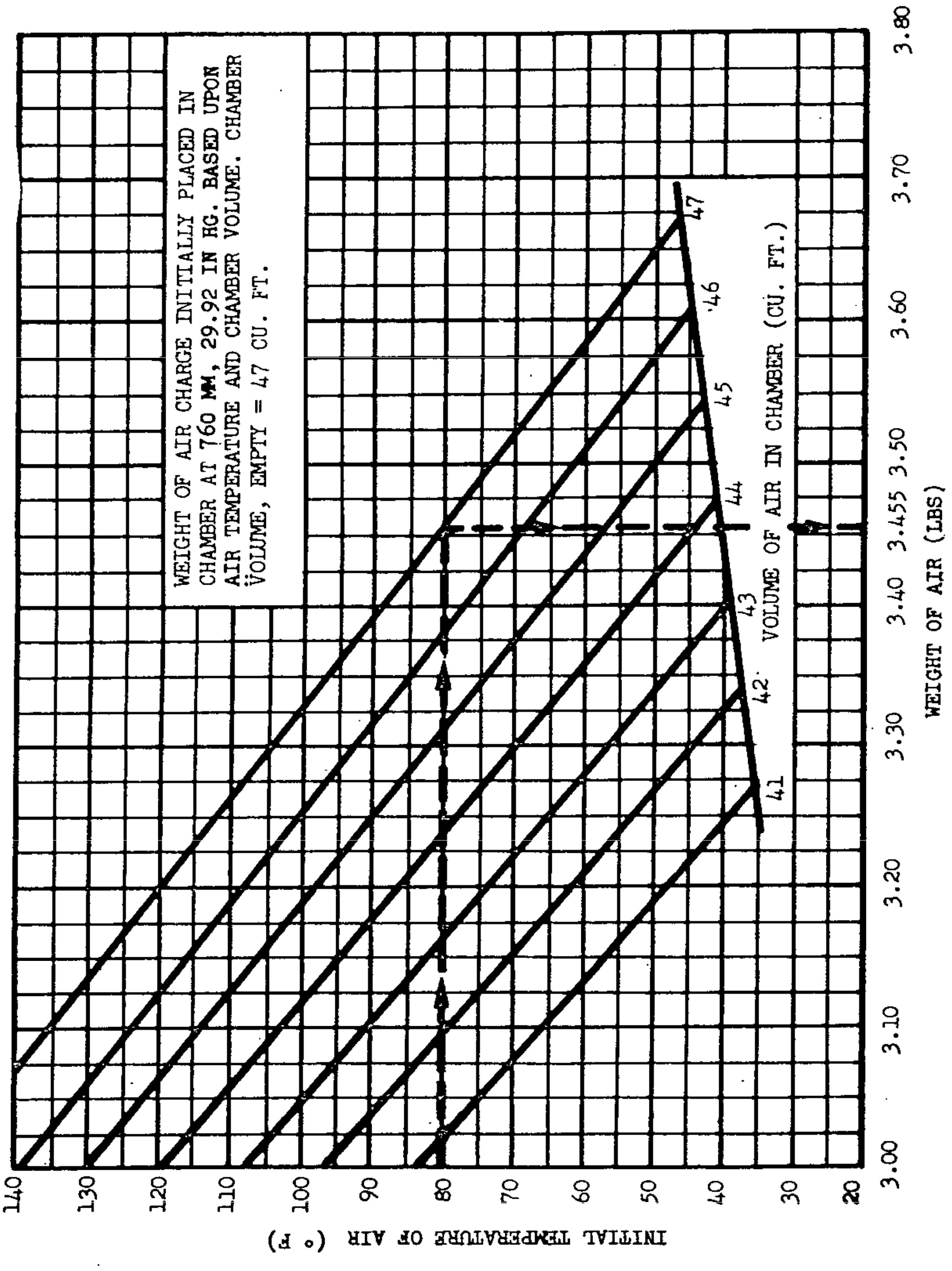
4. **Summary.** The following details shall be specified in the equipment specification:

(a) Pretest data required (section 3, paragraph 3.2.1).

(b) Procedure number.

(c) Mechanical and electrical load (Procedure I, 3.1.1(c)).

(d) Chamber temperature condition, if lower than 71° C (160° F). (Procedure 1, step 1).



WEIGHT OF AIR CHARGE INITIALLY PLACED IN CHAMBER AT 760 MM, 29.92 IN HG. BASED UPON AIR TEMPERATURE AND CHAMBER VOLUME. CHAMBER VOLUME, EMPTY = 47 CU. FT.

FIGURE 511-1. *Weight of air charge vs. temperature.*

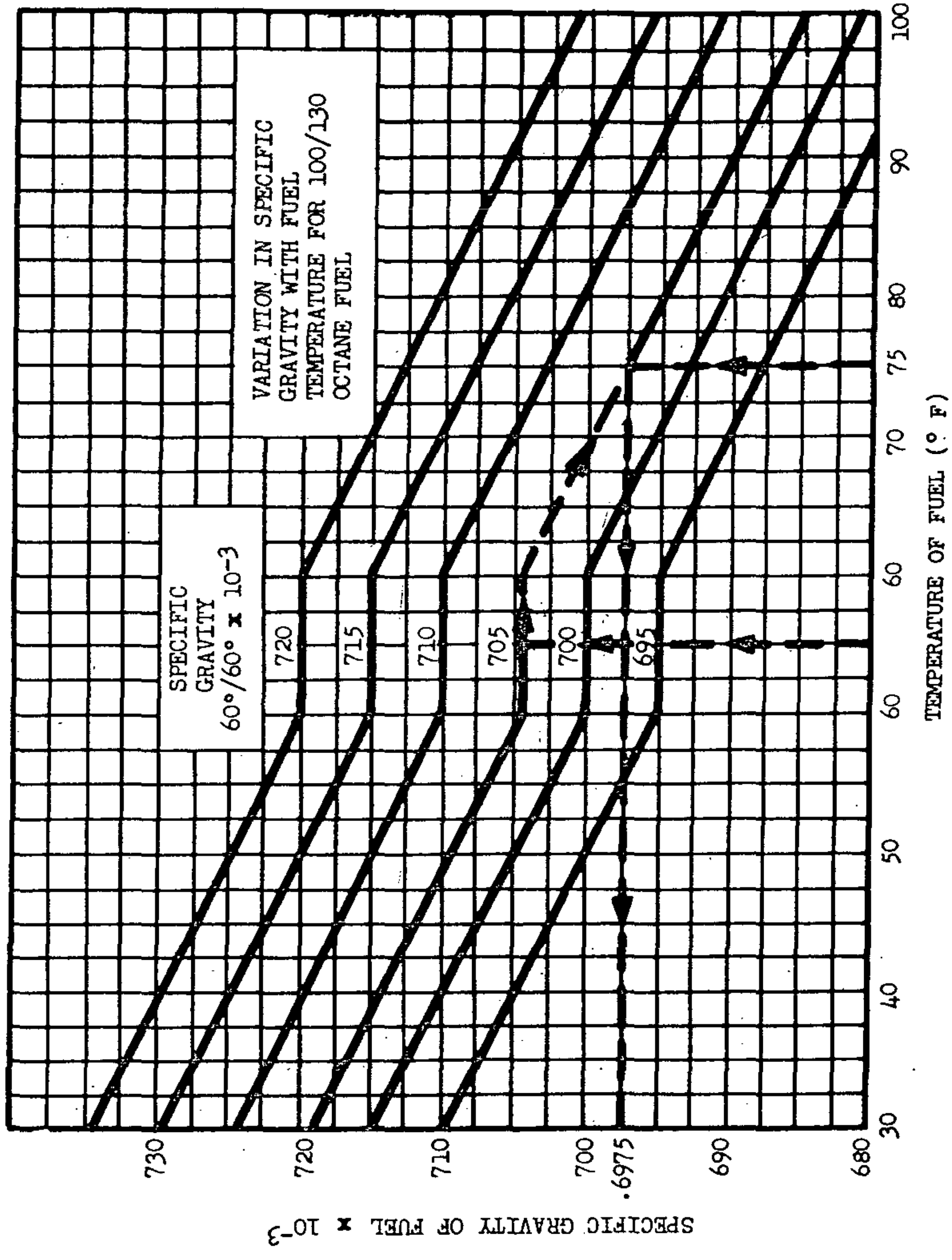


FIGURE 511-2. *Specific gravity vs. temperature.*

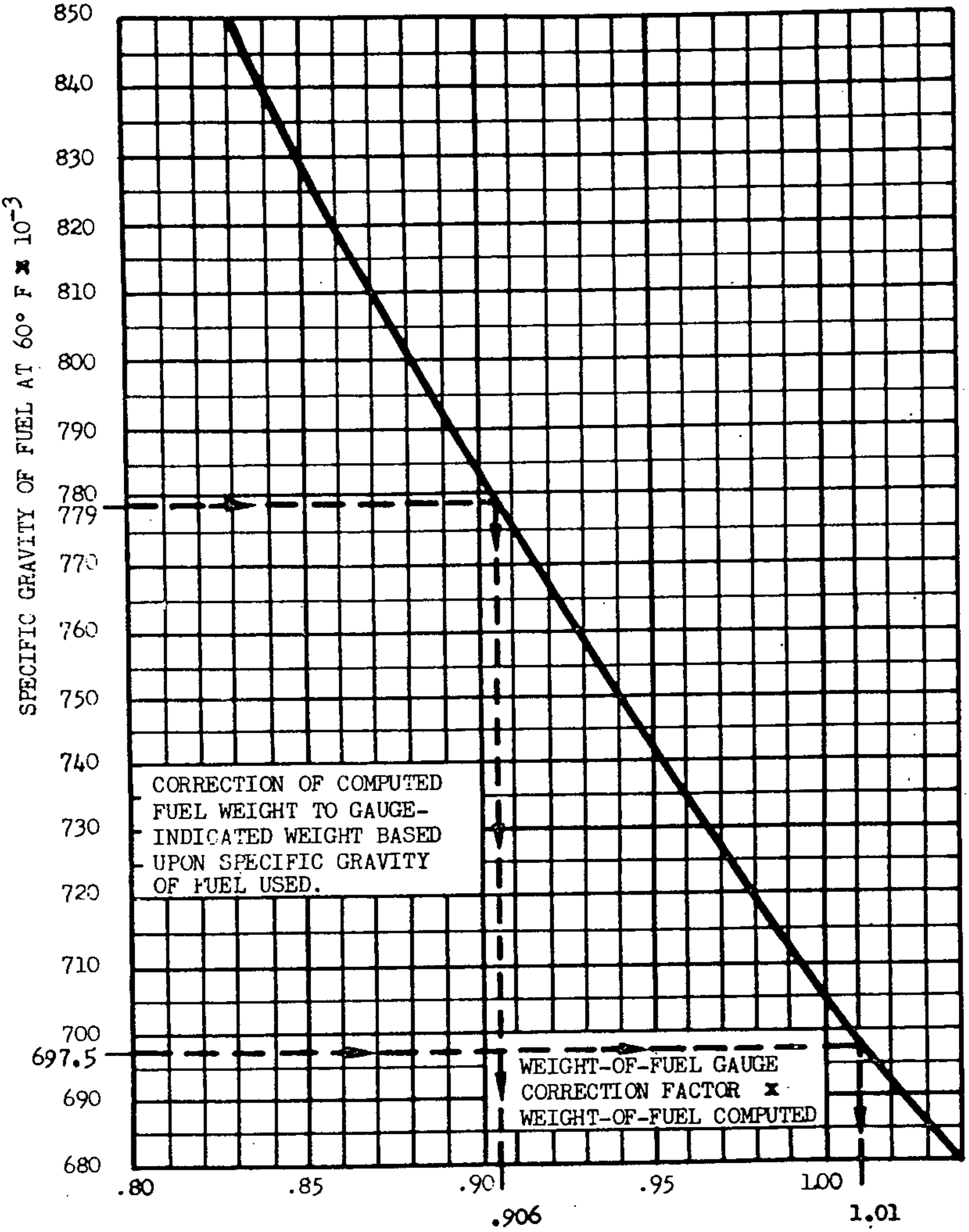


FIGURE 511-3. *Fuel weight to gage indicated weight correction factor.*

METHOD 512

LEAKAGE (IMMERSION)

1. Purpose. The purpose of this test is to determine the ability of the equipment to be immersed in fluid, without leakage of the fluid into the enclosure. Procedure I is a gross leakage test. Procedure II is conducted to determine the integrity of hermetic seals.

2. Apparatus:

Procedure I. Water container and accessories

Procedure II. Heated oil container and accessories

3. Procedures.

3.1 Procedure I.

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° F) and the temperature of the test item shall be 27° ±3° C (49° F) above the temperature of the water used for the test. 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 $^{+5}_{-0}$ 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.

3.1.4 *Failure criteria.* If there is any evidence of water leakage, the test item failed the test.

3.2 Procedure II.

3.2.1 *Test conditions.* The temperature of the oil shall be 128 ±3° C (262° F) and the temperature of the test item shall be 23 ±3° C (73° F). The oil container and oil heating device shall be of sufficient capacity to maintain the oil at 128 ±3° C. (262° F) when the test item is immersed. The oil used shall be clear mineral oil having a universal Saybolt viscosity of 175 to 190 seconds when tested at 38° C (100° F).

3.2.2 *Performance of test.* The test item shall be completely immersed in the oil with the critical side or side of special interest in a horizontal plane facing up. If the test item has no critical side, it shall be immersed with its major axis in a horizontal position. The test item shall be lowered into the oil until the uppermost portion of the enclosure or seal(s) are submerged to 2 ±1 inches below the surface of the oil and left in that position for 60 ±5 seconds.

Note: Caution should be used in conducting this test as the oil is above the boiling point of water (and other common fluids). Do not perform this test on items that may have water (or other lower boiling point fluids) entrapped in cracks, crevasses or around seals as the boiling fluid can spatter the hot oil, causing serious burns. Also, use care in conducting this test on items that might outgas or be damaged by the hot oil such as fuzes, cartridges, or timers with temperature-sensitive explosives or lubricants.

Upon completion of the specified time period, the test item shall be removed from the oil, cleaned with a suitable degreaser, and allowed to dry thoroughly before further tests are performed.

3.2.3 *Failure criteria.* Any observed leakage during the immersion, as evidenced by a continuous stream of bubbles emanating from the test item, will be considered criteria for failure.

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

(a) Pretest data, if required (section 3, paragraph 3.2.1).

(b) Procedure number.

(c) Operational requirements, if desired, including length of time for operation and measurements.

(d) Condition (transit or operational) of equipment (see 3.1.3).

METHOD 513

ACCELERATION

1. **Purpose.** The acceleration test is to determine structural soundness and satisfactory performance of equipment in an environment of steady state acceleration other than gravity. 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 equipments, 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 by the equipment specification.

3.1 **Mounting of test item.** Normally the location of the test item on the centrifuge, with reference to the G level established for the test, shall be determined from a measurement taken from the 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 the 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.

3.2 **Procedure I structural test.** The test item shall be installed on the acceleration apparatus in accordance with section 3, paragraph 3.2.2, by its normal mounting means. The test item shall be nonoperating during the test. The G level to be applied to the test item is contingent on two factors: the forward acceleration level (A) of the vehicle, and the orientation of the test item within the vehicle.

3.2.1 *G level of vehicle known, orientation of test item known.* When the forward acceleration level (A) of the vehicle is known and the orientation of the test item in the vehicle is known, the test level shall be determined as follows:

DIRECTION OF MOTION (See figure 513-1.)

Fore 1.5 x A = G test level
Aft 0.5 x A = G test level
Up 0.75 x A = G test level
Down 2.25 x A = G test level
Lateral 1.0 x A = G test level

Where: A = The highest possible forward acceleration assumed, calculated, or measured.

3.2.2 *G level of vehicle known, orientation of test item unknown.* When the G level of the vehicle is known, and the orientation of the test item is unknown, the test level should be determined as follows:

2.25 X A = G test level

3.2.3 *G level of vehicle unknown, orientation of test item known.* When the forward acceleration level (A) of the vehicle is not known, and orientation of the test item in the vehicle is known, the test level shall be within the ranges shown in table 513-I for the applicable vehicle category.

TABLE 513-I. *G levels for structural test*

Vehicle category		Direction				
		Fore	Aft	Up	Down	Lateral
Aircraft and helicopters		9.0	3.0	4.5	13.5	6.0
Manned aerospace vehicles		9.0 to 18.0	3.0 to 6.0	4.5 to 9.0	13.5 to 27.0	6.0 to 12.0
Air launched missiles		13.5 to 45.0	4.5 to 15.0	7.0 to 23.0	20.0 to 23.0	4.5 to 30.0
Ground launched missiles	Liquid boosters	9.0 to 18.0	3.0 to 6.0	—	—	6.0 to 12.0
	Solid boosters	9.0 to 45.0	3.0 to 15.0	—	—	6.0 to 30.0

3.2.4 *G level of vehicle unknown, orientation of test item unknown.* When both the forward acceleration level (A) of the vehicle and the orientation of the test item in the vehicle are unknown, the test level shall be within the highest range shown in table 513-I for the applicable vehicle category.

3.2.5 *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 one minute following centrifuge stabilization. A test time of 1 minute is usually sufficient to determine structural soundness, however, the test time may be increased. At the conclusion of the test the test item shall be operated and the results compared with the data obtained in accordance with section 3, paragraph 3.2.1. The test item shall then be inspected as specified in section 3, paragraph 3.2.4.

3.3 **Procedure II operational test.** The test item shall be installed on the acceleration apparatus in accordance with section 3, paragraph 3.2.2, by its normal mounting means. The test item shall be operating during the test. The G level to be applied to the test item is contingent on two factors; the forward acceleration level (A) of the vehicle, and the orientation of the test item within the vehicle.

3.3.1 *G level of vehicle known, orientation of test item known.* When the forward acceleration level (A) of the vehicle is known and the orientation of the test item in the vehicle is known, the test level shall be determined as follows:

DIRECTION OF MOTION

Fore 1.1 x A = G test level
Aft 0.33 x A = G test level
Up 0.5 x A = G test level
Down 1.5 x A = G test level
Lateral 0.66 x A = G test level

Where A = The highest possible forward acceleration assumed, calculated or measured.

3.3.2 *G level of vehicle known, orientation of test item unknown.* When the G level of the vehicle is known and the orientation of the test item in the vehicle is unknown, the test level shall be determined as follows:

$$1.5 \times A = G \text{ test level}$$

3.3.3 *G level of vehicle unknown, orientation of test item known.* When the forward acceleration level (A) of the vehicle is not known, and the orientation of the test item in the vehicle is known, the test level shall be within the ranges shown on table 513-II for the applicable vehicle category.

TABLE 513-II. *G levels for operational test*

Vehicle category		Direction				
		Fore	Aft	Up	Down	Lateral
Aircraft and helicopters		6.0	2.0	3.0	9.0	4.0
Manned aerospace vehicles		6.0 to 12.0	2.0 to 4.0	3.0 to 6.0	9.0 to 18.0	4.0 to 8.0
Air launched missiles		9.0 to 30.0	3.0 to 10.0	4.5 to 15.0	13.5 to 45.0	6.0 to 20.0
Ground launched missiles	Liquid boosters	6.0 to 12.0	2.0 to 4.0	—	—	4.0 to 8.0
	Solid boosters	6.0 to 30.0	2.0 to 10.0	—	—	4.0 to 20.0

3.3.4 *G level of vehicle unknown, orientation of test item unknown.* When both the forward acceleration level (A) of the vehicle and the orientation of the test item in the vehicle are unknown, the test level shall be within the ranges in the "fore" direction shown in table 513-II for the applicable vehicle category.

3.3.5 *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 the results compared with the data obtained in accordance with section 3, paragraph 3.2.1. The test item shall then be inspected as specified in section 3, paragraph 3.2.4.

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

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

(b) Protest data required (section 3, paragraph 3.2.1).

(c) Test level and test time (see 3.2 and 3.3).

(d) Length of time required for operation and measurements.

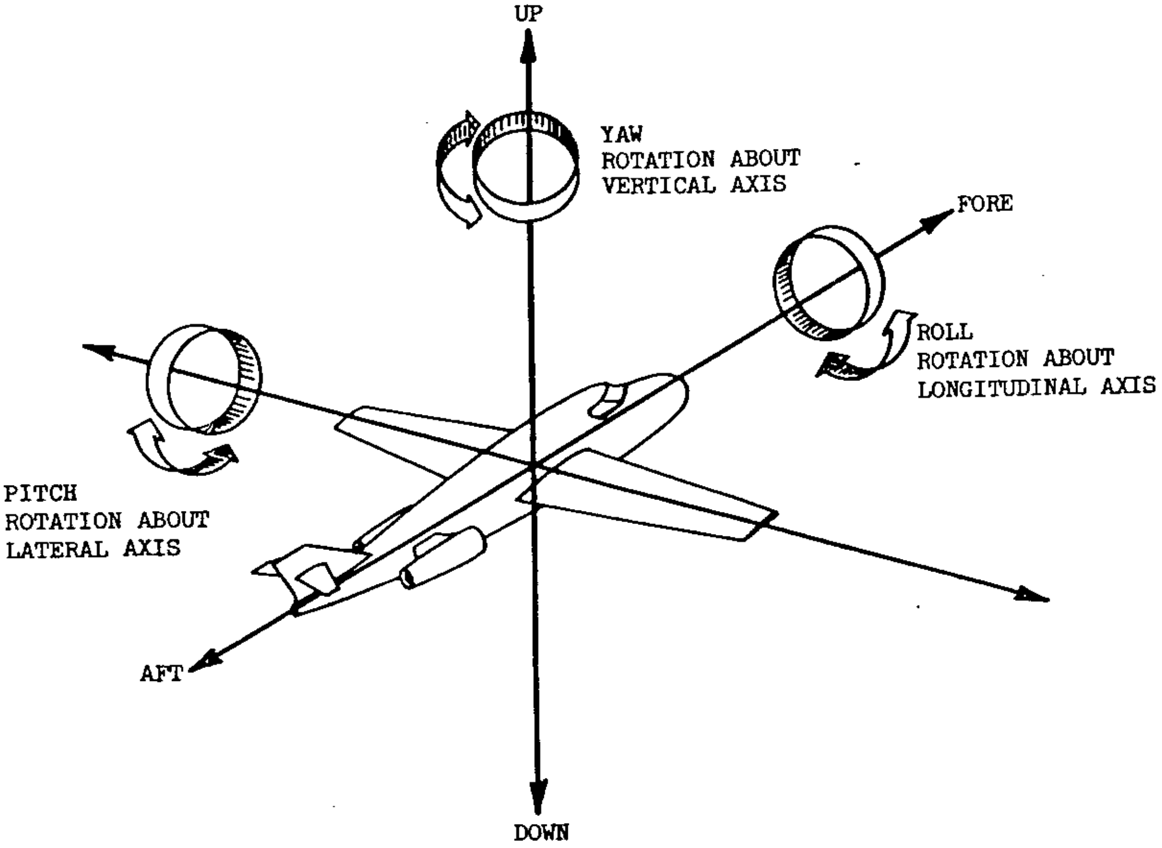


FIGURE 513-1. *Motion orientation*

METHOD 514

VIBRATON

1. **Purpose.** The vibration test is conducted to determine if the equipment is constructed to withstand expected dynamic vibrational stresses and the performance degradations or malfunctions will not be produced by the simulated service vibration environment. The tests specified herein are established for equipment to be used in a variety of military applications. The vibration test selection chart, table 514–1, provides a convenient means of selecting test procedures for these various military applications. The table is divided into two major sections. The section, captioned "Equipment category", refers to the equipment to be tested. The second section, captioned "Procedure Number", specifies the tests to be imposed on the equipment.

2. **Apparatus.** Vibration equipment.

3. **General.**

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

CATEGORY

(a) Aircraft (including helicopters)

(b) Aircraft (excluding helicopters)

(c) Helicopters

(d) Air launched vehicle

(e) Ground launched vehicle

(f) *Ground vehicles*

(g) Shipment by common carrier, land, or air

(h) Ground equipment (excluding category (f))

(i) Shipboard equipment or when a ship is the common carrier

3.2 **Selection of test procedures.** One of the following test procedures shall be selected from table 514–I and specified in the equipment specification:

3.2.1 Aircraft/helicopter, air launched vehicle, or ground launched vehicle equipment mounted without vibration isolators; procedure I (parts 1, 2, and 3), II, or V, respectively.

3.2.2 Aircraft/helicopter, air launched vehicle or ground launched vehicle equipment mounted with vibration isolators; procedure I, III or VI, respectively.

3.2.3 Aircraft/helicopter, air launched vehicle or ground launched vehicle equipment normally using vibration isolators, but tested without vibration isolators; procedure I (part 4), IV or VII, respectively.

3.2.4 Equipment mounted *in ground vehicles*; procedure I (parts 1, 2, and 3), VIII or IX. Procedure I is a general procedure to be used when the vehicle (in which the equipment is to be mounted) or its mileage schedule is not known. Procedure VIII is to be used for more realistic testing when the vehicle is known. Procedure IX is used in addition to procedures I and VIII when the equipment might not always be installed but may be carried in a vehicle.

3.2.5 Equipment shipped by common carrier (land or air), either tied down or loose cargo; procedure X or XI, respectively.

3.2.6 *Ground equipment, excluding ground* vehicles; procedures X or XI. Procedure X is generally used for tied down ground equipment and procedure XI is used in addition to procedure X when ground equipment might be *subject to rough handling*.

3.2.7 Shipboard and amphibious equipment, or when a ship is the common carrier, procedure XII.

3.3 **Number of tests.** All tests listed beside the applicable procedure number in table 514–I shall be performed. For example, referring to table 514–I for testing equipment in category (d) when procedure III is selected, there are four parts with four different test levels indicated by the test curves. The tests indicated by (x) in all four parts shall be performed to evaluate equipment installed in an air launched vehicle for both the captive and flight phase.

3.4 **Selection of test curves.** Test curves by equipment category are given in figures 514–1 through 514–6. In some instances, several curves are shown for one equipment category. A curve shall be selected and specified in the equipment specification after 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. Suggested vibration test curves for missiles according to missile thrust to weight ratios and equipment locations are provided in table 514–III.

3.5 **Test identification.** The equipment specification shall identify which tests are imposed on the equipment by specifying a selected procedure and curve. Table 514–I is *arranged* to accommodate this identification. For example, when the specification calls for the following:

Example No. 1

Procedure I
Curve D (parts 1, 2, and 3)
Curve A (part 4)

Referring to table 514–I, the above identification specifies a resonance search (part 1), a resonance dwell (part 2), and a sinusoidal vibration cycling (part 3) and parts 1, 2, and 3 repeated with vibration isolators removed for part 4. Test to the level of curve D from figure 514–1 within the time schedule I of table 514–II for parts 2 and 3. Part 4 is performed to the test level of curve A from figure 514–1 within the time schedule II of table 514–II.

Example No. 2

Procedure II
Curves C, P, AF

Referring to table 514–I and since all tests shown for any one procedure in a category must be performed, the above identification specifies for part 1, a resonance search, a resonance dwell, and a sinusoidal vibration cycling. Test to the level of curve C from figure 514–1 within the time schedule V of table 514–II. These tests are followed by part 2, a sinusoidal cycling test to the level of curve P from figure 514–3, within the time schedule II of table 514–II, followed by part 3, a random test to the level of curve AF from figure 514–4 within the time schedule II of table 514–II.

4. **Test procedures.** Test procedures consist of all the tests to the right of the test procedure number indicated by an "x" in the applicable colume of table 514–I with the duration of the test designated by a Roman

numeral referring to table 514-II. The vibration environment specified by the curve shall be applied to each of the three mutually perpendicular axes of the test item. The entire sequence of tests may be accomplished for any one axis before changing to the next axis. Unless otherwise specified, for one axis before changing to the next axis. Unless otherwise specified, for resonance and sinusoidal vibration cycling tests of items weighing more than 50 pounds, the vibratory accelerations shall be reduced by ±1 g for each 10 pound increment of weight over 50 pounds. However, the vibratory acceleration shall in no case be less than 50 percent of the specified curve level. When a test item performance test is required during a vibration test and the duration of the performance test is greater than the duration of the vibration test, the performance test shall be abbreviated accordingly.

4.1 Procedure I.

4.1.1. *Part 1, resonance search.* The test item shall be installed in accordance with section 3, paragraph 3.2.2, and attached by its normal mounting means directly to the vibration exciter table, or by means of a rigid fixture capable of transmitting the vibration conditions specified herein. Whenever possible, the test load shall be distributed uniformly on the vibration exciter table in order to minimize effects of unbalanced loads.

Resonant modes of the equipment shall be determined by varying the frequency of applied vibration slowly through the specified range at reduced input amplitudes. Individual resonance searches shall be conducted with vibration applied along each of the three mutually perpendicular axis of the equipment.

4.1.2 *Part 2, resonance dwell.* Unless otherwise specified, the test item shall be operating during the test so that functional effects caused by internal resonances may be observed. The test item shall be vibrated along each axis at the most severe resonant frequencies according to the time schedule I of table 514-II and according to the applicable double amplitudes or accelerations of the specified curve from figure 514-1, 514-2, or 514-5. If more than four significant resonances have been found for any one axis, the four most severe resonances shall be chosen for the test. If a change in the resonant frequency occurs during the test, immediately the frequency shall be adjusted to maintain the resonance condition. At the conclusion of the test, the test item shall be operated and the results compared with the data obtained in accordance with section 3, paragraph 3.2.1. The test item shall then be inspected in accordance with section 3, paragraph 3.2.4.

4.1.3 *Part 3, vibration cycling.* Unless otherwise specified, the test item shall be operating throughout the vibration cycling test. The frequency of applied vibration shall be cycled at a logarithmic rate between the frequency limits and at the vibratory acceleration levels of the specified curve from figure 514-1, 514-2, or 514-5. Logarithmic cycling rates shall be in accordance with figure 514-8 and the time schedule I of table 514-II. A linear cycling rate may be substituted for logarithmic cycling when performed in accordance with 5.2. During, and at the conclusion of the test, the operation of the test item shall be compared with the data obtained in accordance with section 3, paragraph 3.2.1, and shall meet the requirements of the equipment specification. The test item shall then be inspected in accordance with section 3, paragraph 3.2.4.

4.1.4 *Part 4, vibration isolated equipment with isolators removed.* The test item shall be mounted directly to the vibration table with external vibration isolators removed but including any other required holding devices. The test item shall then be tested in accordance with parts 1, 2, and 3. except that the test level shall be the lower g level specified and the time schedule II of table 514-II.

4.2 Procedure II.

4.2.1 *Part 1.* Proceed the same as in procedure I, parts 1, 2, and 3, except that the test level shall be in accordance with curve C, D, H or J from figure 514-1 and time schedule V of table 514-II.

4.2.2 *Part 2.* Proceed the same as in procedure I, part 3, except that the test level shall be in accordance with curve P, Q, R, and S from figure 514-3 and time schedule II of table 514-II.

4.2.3 *Part 3, random.* Random vibration (controlled and analyzed according to 5.3) shall be applied according to one specified curve of AF through AK from figure 514-4 and time schedule II of table 514-II. Unless otherwise specified, during, and at the conclusion of the test, the operation of the test item shall be compared with the data obtained in accordance with section 3, paragraph 3.2.1, and shall meet the requirements of the equipment specification. The test item shall then be inspected in accordance with section 3, paragraph 3.2.4.

4.3 Procedure III.

4.3.1 *Part 1.* Test items of equipment normally provided with vibration isolators shall be first tested with the isolators in place the same as in procedure I, parts 1, 2, and 3, except that the test level shall be in accordance with curve C, D, H, or J from figure 514-1 and time schedule V of table 514-II.

4.3.2 *Part 2.* The isolators shall then be removed, the test item rigidly mounted and the resonance and sinusoidal vibration cycling tests repeated as in procedure I, parts 1, 2, and 3, except that the test level shall be in accordance with curve A, B, or K from figure 514-1 and time schedule II of table 514-II.

4.3.3 *Part 3.* The vibration isolators shall be replaced and the test continued using procedure I, part 3, except that the test level shall be in accordance with curve P, Q, R, or S from figure 514-3 and time schedule II of table 514-II.

4.3.4 *Part 4, random.* Again with isolators in place, random vibration, (controlled and analyzed according to 5.3) shall be applied to the test item according to one specified curve of AF through AK from figure 514-4 and time schedule II or table 514-II. Unless otherwise specified, during, and at the conclusion of the test, the operation of the test item shall be compared with the data obtained in accordance with section 3, paragraph 3.2.1, and shall meet the requirements of the equipment specification. The test item shall then be inspected in accordance with section 3, paragraph 3.2.4.

4.4 Procedure IV.

4.4.1 *Part 1.* Proceed the same as in procedures I, parts 1, 2, and 3, except that the test level shall be in accordance with curve A, B, or K from figure 514-1 and time schedule V of table 514-II.

4.4.2 *Part 2.* Proceed the same as in procedure I, part 3, except that the test level shall be in accordance with curve N from figure 514-3 and time schedule II of table 514-II.

4.4.3 *Part 3, random.* Random vibration (controlled and analyzed according to 5.3) shall be applied according to curve AE from figure 514-4 and time schedule II of table 514-II. Unless otherwise specified, during, and at the conclusion of the test, the operation of the test item shall be compared with the data obtained in accordance with section 3, paragraph 3.2.1, and shall meet the requirements of the equipment specificaton. The test item shall then be inspected in accordance with section 3, paragraph 3.2.4.

4.5 Procedure V.

4.5.1 *Part 1.* Proceed the same as in procedure I, part 3, except that the test level shall be in accordance with one curve of P through U from figure 514-3 and time schedule II of table 514-II.

4.5.2 *Part 2, random.* Random vibration (controlled and analyzed according to 5.3) shall be applied according to one specified curve of AE through AP from figure 514-4 and time schedule II of table 514-II. Unless otherwise specified, during, and at the conclusion of the test, the operation of the test item shall be compared with the data obtained in accordance with section 3, paragraph 3.2.1, and shall meet the requirements of the equipment specification. The test item shall then be inspected in accordance with section 3, paragraph 3.2.4.

4.6 Procedure VI.

4.6.1 *Part 1.* Equipment normally provided with vibration isolators shall be first tested with the isolators in place. Proceed the same as in procedure I, part 3, except that the test level shall be in accordance with one curve of P through U from figure 514-3 and time schedule II of table 514-II.

4.6.2 *Part 2.* The isolators shall then be removed, the equipment rigidly mounted, and tested again in accordance with procedure I, part 3, except the test level shall be in accordance with curve N from figure 514-3 and time schedule II of table 514-II.

4.6.3 *Part 3, random.* The vibration isolators shall be replaced and random vibration (controlled and analyzed according to 5.3) shall be applied according to one specified curve of AE through AP from figure 514-4 and time schedule II of table 514-II. Unless otherwise specified, during, and at the conclusion of the test, the operation of the test item shall be compared with the data obtained in accordance with section 3, paragraph 3.2.1, and shall meet the requirements of the equipment specification. The test item shall then be inspected in accordance with section 3, paragraph 3.2.4.

4.7 Procedure VII.

4.7.1 *Part 1.* Proceed the same as in procedure I, part 3, except that the test level shall be in accordance with curve N from figure 514-3 and time schedule II of table 514-II.

4.7.2 *Part 2, random.* Random vibration (controlled and analyzed according to 5.3) shall be applied according to one specified curve AE from figure 514-4 and time schedule II of table 514-II. Unless otherwise specified, during, and at the conclusion of the test, the operation of the test item shall be compared with the data obtained in accordance with section 3, paragraph 3.2.1, and shall meet the requirements of the equipment specification. The test item shall then be inspected in accordance with section 3, paragraph 3.2.4.

4.8 Procedure VIII. Proceed the same as in procedure I, parts 1, 2, 3, using curve V, W, or Y from figure 514-5 and time schedule III of table 514-II.

4.9 Procedure IX.

4.9.1 *Part 1, vibration (resonance search).*

4.9.1.1 *Test conditions.* The test item shall be secured to a vibration table that can be controlled within 10 percent of the specified amplitude. Mounting method shall be such that the vibration within the test item can be observed and measured. To facilitate this observation and measurement, sub-assemblies may be tested separately, provided they are secured to the table in a manner similar to that used to mount them in the test item.

4.9.1.2 *Performance of test.* The shockmounts (if any) of the test item shall be blocked. The test item shall be vibrated successively in three mutually perpendicular directions over a frequency range of 10 to 55 cycles per second. The total excursion of the applied vibration shall not be less than 0.030 inch. In each of the three directions, the frequency shall be changed in steps of 1 cycle per second and maintained for at least 10 seconds. Vibration amplitudes shall be measured by optical or any other means, provided that the vibration of the test item is not affected by the measurement.

4.9.1.3 *Failure criteria.* The equipment shall have no resonance in the frequency range of 10 to 55 cycles per second that exceed twice the amplitude of the applied vibration. This applies for equipment designed to operate with or without shock mounts.

4.9.2 *Part 2, bounce, vehicular.*

4.9.2.1 *Apparatus.* A package tester of suitable capacity for testing military equipment as made by L.A.B. Corporation, Skaneateles, New York, or equal.

4.9.2.2 *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 sixpenny 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. Fences shall be a distance from the test item more than sufficient to insure that the test item will not rebound from fence to fence. Additional barriers may be used to safeguard personnel.

4.9.2.3 *Performance of test.*

Step 1—Secure the test item to the vehicular, or simulated, adapter plate in accordance with section 3, paragraph 3.2.2, and place on the package tester within the constraints outlined in 4.9.2.2 (b). If the test item weighs over 200 pounds, a simulated adapter plate 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 motion, to a speed such that the average value of the random acceleration peaks shall be 7.5 ± 2.5 g's. Measure this input with an accurate measuring or recording system incorporating a 100 cycles per second low pass filter. Due to the random nature of the input, pulses greater than 10 g's can be expected to occur, however, if they are infrequent, they need not be used in calculating the average. In no case shall the speed of the package tester exceed 285 revolutions per minute. Conduct 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 the test item and compare the results with the data outlined in accordance with section 3, paragraph 3.2.1. Then inspect the test item as specified in section 3, paragraph 3.2.4.

4.10 Procedure X. Proceed the same as in procedure 1, parts 1, 2, and 3, except that the test level shall be in accordance with curve AB, or curves AA and AQ from figure 514-6 and time schedule IV of table 514-II.

4.11 Procedure XI.

4.11.1 *Part 1.* Proceed the same as in part 1 of procedure IX.

4.11.2 *Part 2. Bounce, loose cargo.*

4.11.2.1 *Purpose.* To determine that the equipment, as prepared for field use, shall be capable of withstanding the vibrations normally induced during transportation as loose cargo. Equipment in this class is normally transported in a shipping case, transit case, or combination case.

4.11.2.2 *Apparatus.* A package tester of suitable capacity for testing military equipment as made by L.A.B. Corporation, Skaneateles, New York, or equal.

4.11.2.3 *Test conditions.* The test bed of the package tester shall be covered with a panel of ½-inch plywood, with the grain parallel to the drive chain. The plywood shall be secured with sixpenny 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 shafts of the package tester, and in a direction perpendicular to the axes of the shafts, a distance more than sufficient to insure the test item will not rebound from fence to fence.

4.11.2.4 *Performance of test.* The test item, as secured in its shipping case, 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 package tester shall be operated in the synchronous mode with the shafts in phase. (In this mode any point on the bed of the tester will move in a circular path in a vertical plane perpendicular to the axes of the shafts,) The tester shall be operated at a speed of 284 rpm ±2 rpm for a total of 3 hours. At the end of each ½-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 the results compared with the data obtained in accordance with section 3, paragraph 3.2.1. The test item shall then be inspected as specified in section 3, paragraph 3.2.4. 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.

(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.

4.12 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.

5. Test details and techniques.

5.1 Combined sinusoidal cycling and random vibration test. The sinusoidal cycling random vibration test may be combined when the test apparatus permits. The sinusoidal vibration test curve acceleration level (specified in peak g) shall be converted to rms G. The acceleration level to be used for the combined test shall then be determined by squaring both test curve acceleration levels, adding them, and then taking the square root of the sum. The combined test level may then be achieved by obtaining the lower of the two separate levels first, then advancing the gain control for the other separate level until the overall combined test level is achieved. All other test parameters shall be the same as the separate test instructions.

5.2 Substitution of linear cycling for logarithmic cycling. When linear cycling rate is used, the total frequency range shall be divided into logarithmic frequency bands of equal cycling time intervals. The linear cycling rate for each band is then determined by dividing each bandwidth in cps by the time in minutes for each band. The logarithmic frequency bands may be readily determined from figure 514-8. The frequency bands and linear cycling rates shown in table 514-IV shall be used for the 2 to 500 cps and 5 to 2,000 cps frequency ranges. For test frequency ranges of 100 cps or less, no correction of the linear cycling rate is required.

5.3 Control and analysis of random vibration. The instantaneous random vibration acceleration peaks may be limited to 3 times the rms acceleration level. Resonant modes of the moving mass (vibration exciter moving element, fixture and either the test item or substitute equivalent mass) shall be equalized or compensated for within the frequency range of the test curve. The applied vibration spectrum shall normally be within the tolerances of +40, —30 percent between the frequencies of 50 and 1,000 cps, and within +100, —50 percent between 1,000 and 2,000 cps. For a power spectral density analysis of the test spectrum, these tolerances may be expressed at ±1.5 db and ±3 db, respectively. Tolerance levels in terms of db are defined as:

$$\text{db} = 10 \log \frac{(G_1)^2/\text{cps}}{(G_0)^2/\text{cps}} \text{ or}$$

$$\text{db} = 20 \log \frac{G_1}{G_0}$$

Where $(G_1)^2/\text{cps}$ = acceleration power spectral density, and

G_1 = G rms (measured over the analyzer effective bandwidth).

The term G_0 defines the specified level.

A wave analyzer shall be used to assure the specified equalization tolerances. The following wave analyzer characteristics shall be required for each test:

(a) Filter bandwidths = B = 25 cps max. below 1000 cps and 1/3 octave max. above 1000 cps

(b) Sweep rate = R = $B^2/32$ cps/sec. max.

(c) Integrator time constant = 1 second minimum

5.4 Sinusoidal vibration input control. The vibratory acceleration levels or double amplitudes of the specified test curve shall be maintained at the test item mounting points. When the input vibration is measured at more than one control point, the minimum input vibration shall normally be that of the specified curve. For massive test items, fixtures, large force exciters or multiple vibration exciters, it is recommended that the input control level be an average of at least three or more inputs. Unless otherwise specified, the transverse motion at the input monitoring point(s) shall be limited to 100 percent of the input motion. It should be noted that cross talk limitation of small equipment (20 pounds or less) can usually be achieved. For larger equipment such cross talk limitation may not be possible.

5.5 **Transducer mounting.** The input monitoring transducer(s) shall be rigidly attached to and located on or near the attachment point or points of the test item.

5.6 **Combined temperature-vibration test.** Tests shall be conducted under room ambient conditions unless the equipment specification requires a high or low temperature vibration test, in which case the temperature extremes and time duration shall be as specified in the equipment specification.

6. **Summary.** The following details shall be specified in the equipment specification:

(a) Procedure number (see 3.2).

(b) Pretest data required (section 3, paragraph 3.2.1).

(c) Curve selection (see 3.4).

(d) Nonoperation of equipment during test, if desired.

(e) Limitation of transverse motion if other than 100 percent (see 5.4).

(f) Temperature extremes and test time duration (see 5.6).

TABLE 514-I. *Vibration test selection chart*

Equipment category (Par. 3.1)	Test procedures										Time schedule table 514-II
	Procedure number (Par. 3.2)	Curve (Par. 3.4) (Note 1)	Fig. 514–	Parts	Test type						
					Resonance search	Resonance dwell	Sinusoidal cycling	Random	Bounce, vehicular	Bounce, loose cargo	
(a) Aircraft including helicopters	I	Z	1	Parts 1, 2, and 3	X	X	X				I
		B	1	Part 4	X	X	X				II
(b) Aircraft except helicopters	I	C, D, E, F, G, H, J, or L	1 or 2	Parts 1, 2, and 3	X	X	X				I
		A, B or K	1 or 2	Part 4	X	X	X				II
(c) Helicopters	I	M	1	Parts 1, 2, and 3	X	X	X				I
		B	1	Part 4	X	X	X				II
(d) Air launched vehicles	II	C, D, H or J	1 or 2	Captive phase Part 1	X	X	X				V
		P, Q, R or S	3	Flight phase Part 2			X				II
		one of AF thru AK	4	Part 3				X			II
	III	C, D, H or J	1 or 2	Captive phase (Note 2) Part 1	X	X	X				V
		A, B or K	1 or 2	Part 2	X	X	X				II
		P, Q, R or S	3	Flight phase Part 3			X				II
		one of AF thru AK	4	Part 4				X			II
	IV	A, B or K	1 or 2	Captive phase Part 1	X	X	X				V
		N	3	Flight phase Part 2			X				II
		AE	4	Part 3				X			II

TABLE 514-I. *Vibration test selection chart* (continued)

Equipment category (Par. 3.1)	Test procedures										Time schedule table 514-II
	Procedure number (Par. 3.2)	Curve (Par. 3.4) (Note 1)	Fig. 514–	Parts	Test type						
					Resonance search	Resonance dwell	Sinusoidal cycling	Random	Bounce, vehicular	Bounce, loose cargo	
(e) Ground launched vehicles	V	one of P thru U	3	Part 1			X				II
		one of AE thru AP	4	Part 2				X			II
	VI	one of P thru U	3	Part 1			X				II
		N	3	Part 2 (Note 2)			X				II
		one of AE thru AP	4	Part 3				X			II
	VII	N	3	Part 1			X				II
		AE	4	Part 2				X			II
(f) Ground vehicles	I	V, W or Y	5	Parts 1, 2, and 3 (Note 3)	X	X	X				I
	VIII	V, W or Y	5	(Note 3)	X	X	X				III
	IX			Parts 1 and 2	X				X		
(g) Shipment by com. carrier	X	AB or (AA & AQ)	6	(Note 3)	X	X	X				IV
	XI			Parts 1 and 2	X					X	
(h) Ground equipment excluding cat. (f)	X	AB or (AA & AQ)	6	(Note 3)	X	X	X				IV
	XI			Parts 1 and 2	X					X	
(i) Shipboard	XII										

TABLE 514-I. *Vibration test selection chart* (continued)

Note 1: Unless otherwise specified in the equipment specification, for resonance and sinusoidal vibration cycling tests of items weighing more than 50 pounds, the vibratory accelerations shall be reduced by ±1 g for each 10 pound increment of weight over 50 pounds. 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 shall first be tested with the isolators in place. The isolators shall then be removed, the test item rigidly mounted, and subjected ot the lower g level indicated.

Note 3: When a transit case or crate is provided for the item, the case or crate shall be included in the test setup. For equipment weighing more than 100 pounds, the upper frequency limit of figure 514-5 or 514-6 shall be reduced according to the cut-off frequency vs. weight requirement of figure 514-7.

TABLE 514–II. *Time table*

Time schedule	Resonance dwell		Cycling time per axis	Random time per axis	Sweep time	
	Number of resonances	Time at resonance per axis			5–500–5 cps	5–2000–5 cps
I	0	—	3 hr.		15 min.	20 min.
	1	½ hr.	2½ hr.		(Note 1)	
	2	1 hr.	2 hr.			
	3	1½ hr.	1½ hr.			
	4	2 hr.	1 hr.			
	Dwell 30 min. at each resonance					
II	0	—	30 min.	30 min.	15 min.	20 min.
	1	10 min.				
	2	20 min.				
	3	30 min.				
	4	40 min.				
	Dwell 10 min. at each resonance					
III	0	—	20 min/1000 miles as determined from vehicle mileage chart or equipment specification — see table 514–V		15 min.	
	1	Dwell 1/6 of cycling time at each resonance (30 min. max.)			(Note 1)	
	2					
	3					
	4					
IV	0	—	45 min. (Note 1)		15 min.	
	1	½ hr.				
	2	1 hr.			(Note 1)	
	3	1½ hr.				

TABLE 514-II. *Time table* (continued)

Time schedule	Resonance dwell		Cycling time per axis	Random time per axis	Sweep time	
	Number of resonances	Time at resonance per axis			5-500-5 cps	5-2000-5 cps
IV (Cont.)	4 Dwell 30 min. at each resonance (see Note 2)	2 hr.				
V	0 1 2 3 4 Dwell 30 min. at each resonance	— ½ hr. 1 hr. 1½ hr. 2 hr.	2 hr. 1½ hr. 1 hr. ½ hr. 0		15 min.	20 min.

Note 1: Sweep time can be as long as 18 minutes if test frequencies go lower than 5 cps (see figures 514-5 and 514-6).

Note 2: When testing to curve AQ of figure 514-6, the 30 minute dwell time shall be broken into six 5-minute vibrations with five 2-minute shut down intervals.

TABLE 514-III. *Suggested vibration test curves (launched vehicles)*

Vehicle type	Vibration test curves		Approx. thrust to weight ratio or thrust in pounds	Equipment location by vehicle section
	Sinusoidal Fig. 514-3	Random Fig. 514-4		
Air launched (flight phase)	S	AK	20/1 or greater	Booster
	R	AJ	5/1 thru 20/1	
	Q	AH	5/1 or less	
	Q	AG	15/1 or greater	All except booster
	P	AF	Less than 15/1	

TABLE 514-III. *Suggested vibration test curves (launched vehicles)* (Continued)

Vehicle type	Vibration test curves		Approx. thrust to weight ratio or thrust in pounds	Equipment location by vehicle section
	Sinusoidal Fig. 514-3	Random Fig. 514-4		
Ground launched	P or Q	AE, AF or AG	ALL—	All except booster
	Q or R	AH, AJ or AK	250,000 lb. or less	By individual booster stage
	R or S	AK, AL or AM	250,000 lb. - 500,000 lb.	
	T or U	AM, AN or AP	Over 500,000 lb.	

TABLE 514-IV. *Linear cycling rates*

Total frequency range	Frequency bands	Sweep time in minutes	Linear cycling rate (cps/min)
2-500 cps	2 to 5	1.5	2
	5 to 22.5	2.5	7
	22.5 to 100	2.5	31
	100 to 500	2.5	160
5-2000 cps	5 to 22.5	2.5	7
	22.5 to 100	2.5	31
	100 to 500	2.5	160
	500 to 2000	2.5	600

TABLE 514-V. *Mileage schedule*

Group	*Classification*	*Total mileage*
Trailers, semitrailers, and dollies:		
A	Trailers, semitrailers and dollies	6,000
B	Trailer bodies and equipment	3,000
C	Electronic and missile systems trailers and semitrailers	4,000
Wheeled vehicles:		
D	Tactical trucks	25,000
E	Truck bodies, equipment	11,400
F	Light weight, low mileage trucks	
	1 — Sprung type	4,000
	2 — Unsprung types	5,000
G	High flotation vehicle	4,000

H	Amphibious	8,400
I	Fire trucks	5,000
J	Commercial trucks, buses, passenger cars	35,000
Tracked vehicles:		
K	Tanks and self-propelled (SP) weapons	5,000
L	Armored personnel carriers (APC), cargo carriers, missile support vehicles, wreckers, recovery vehicles and cargo tractors (with towed load)	6,000
M	Engineer combat vehicle (ECF) and engineer assault vehicle, etc.	5,000
N	Engineer crawler tractors — military type	6,000
O	Amphibious vehicles (LVT type)	5,000
P	Turret-mounted accessories such as integrally mounted flamethrowers and searchlights	700
Q	Bulldozers	200
R	Fording kits	50

NOTES FOR FIGURES 514–1 AND 514–2

Aircraft equipment location

Curve	
A	Equipment installed on vibration isolated panels and racks when the panel or rack is not available for test and when specified in Table 514–I for aircraft application.
B	Equipment installed on vibartion isolated panels and racks when the panel or rack is not available for test and when specified in Table 514–I for helicopter application.
C	Equipment in forward half of fuselage or equipment in wing areas of aircraft with engines at rear of fuselage.
D	Equipment in rear half of fuselage or equipment in wing areas of aircraft with wing mounted engines or other locations not specifically mentioned for other curves.
E	Equipment located in the engine compartment or pylon.
F	Equipment mounted directly on aircraft engine.
G through L	Same as A and C through F where higher frequencies are anticipated.
M	Equipment designed for helicopter application.
Z	Equipment designed for both helicopter and airplane application.

Air launched vehicle (captive phase)

A, B	Same as for aircraft.
C	Equipment in vehicle attached to wing of aircraft with engine in rear of fuselage.
D	Equipment in vehicle carried in aircraft fuselage or attached to wing in aircraft with wing mounted engines.
H through K	Same as A, C, and D where higher frequencies are anticipated.

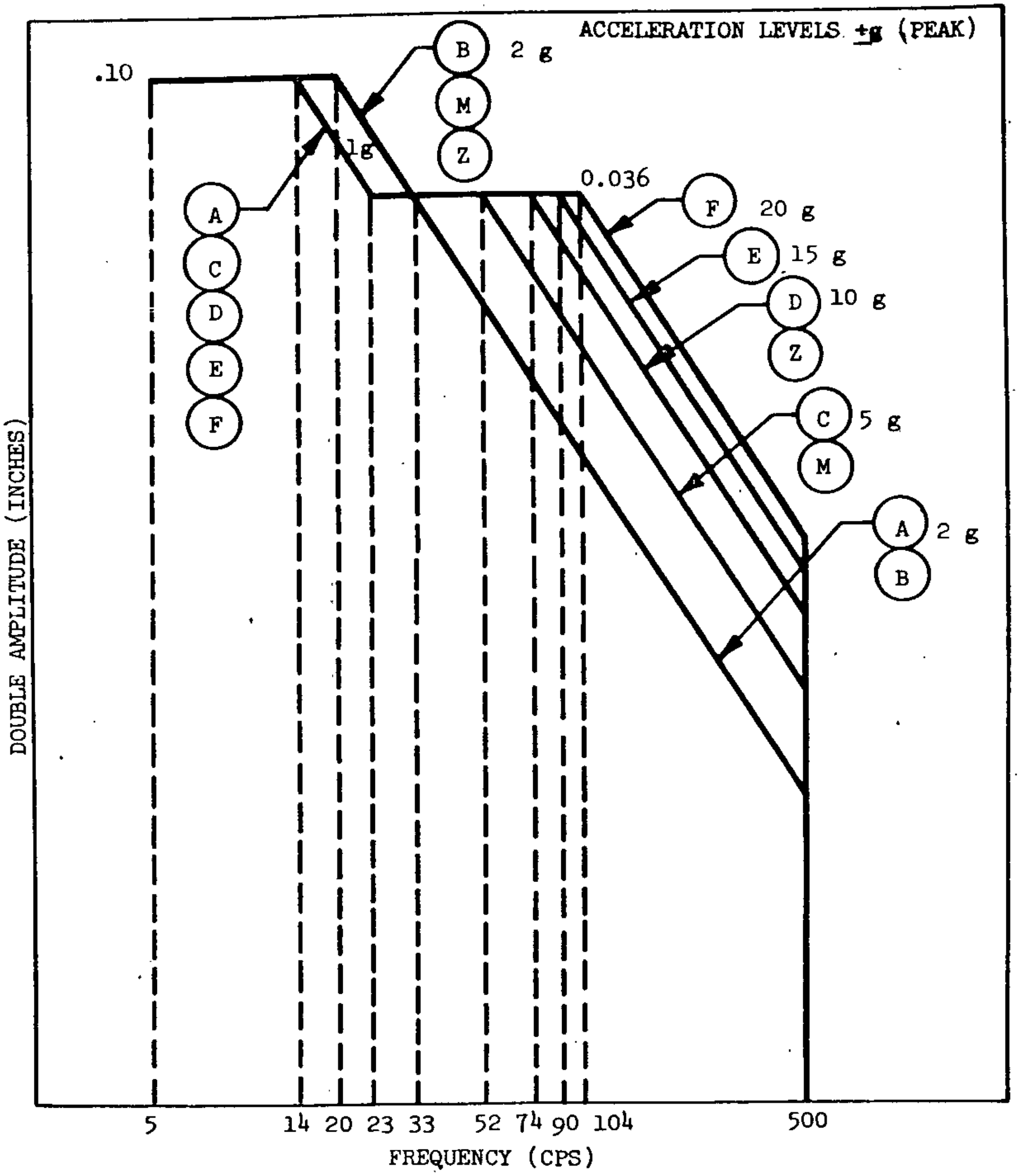


FIGURE 514–1. *Vibration test curves (sinusoidal) aircraft and helicopter, and air launched vehicle (captive phase) equipment with maximum frequency of 500 cps.*

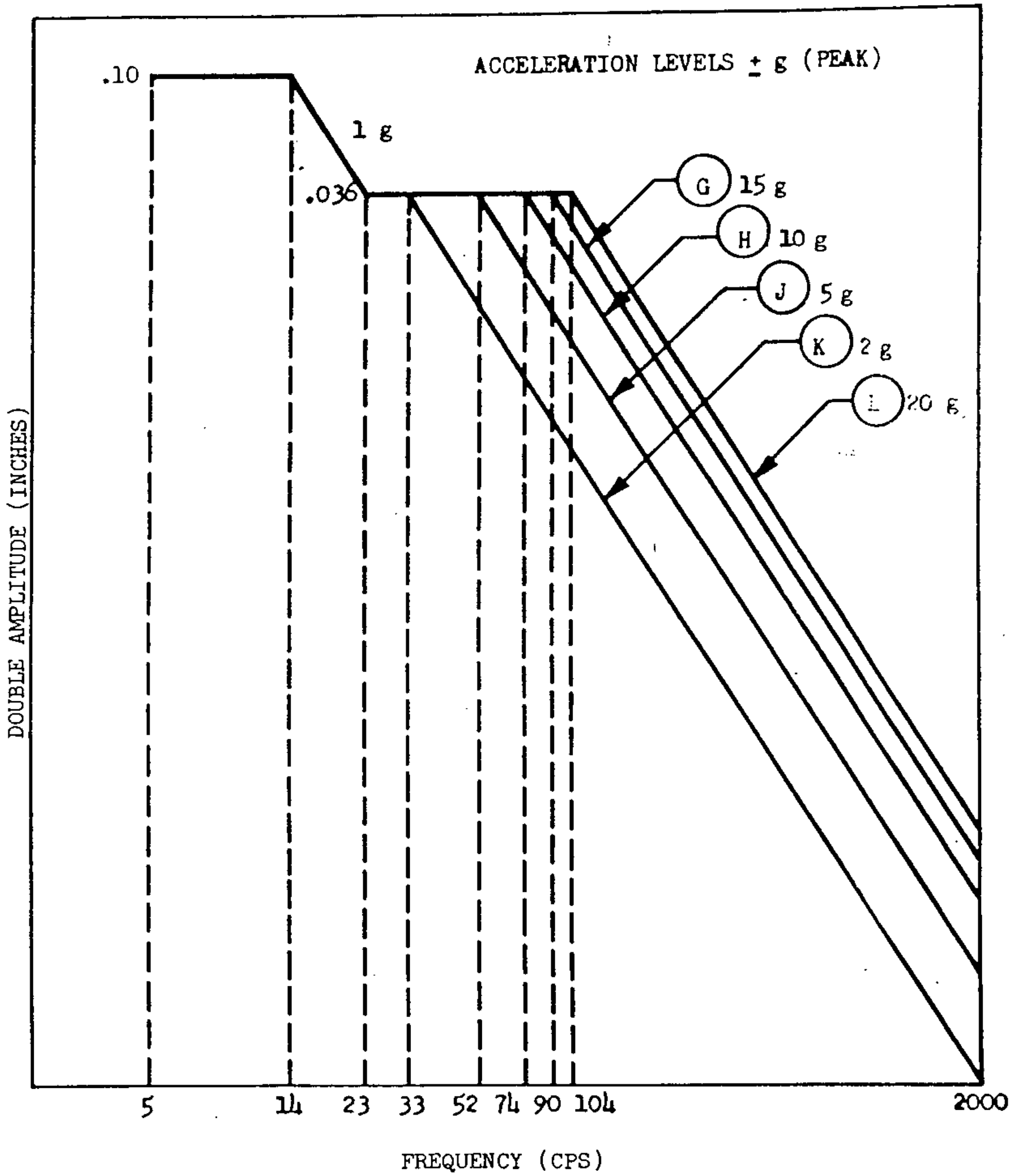


FIGURE 514-2. *Vibration test curves (sinusoidal) aircraft and air launched vehicle (captive phase) equipment with maximum frequency of 2,000 cps.*

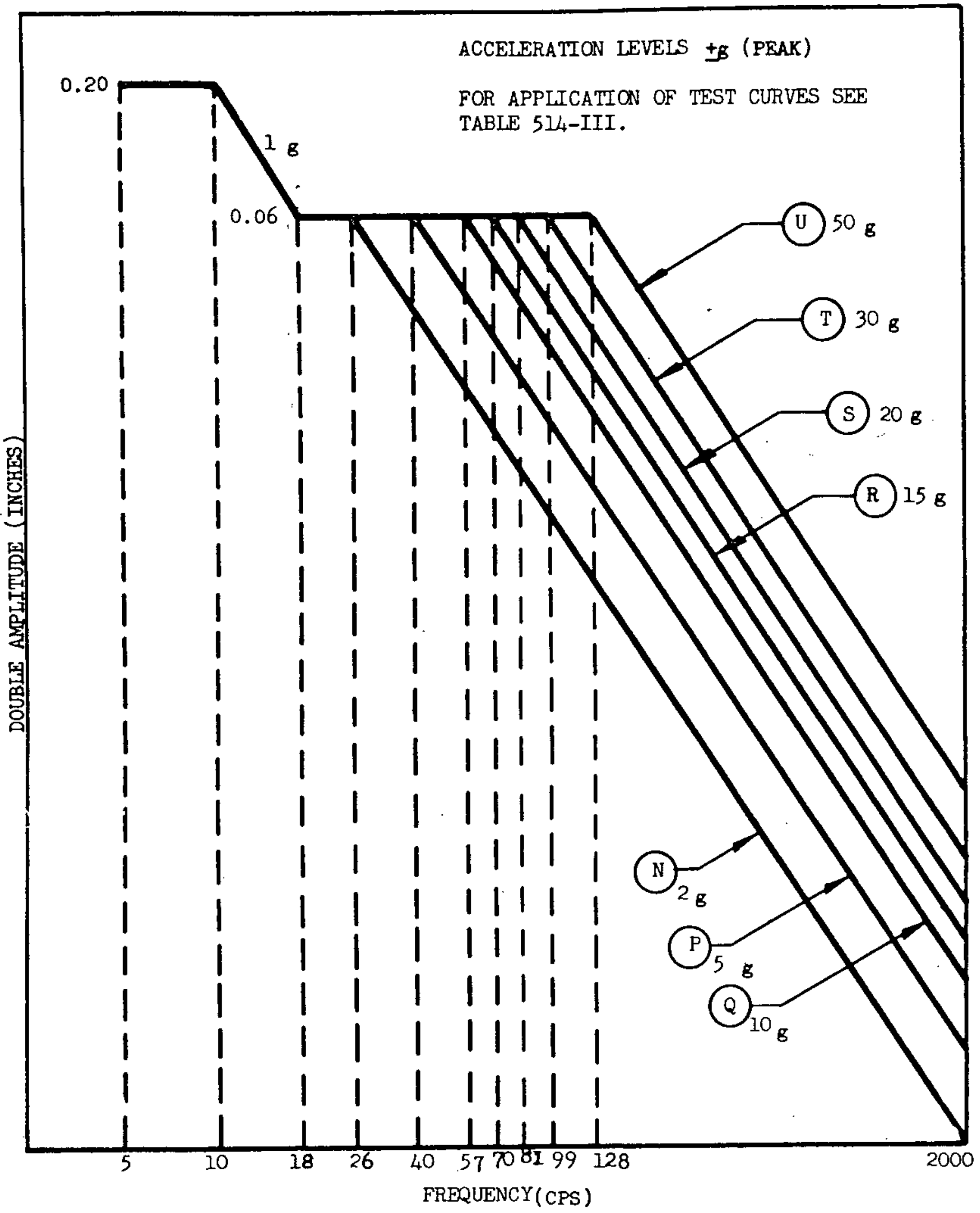
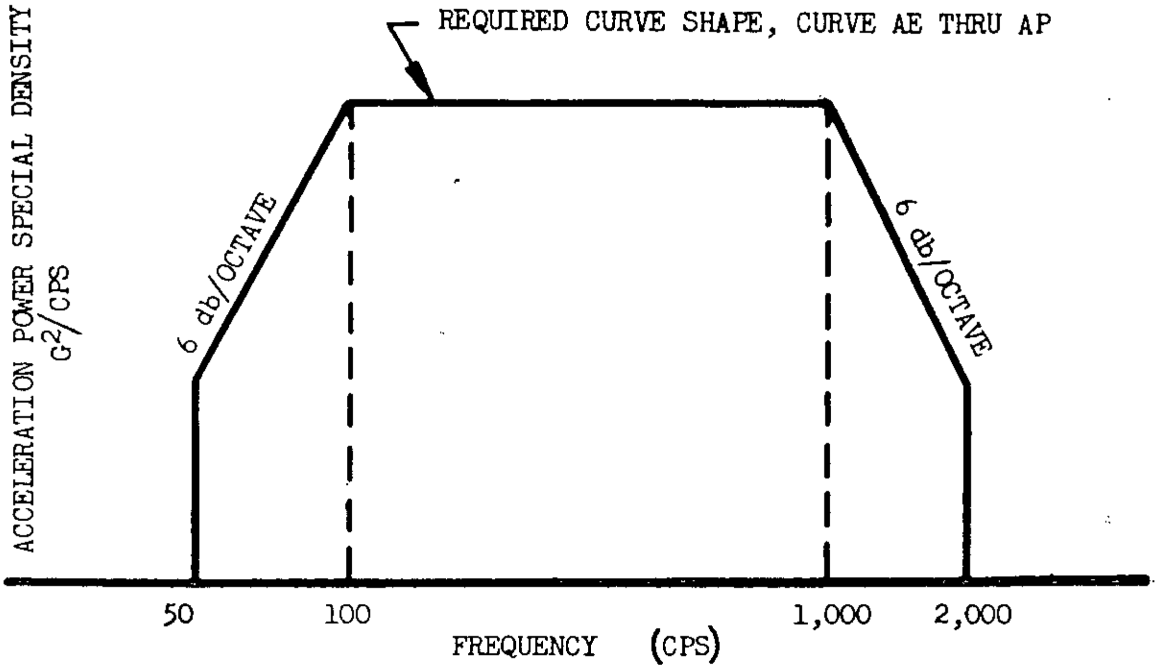


FIGURE 514-3. *Vibration test vurves (sinusoidal), air launched vehicle (flight phase) and ground launched vehicle (flight phase) equipment.*

RANDOM VIBRATION TEST CURVE ENVELOPE



TEST CURVE	ACCELERATION POWER SPECTRAL DENSITY	OVERALL RMS G MINIMUM
AE	0.02	5.3
AF	0.04	7.4
AG	0.06	9.3
AH	0.1	11.9
AJ	0.2	16.9
AK	0.3	20.7
AL	0.4	23.9
AM	0.6	29.3
AN	1.0	37.8
AP	1.5	46.3

NOTE: OVERALL RMS G = $\left(\int_{f_1}^{f_2} W(f)df\right)^{\frac{1}{2}}$ Where f_1 & f_2 ARE THE LOWER AND UPPER TEST FREQUENCY LIMITS RESPECTFULLY; & $W(f)$ = ACCELERATION POWER SPECTRAL DENSITY, IN G^2/CPS UNITS.

FIGURE 514-4. *Vibration test curves (random), air launched vehicles (flight phase) and ground launched vehicles (flight phase) equipment.*

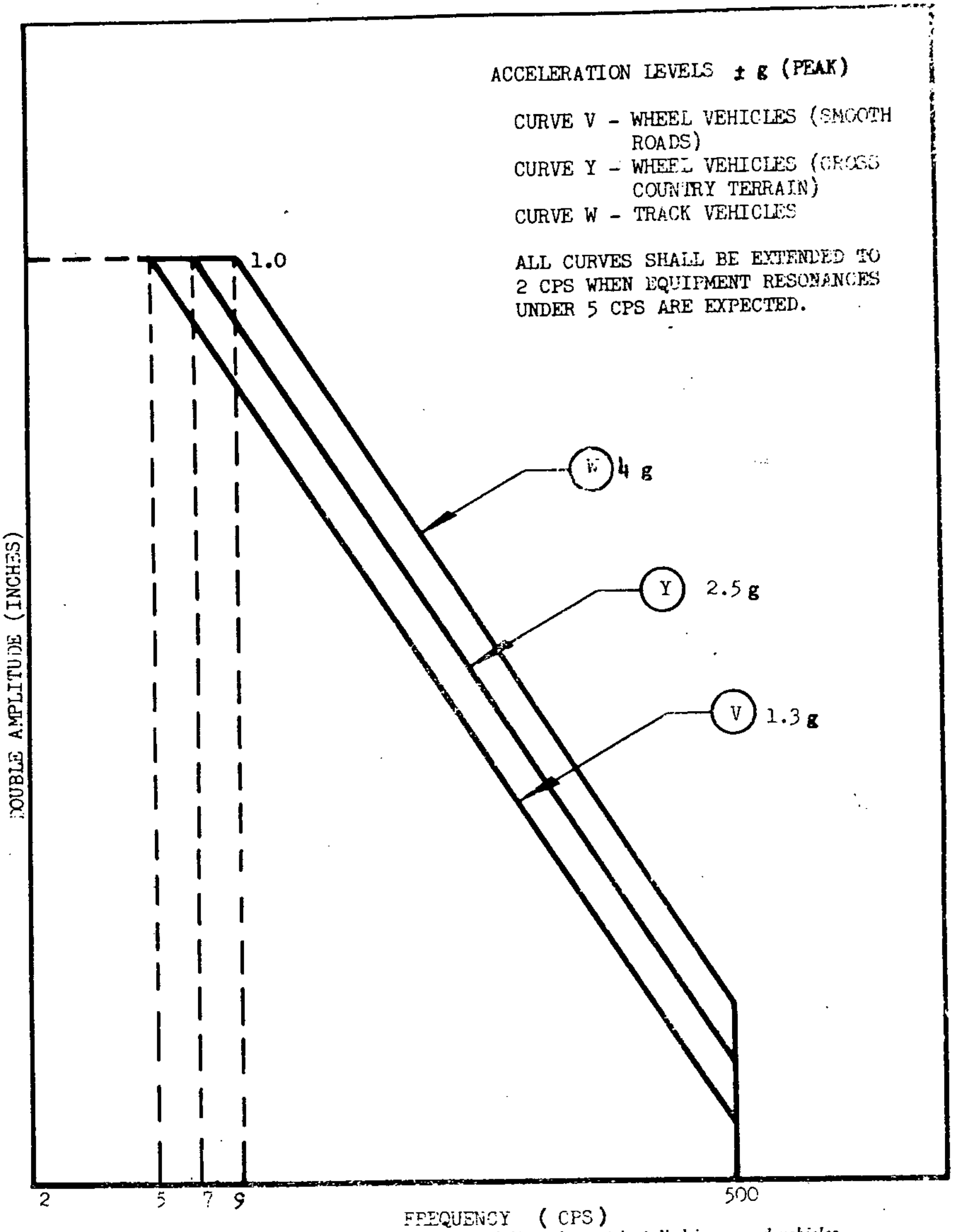


FIGURE 514-5. *Vibration test curves (sinusoidal) equipment installed in ground vehicles.*

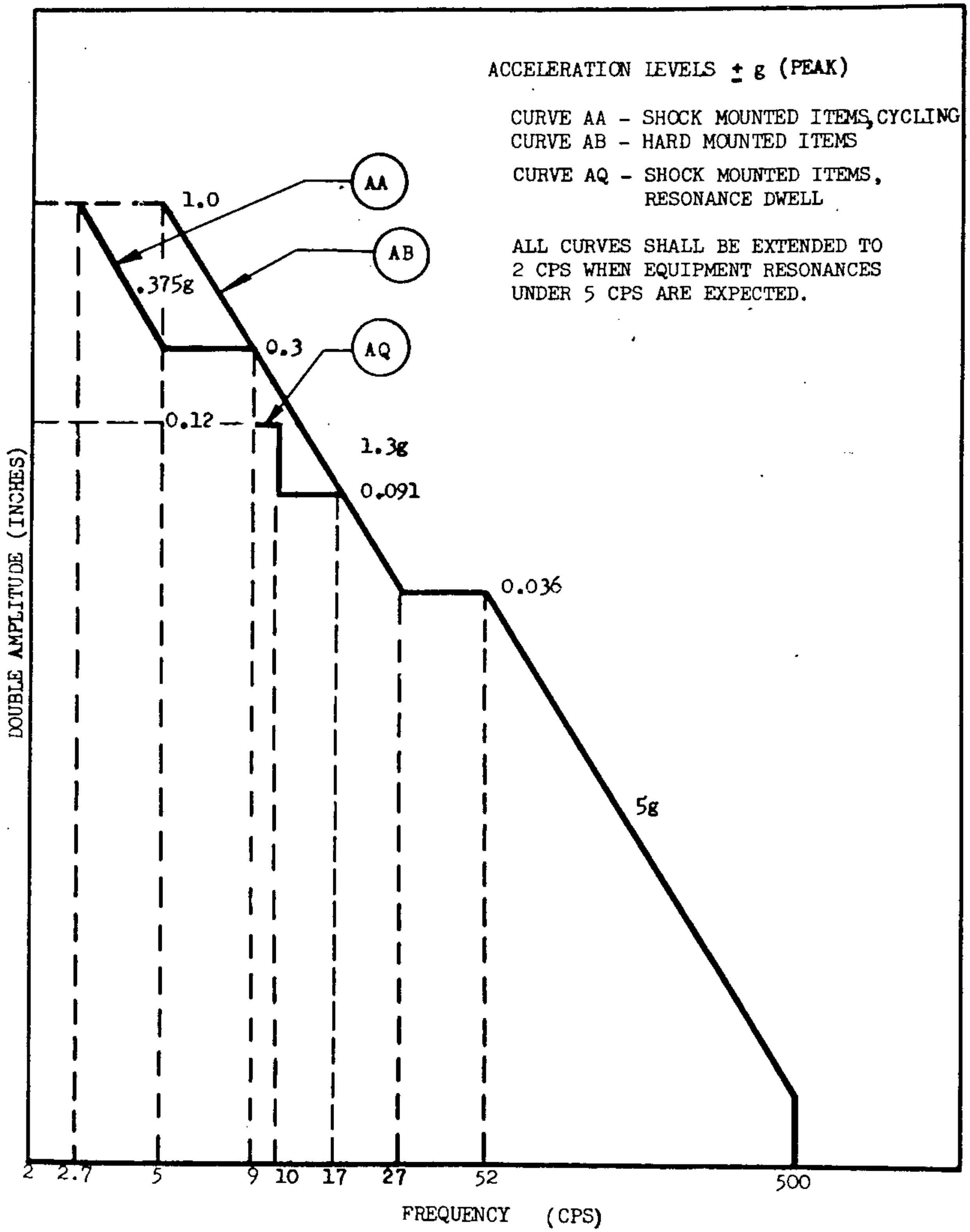


FIGURE 514–6. *Vibration test curves (sinusoidal) ground equipment and equipment transported by common carrier (land or air) tied down.*

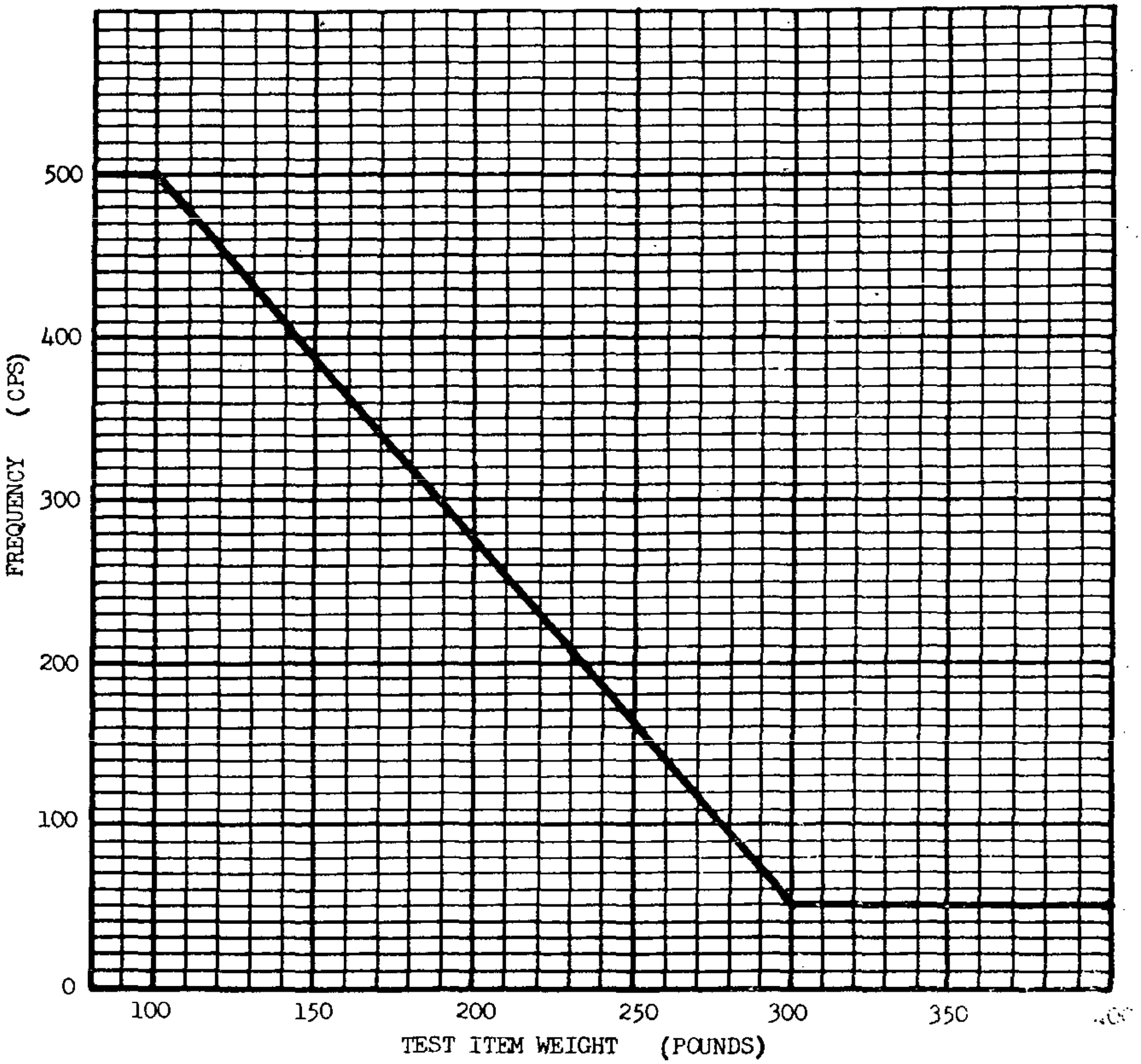


FIGURE 514-7. *Cut-off frequency vs. weight. Equipment shipped by common carrier, ground equipment and equipment installed in ground vehicles.*

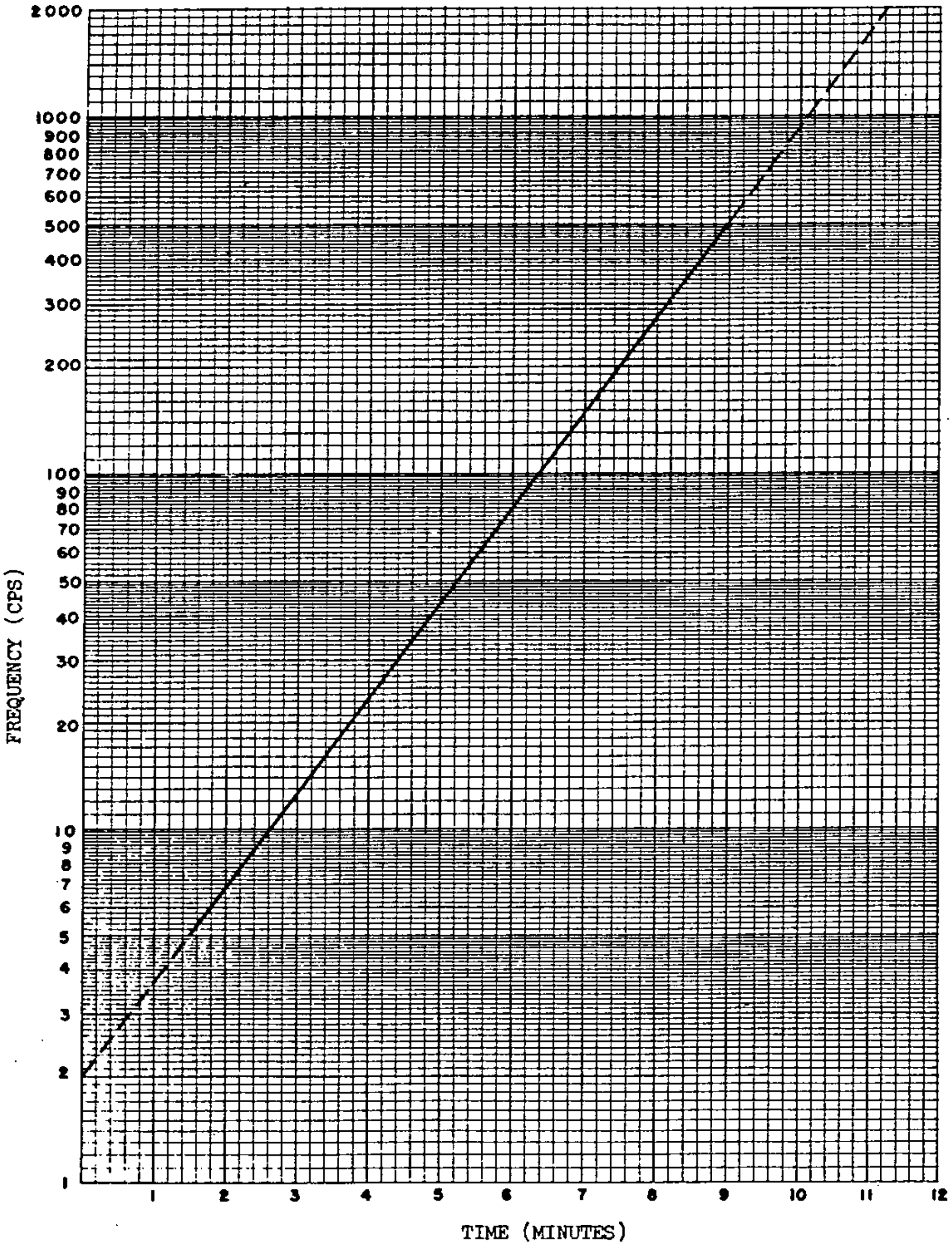


FIGURE 514-8. *Logarithmic cycling rates: For cycling tests of less than 500 cps maximum frequency, the frequency range shall be cycled logarithmically from 5 cps to maximum in 7.5 minutes for the total cycling time specified.*

METHOD 515

ACOUSTICAL NOISE

1. **Purpose.** The acoustical noise test is conducted to determine the effects on equipment of acoustic sound fields that are characteristic of aircraft, missile and other high performance vehicles. In general, equipments located in areas where noise levels are 130 dB overall or less will not require testing to noise environments. The acoustic noise test is not intended to be a substitute for the conventional sinusoidal or random vibration test when specified in the equipment specification.

2. **Apparatus.** A reverberation type test chamber, suitably formed and proportioned to produce, as close as possible, a diffuse sound field, the sound energy density of which is very nearly uniform throughout the enclosure. A pentagonal chamber configuration is recommended. Acute angles of adjacent chamber walls shall be avoided wherever possible. Acoustical generation reproduction and measuring equipment suitable to accomplish these tests.

3. **Procedure.**

3.1 **Definitions and terms.** A comprehensive list of standard terminology is contained in United States of America Standards Institute document S 1.1-1960, titled "Acoustical Terminology (Including Mechanical Shock and Vibration)."

3.2 **Criteria for application.** Some equipments are insensitive to acoustic stimulation even at very high levels. Other equipments may respond in a manner that will modify or disrupt the equipment function. In extreme cases mechanical failure may result. Equipments that are sensitive to vibration are usually sensitive to sound field exposure. For this reason a suitable vibration test is often a good indicator of acoustic sensitivity. However, it is posible 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 test jig and the equipment under test. The following criteria are presented as a guide for the initial determination of equipment sensitivity to acoustic stimuli. Such criteria cannot be considered as the single determining factor. The final decision, whether or not to test, must be supplemented by such additional factors as a description of the characteristics and duration of the sound field, the location of the equipment within the vehicle structure, and a consideration of special mounting means or protective enclosures employed for the equipment.

3.3 **Assessment of equipment.** Of importance is the fact that some equipments may possess both sensitive and insensitive properties, and that in some equipment it may be difficult to assess the properties themselves. With this understanding, the general criteria for evaluating the incipient acoustic sensitivities of equipments are contained in the following paragraphs.

3.3.1 *Insensitive properties.* Equipments with insensitive properties are those having small surface areas, high mass to volume 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) Mass-like valves, hydraulic servo controls, auxiliary power unit pumps, etc.

(d) Equipments surrounded by heavy

metallic castings, particularly those that are potted or are encased within the casting by attenuating media.

3.3.2 *Sensitive properties.* Equipments with sensitive properties are those normally classified as being microphonic and those having large compliant areas of exposure, low mass to area ratios and low internal damping. Examples are as follows:

(a) Equipment containing microphonic elements with high frequency resonances such as electron tubes, wave guides, klystrons, magnetrons, piezoelectric components, and relays attached to thin plate surfaces.

(b) Equipments containing or consisting of exposed diaphragmatic elements such as pressure sensitive transducers, valves, switches, relays, and flat spiral antenna units.

3.4 **Selection of test intensity.** The noise levels and duration of exposure are divided into four intensity categories as listed in table 515-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 acoustic level. Normally category (A) will cover the majority of applications in jet aircraft. In some cases where the location of the equipment is very close to the noise source (within several feet) or within the 45 degree cone of the jet, and if the intervening partitions are of thin shell-like walls, testing to the intensity of category (B) may be required. Categories (C) and (D) represent the intense sound fields generated by large rocket thrust vehicles. Category (C) is recommended for equipment locations forward of the booster compartment extending to the forward or nose cone regions. Category (D) is recommended for locations in the booster compartment near the thrust source and may include instrument pods externally mounted on the booster sides.

TABLE 515-I. *Sound test schedule*

Category	Test overall sound pressure level (dB[1])	Exposure time
A	140	30 minutes
B	150	30 minutes
C	160	30 minutes
D	165	30 minutes

[1] Ref. 2×10^4 dynes/cm^2.

3.5 Procedure I.

3.5.1 *Test item mounting.* The test item shall be suspended in the test chamber by means of soft suspension cords such as soft springs or elastic cord in accordance with section 3, paragraph 3.2.2. The natural frequency of all modes of suspension shall be less than 25 cps. 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 should be no more than 10 percent of the test chamber volume. When the test chamber is a rectanguloid, no major surface of the test item shall be installed parallel to a chamber wall.

3.5.2 *Performance of test.*

Step 1—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% of the chamber volume). The overall sound pressure level desired or selected from table 515-I shall then be introduced into the test chamber and adjusted to conform with the octave band spectrum specified in figure 515-1 or 515-2[2]. The average sound pressure distribution (overall level) should be uniform within −2 to +4 dB of the desired value.

Step 2—The test item shall be placed in the chamber as specified in 3.5. 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 should be uniform within −2 to +4 dB of the desired value. Test times shall be as specified in table 515-I. The operation of the test item shall be monitored when and as specified in the equipment specification.

When measurements are made during or following the test, they shall be compared with the data obtained in acordance with section 3, paragraph 3.2.1. At the conclusion of the test the test item shall be inspected in accordance with section 3, paragraph 3.2.4. In the event the test item malfunctions during the test, but performs satisfactorily afterwards, a single frequency sound or vibration test should be performed to determine whether the malfunction can be duplicated. In the application of a single frequency sound, the sound pressure field shall be measured as specified in procedure I, step 2. A single frequency sound or vibration threshold at which a similar malfunction is observed should be recorded and compared with the results obtained from the continuous spectrum tests.

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

(a) Pretest data required (section 3, paragraph 3.2.1).

(b) Test category (see 3.4).

(c) Whether operation during the test is required, and if and how the operation is to be monitored.

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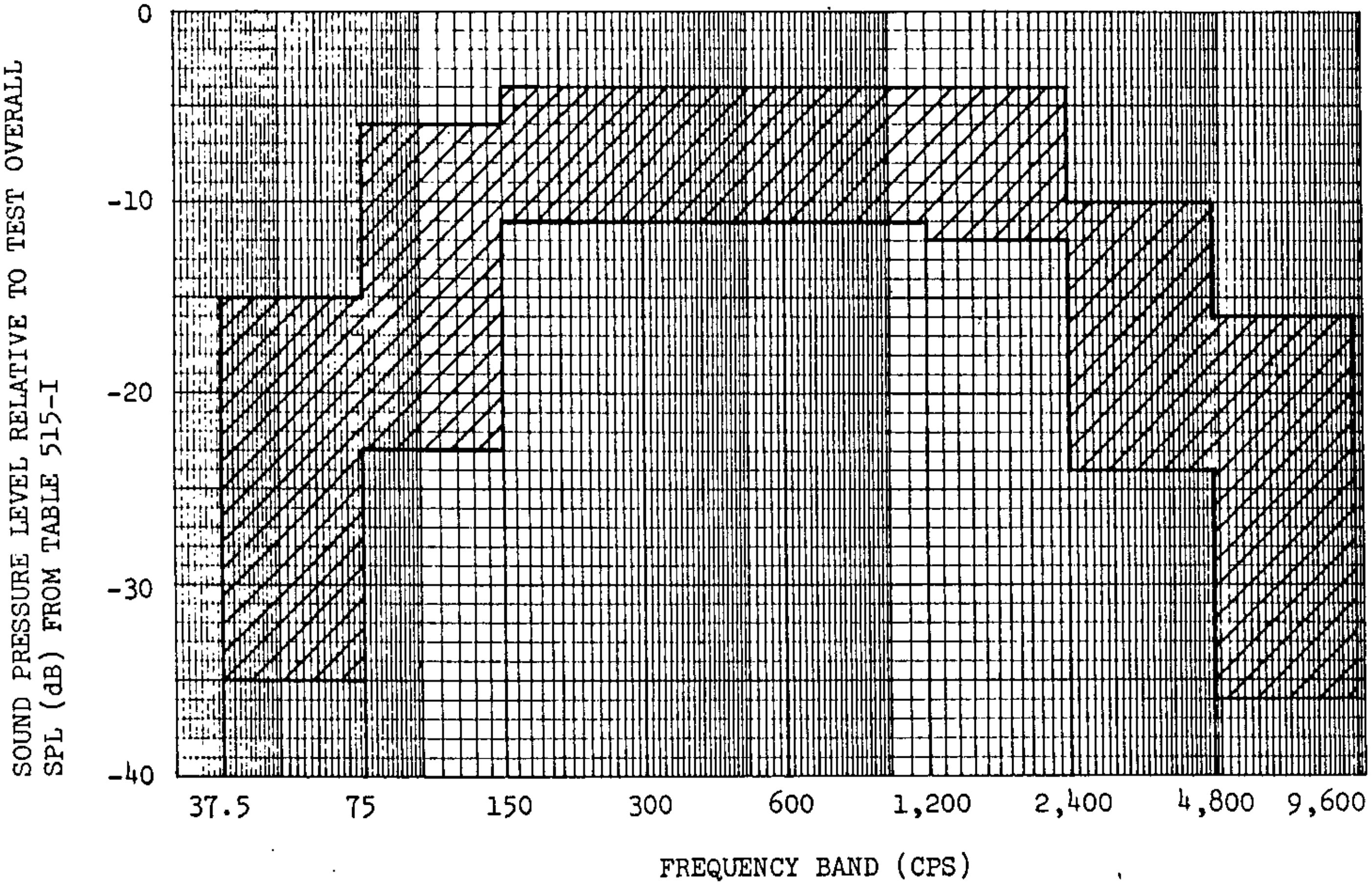
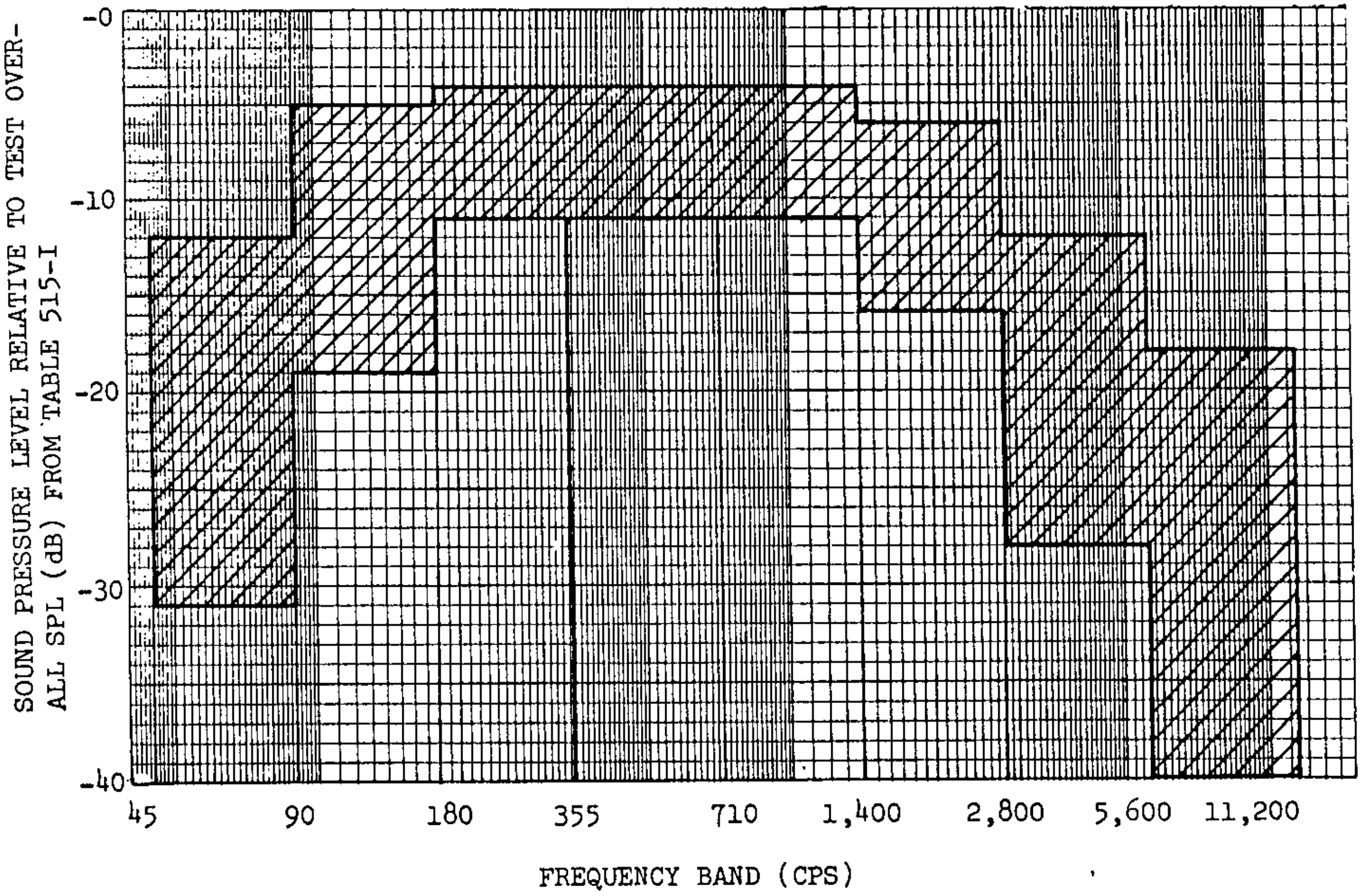
[2] Use of figure 515-1 or 515-2 is dependent on test equipment availability.



NOTE: CROSS HATCHED AREA BOUNDARIES REPRESENT S.P.L LIMITS FOR EACH OCTAVE BAND.

FIGURE 515-1. *Continuous spectrum for acoustical test.*



NOTE: CROSS HATCHED AREA BOUNDARIES REPRESENT S.P.L LIMITS FOR EACH OCTAVE BAND BASED ON THE UNITED STATES OF AMERICA STANDARDS INSTITUTE RECOMMENDED CENTER FREQUENCIES.

FIGURE 515-2. *Continuous spectrum for acoustical test.*

METHOD 516

SHOCK

1. **Purpose.** The shock test is conducted to determine that structural integrity and performance of equipment are satisfactory with respect to the mechanical 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 in figure 516-1 or 516-2. The shock machine may be free fall, resilient rebound, nonresilient, hydraulic, compressed gas, or other.

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 of 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 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 test shall be considered to meet the requirements of the specified waveform. (It is recommended that the actual test waveform be recorded for later use in a failure analysis if the test item fails.)

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 specified by figure 516-3. 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 cps (resonant frequencies of 30 kc 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 cps with damping approximately 0.64 to 0.70 of critical.

2.2.4 *Accelerometer calibration.* The accelerometer shall be calibrated against a standard transducer or by optical means.

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 shall be as shown in figure 516-1 or 516-2 (whichever is specified in the equipment specification). All points of the acceleration wave form obtained shall lie within the area enclosed by the tolerance limit lines. In general, 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 section 3, paragraph 3.2.2. 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 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 the 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 516-1 or 516-2, of amplitude a or b and time duration c or d, as specified in the equipment specification. 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 the results compared with the data obtained in accordance with section 3, paragraph 3.2.1. The test item shall then be inspected as specified in section 3, paragraph 3.2.4.

3.4 **Procedure II. Transit drop test.**

3.4.1 *Purpose.* The equipment, in its transit or combination case as prepared for field use, shall be capable of withstanding the shocks normally induced by loading and unloading of equipment.

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 solid wood, 2-inch thick fir backed by concrete or a rigid steel frame. For equipment over 1,000 pounds, the floor or barrier shall be concrete or its equivalent.

3.4.3 *Performance of test.* Subject the test item to the number and heights of drop as required in table 516-I. Upon completion of the test, the test item shall be operated and the results compared with the data obtained in accordance with section 3, paragraph 3.2.1. The test item shall then be inspected as specified in section 3, paragraph 3.2.4.

TABLE 516-I. *Transit drop test (procedure II)*

Weight of test item, including case	Largest dimension (inches)	Notes	Height of drop (in.)	No. of drops
Under 100 pounds man-packed and man-portable	Under 36	A	48	Drop on each face, edge, and corner. Total of 26 drops.
	36 and over	A	30	
100 to 200 pounds, inclusive	Under 36	A	30	Drop on each corner. Total of 8 drops.
	36 and over	A	24	
Over 200 to 1,000 pounds, inclusive	Under 36	A	24	
	36 to 60	B	36	
	Over 60	B	24	

TABLE 516-I. *Transit drop test (procedure II)* (Continued)

Weight of test item, including case	Largest dimension (inches)	Notes	Height of drop (in.)	No. of drops
Over 1,000 pounds	No limit	C	18	4 edgewise drops. 2 corner drops.

Note A. Drops shall be made from a quick-release hook; or pendulum tester as made by the L.A.B. Corporation, Skaneateles, New York, or equal. The test item shall be oriented for the corner drops so that the sides are at an angle of 45 degrees.

Note 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 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.

Note C. With the normal transit position and the largest dimension in that position parallel to the floor, the transit or combination case, with the test item within, shall be subjected to the edgewise and cornerwise drop test as follows:

1. *Edgewise drop test.* One edge of the base of the test item 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 test item (total of four drops).
2. *Cornerwise drop test.* One corner of the base of the test item shall be supported on a block approximately 5 inches in height. A block nominally 12 inches in height shall be placed under the other corner of the same end. The opposite end of the test item shall be raised to the specified height at the lowest unsupported corner and allowed to fall freely. This test shall be applied once to each of two diagonally opposite corners of the base (total of two drops). When the proportions of width and height of the test item are such as to cause instability in the cornerwise drop test, edgewise drops shall be substituted. In such instances two more edgewise drops on each end shall be conducted (total of four drops).

3.5 Procedure III. Crash safety test. This test is conducted 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 the three mutually perpendicular axes of the equipment (total of 12 shocks). The shock pulse shape shall be in accordance with either figure 516-1 or 516-2, of amplitude a or b and time duration c or d, as specified in equipment specification. 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. This test shall be utilized for testing such items as small, high density electronic equipments and other items of small size mounted without shock and vibration isolators. Two shocks shall be applied to the test item in each direction along each of the three mutually perpendicular axes (total of 12 shocks). The shock pulse shape shall be in accordance with either figure 516-1 or 516-2, of amplitude a or b and time duration c or d, as specified in equipment specification. 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 the results compared with the data obtained in accordance with section 3, paragraph 3.2.1. The test item shall then be inspected as specified in section 3, paragraph 3.2.4.

3.7 Procedure V. Bench handling test. This test is conducted 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 the results compared with the data obtained in accordance with section 3, paragraph 3.2.1. The test item shall then be inspected as specified in section 3, paragraph 3.2.4.

3.8 **Procedure VI. Rail impact test.** This test is performed to determine the effect that impact, due to shipping and other types of transportation, 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 (total of 12 impacts). If an item can be shipped only in one orientation, it shall be impacted twice in each direction of each orientation at speeds of 8, 9, and 10 miles per hour (total of 12 impacts).

3.8.1 *Apparatus.* The following equipment will be necessary to perform this test:

(a) Three ordinary railroad cars, only one of which is a flat car, with standard draft gear couplings.

(b) A prime mover for moving the cars.

(c) A calibrated means to determine the speed at time of impact within ±5 percent.

(d) Accelerometers and associated circuitry to measure the impact shock, if required by the equipment specification.

3.8.2 *Performance of test.*

(a) Two cars will act as buffer cars and be located on a level section of track. The air brakes 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 (flat) 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. Positions of the equipment with respect to the test car and whether or not packaging is necessary shall be specified in the equipment specification.

(c) Impact the test car (flat) into the two loaded cars.

(d) Impacts shall be made in progressive steps with impacts at 8, 9, and 10 miles per hour. The speed just prior to impact shall be measured by electronic or electrical means having an accuracy of ±5 percent.

3.9 *Related shock tests.*

3.9.1 *Missile impact.* A test for simulating missile impact, hard landings, etc., may be performed by employing a rocket sled test facility with a suitable impact barrier.

3.9.2 *Hardsites.* Equipment located in or at missile hardsites usually demands special tests, however, for some zones special adaptations of conventional shock machines can be used. For the critical zones, shock tubes, explosion chambers, hydraulic actuators, etc., can be used.

3.9.3 *High impact.* Unless otherwise specified, ballistic shock tests and high impact tests shall be conducted in accordance with MIL-S-901.

3.9.4 *Shipboard equipment.* Shock tests for shipboard equipment shall be conducted in accordance with MIL-S-901.

3.10 Combined temperature-shock test. Tests shall be conducted under room ambient conditions unless the equipment specification requires a high or low temperature shock test in which case the temperature extremes shall be as specified in the equipment specification.

4. Summary.

The following details shall be specified in the equipment specification:

(a) Pretest data required (section 3, paragraph 3.2.1).

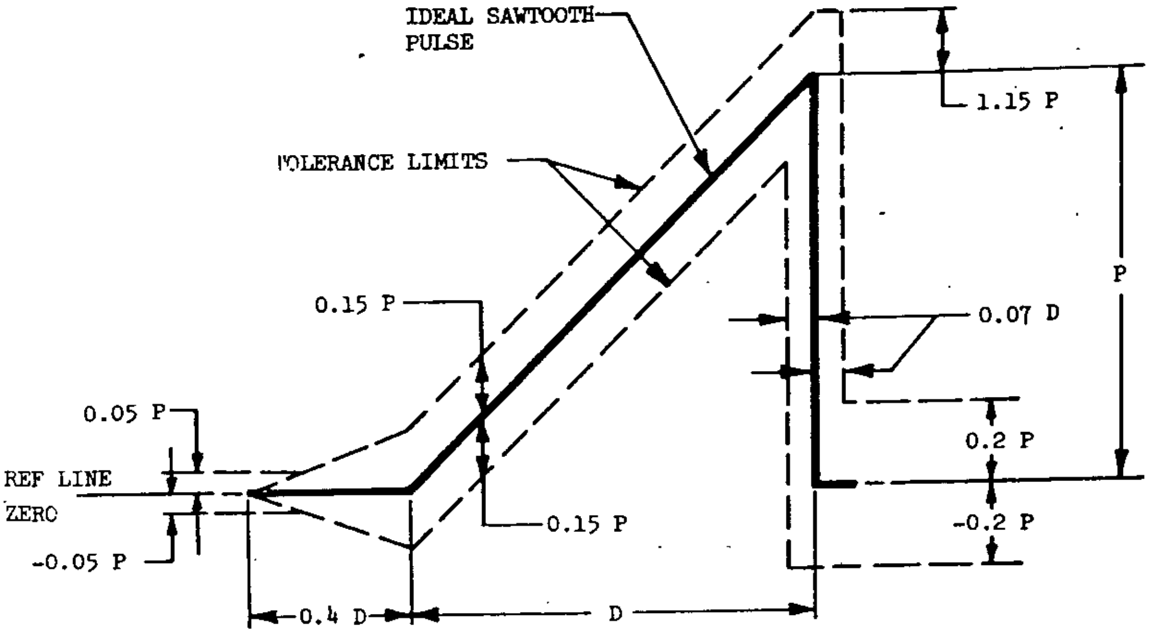
(b) Procedure number.

(c) Shock pulse selection, specify shape, peak value, and duration.

(d) Temperature extremes (see 3.10).

(e) Filter(s) used shall be identified.

(f) Whether operation during the test is required, and if and how the operation is to be monitored.

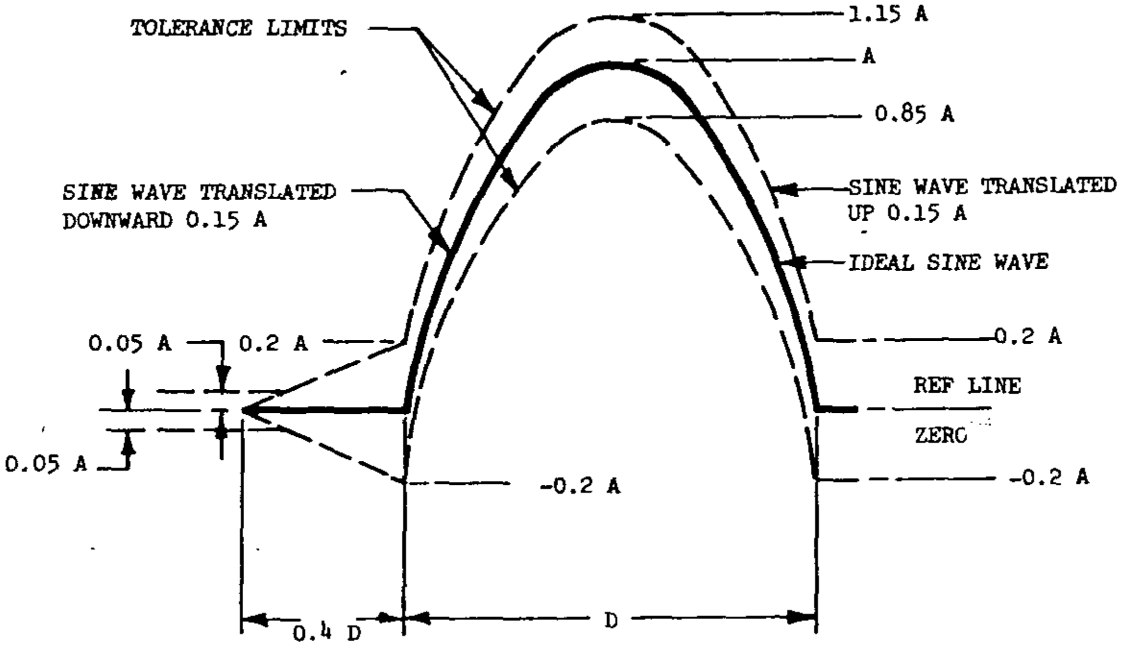


		PEAK VALUE (P) g's		NOMINAL DURATION (D) ms	
PROCEDURE	TEST	FLIGHT VEHICLE EQUIPMENT (a)	GROUND EQUIPMENT (b)	FLIGHT VEHICLE EQUIPMENT (c)	GROUND EQUIPMENT (d)
I	BASIC DESIGN	20	40	11	18
III	CRASH SAFETY	40	75	11	11
IV	HIGH INTENSITY	100	100	6	11

NOTE: SHOCK PARAMETERS (a) AND (c): RECOMMENDED FOR EQUIPMENT NOT SHOCK MOUNTED AND WEIGHING LESS THAN 300 POUNDS.

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. ANY MEASURED ACCELERATION PULSE WHICH CAN BE CONTAINED BETWEEN THE BROKEN LINE BOUNDARIES IS ACCEPTABLE. 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 BEYOND THE PULSE.

FIGURE 516-1. *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	40	11	18
III	CRASH SAFETY	30	75	11	11
IV	HIGH INTENSITY	100	100	6	6

NOTE: SHOCK PARAMETERS (a) AND (c): RECOMMENDED FOR EQUIPMENT SHOCK MOUNTED OR WEIGHING 300 POUNDS OR MORE.

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. ANY MEASURED ACCELERATION PULSE WHICH CAN BE CONTAINED BETWEEN THE BROKEN LINE BOUNDARIES IS ACCEPTABLE. 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 BEYOND THE PULSE.

FIGURE 516-2. *Half sine shock pulse configuration and its tolerance limits.*

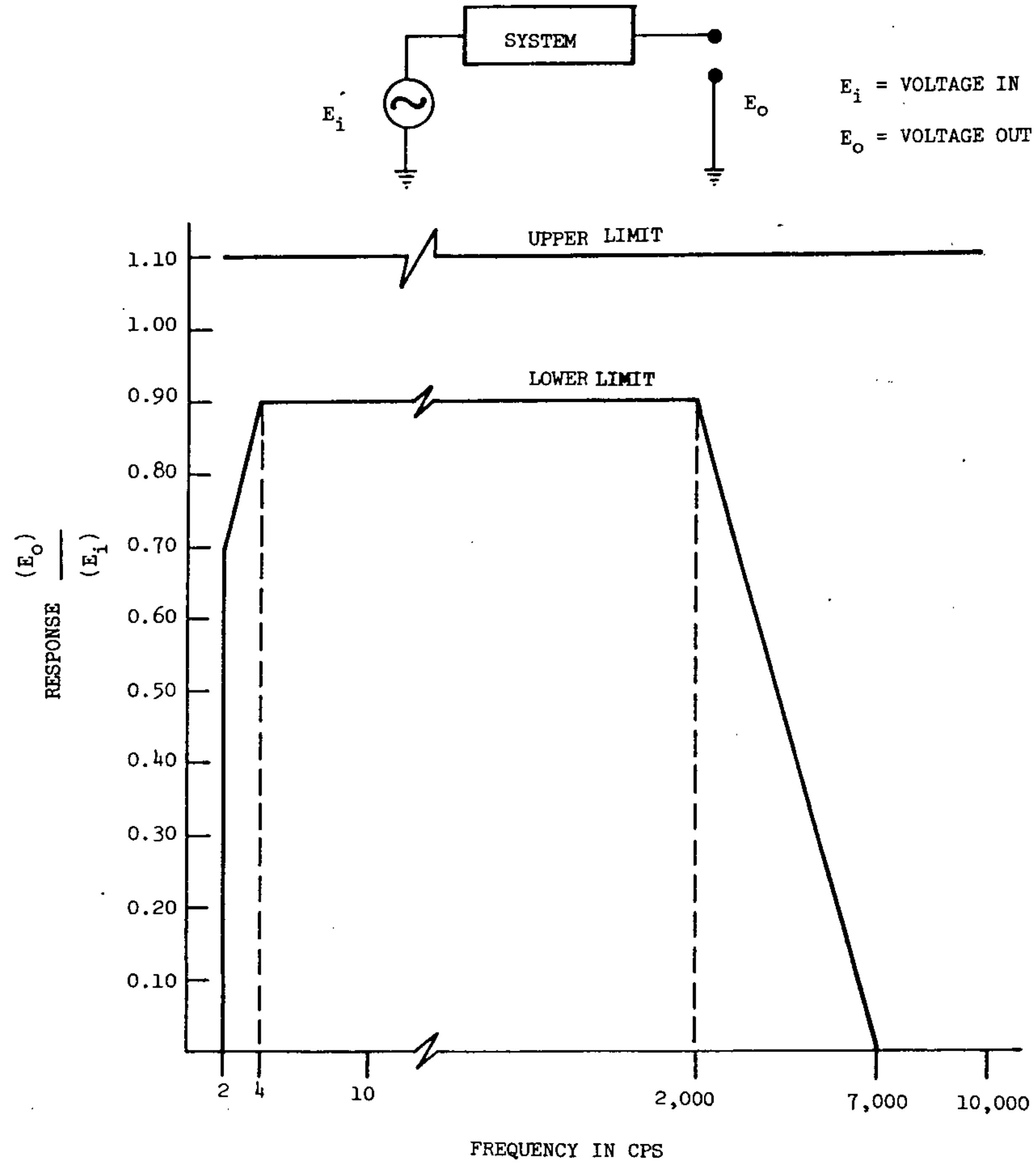


FIGURE 516–3. *System frequency response.*

This tentative test method has been approved by the Department of the Air Force. It is optional for use by all activities.

METHOD T517

SPACE SIMULATION

1. **Purpose.** The tests described in this test method are intended for the evaluation of space vehicle components, space vehicle subsystems and complete space vehicles including installed equipment.

The space simulation test is conducted 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 distributions 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.

2. **Apparatus.** This section deals with general performance requirements of several apparatus items used in space simulation testing. Performance requirements for a specific test would 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 10-5 Torr. with the test item installed. Provisions shall be made for black-coated cryogenic shrouds capable of near liquid nitrogen temperatures (—195° C or 78° K) and of sufficient area and shape to prevent the test item from "seeing" warm chamber walls.

2.2 **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–I, column 2, and variations of this intensity with time shall be kept to ±2.5 percent or less. At all points in the test plane, the intensity shall not deviate by more than ±2.5 percent from the average, measured by a sensor of area 0.1 ft.^{2} or 1/1,000 of the irradiated area, whichever is smaller. To insure uniformity in depth, the field angle of the simulated sun shall not exceed 4 degrees, except in special cases, and should be less than 2 degrees, if possible. As it is likely that the spectrum of the simulated radiation will differ in certain wavelength regions from the spectrum of the true solar radiation, which is listed in table 517–II, the total effective absorptance of the surface of the test item shall not differ by more than ±2.5 percent from the total solar absorptance value if significant test item temperature errors are to be avoided.

TABLE 517–I. *Average radiation characteristics of planets*

Planet	Incident solar radiation intensity (watts/sq. ft.)	Planet reflectivity (albedo)	Planet thermal radiation (watts/sq. ft.)	Planet temp. (°K)
Earth	130.0	0.36	20.7	250
Mars	56.2	0.148	12.0	226
Venus	245.0	0.67	20.3	249
Earth's Moon	130.0	0.072	30.1	284

TABLE 517-II. *Solar electromagnetic energy distribution*

Wavelength band (angstroms)	Percent of total energy	Allowable variation of band energy
(Note 1)		
1,800- 2,500	0.2	±15%
2,500- 3,300	2.8	±10%
3,300- 5,000	20.0	±10%
5,000- 7,000	26.0	±10%
7,000- 9,000	17.0	±10%
9,000-11,000	11.0	±10%
11,000-15,000	12.0	±10%
15,000-30,000	11.0	±10%

Note 1. Due to the cost involved and difficulties in simulation, the need for simulating the 1,800-2,500°A wavelength band should be carefully analyzed.

2.3 Heat flux simulator. 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.

(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 (a) with a uniform external finish (α/ξ), (b) with no sensitive parts mounted in deep crevices, where the collimation of the radiation would be important, or (c) 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 non-uniform α/ξ surface finishes.

If the above conditions are met, and the decision is made to perform the simulation with a heat flux source test, the temperature of each heat flux source which irradiates the spacecraft may be established from the following equation:

$$\sigma T_s^4 = \frac{\alpha}{\xi} (S + e) + w$$

where,

σ = Boltzman's constant = 5.669 x 10^{-8} watts meter^{-2} deg. $K)^{-4}$

T_s = Temperature of shroud (heat source) in degrees K

α = Absorptivity of the spacecraft surface irradiated. This is the ratio of the incident energy with spectral characteristics of the sun's radiation which would be absorbed by the surface to the incident energy of the same spectral and intensity characteristics which would be absorbed by a true black body surface.

ξ = Emissivity of the spacecraft surface irradiated at the temperature T_s. This is the same as the ratio of the emissive power of the spacecraft surface at the temperature T_s and the emissive power of the black body at the same temperature.

S = Intensity of the sun's radiation being simulated in watts meter^{-2}.

e = Intensity of the planet albedo being simulated in watts meter^{-2}.

w = Intensity of the planet thermal radiation being simulated in watts meter^{-2}.

The heat flux sources may consist of isothermal shrouds maintained at the temperatures as computed from the preceding equation. The shrouds should have the emissivity characteristics of a true black body for the temperature as computed from the equation to be correct.

Those surfaces of the spacecraft which would not be irradiated either by the sun or planet radiation but would normally "see" black space should view "black" chamber shrouds maintained near the temperature of liquid nitrogen (—195° or 78° K).

The above is intended to serve only as a guide for establishing temperatures to be employed in space thermal-vacuum testing. The exact temperature must be computed considering specific spacecraft geometric and surface characteristics, and thermal vacuum test equipment configuration. These proper simulation temperatures would be stated in the specific space thermal-vacuum test procedure.

3. *Preparation for test. In preparing the* environmental and flight program for a test, *typical information* needed would be as follows:

(a) Need for simulating planet/moon radiation/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).

(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 rechargeable batteries for the vehicle's primary power source.

(k) Emission of fuels and oxidizers.

(l) Statement of reliability and failure criteria.

(m) Other applicable requirements.

3.1 Test discipline.

3.1.1 *Solar simulation.* The test item shall be subjected to a pressure of 10^{-5} Torr. or lower in order to eliminate heat transfer from the vehicle to its surroundings by convection. The test item shall also "see" black coated chamber walls maintained at —195° C (78° K) in order to simulate the heat sink of space. Simulated solar radiation shall be applied to the test item in the direction corresponding to that of the sun in space. The total solar energy shall be equal to the applicable value of table 517–I, column 2, and variations of this intensity with time shall be kept to ±2.5 percent or less. At all points in the test plane, the intensity shall not deviate by more than ±2.5 percent from the average, measured by a sensor of area 0.1 ft.^{2} or 1/1,000 of the irradiated area, whichever is smaller. To insure uniformity in depth, the field angle of the simulated sun shall not exceed 4 degrees, except in special cases, and should be less than 2 degrees, if possible. As it is likely that the spectrum of the simulated radiation will differ markedly in certain wavelength regions from the spectrum of the true solar radiation, which is listed in table 517-II, the total effective absorptance of the surface of the test item shall not differ by more than ±2.5 percent from the total solar absorptance value. If photovoltaic devices and concentrator devices are to be tested, much tighter tolerances are required on uniformity and field angle.

3.1.1.1 *Thermal effects, Planet/moon radiation/albedo.* When the mission of the test item is such that the flight path will lie sufficiently near a planet or moon for a time period long enough that the temperature of any part of the test item may vary by more than 10° C from the temperature it would have if no planet or moon were present, simulation of the planet/moon radiation/albedo should be attempted in addition to direct solar radiation.

The minimum acceptable test requirements for simulating the effects of planet/moon radiation/albedo entail simulation of the maximum and minimum incident energy conditions to be expected in the given orbit. The secondary radiation flux must be adjusted for the actual orbital altitude.

In general, as the space vehicle may exhibit appreciable thermal lag, the albedo and thermal radiation flux should be programmed to follow the incident energy variations that will be met along the actual orbital path.

Note: Speficication of temperature tolerances is meaningless unless the user is willing to pay the dollar cost in terms of facility equipment and sophistication.

3.1.2 *Time.* 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 the approximate duration of the mission. Test items 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. A pressure of 1 x 10^{-8} Torr. or lower shall be employed where changes in physical properties of materials, outgassing, cold welding, etc., are of concern. A pressure level of 1 x 10^{-10} Torr. or lower shall be employed for friction experiments in space.

4. Procedure-performance of test. The test item shall be placed in the test chamber in accordance with section 3, paragraph 3.2.2. 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 section 3, paragraph 3.2.1. 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 paragraph 2.1.2 of this test method and the chamber walls cooled to —195° C (78° K). Thermal energy corresponding to the applicable value and manner of exposure determined through compliance with 2.1.1 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 section 3, paragraph 3.2.1. 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 section 3, paragraph 3.2.4.

5. Summary. The following details shall be specified in the equipment specification:

(a) Pretest data required (section 3, paragraph 3.2.1).

(b) All information necessary for the completion of 3(a) through 3(m).

(c) Length of time required for measurements.

METHOD 518

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—Place the test item in the test chamber in accordance with section 3, paragraph 3.2.2.

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 2½ 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 2½ 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 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.

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 2½ 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 the item and compare the results with the data obtained in accordance with section 3, paragraph 3.2.1. During this period, special attention shall be given to electrical and electronic test items for erratic operation or malfunction resulting from arcing or corona effects.

Step 16—Inspect the test item in accordance with section 3, paragraph 3.2.4.

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

(a) Pretest data required (section 3, paragraph 3.2.1.).

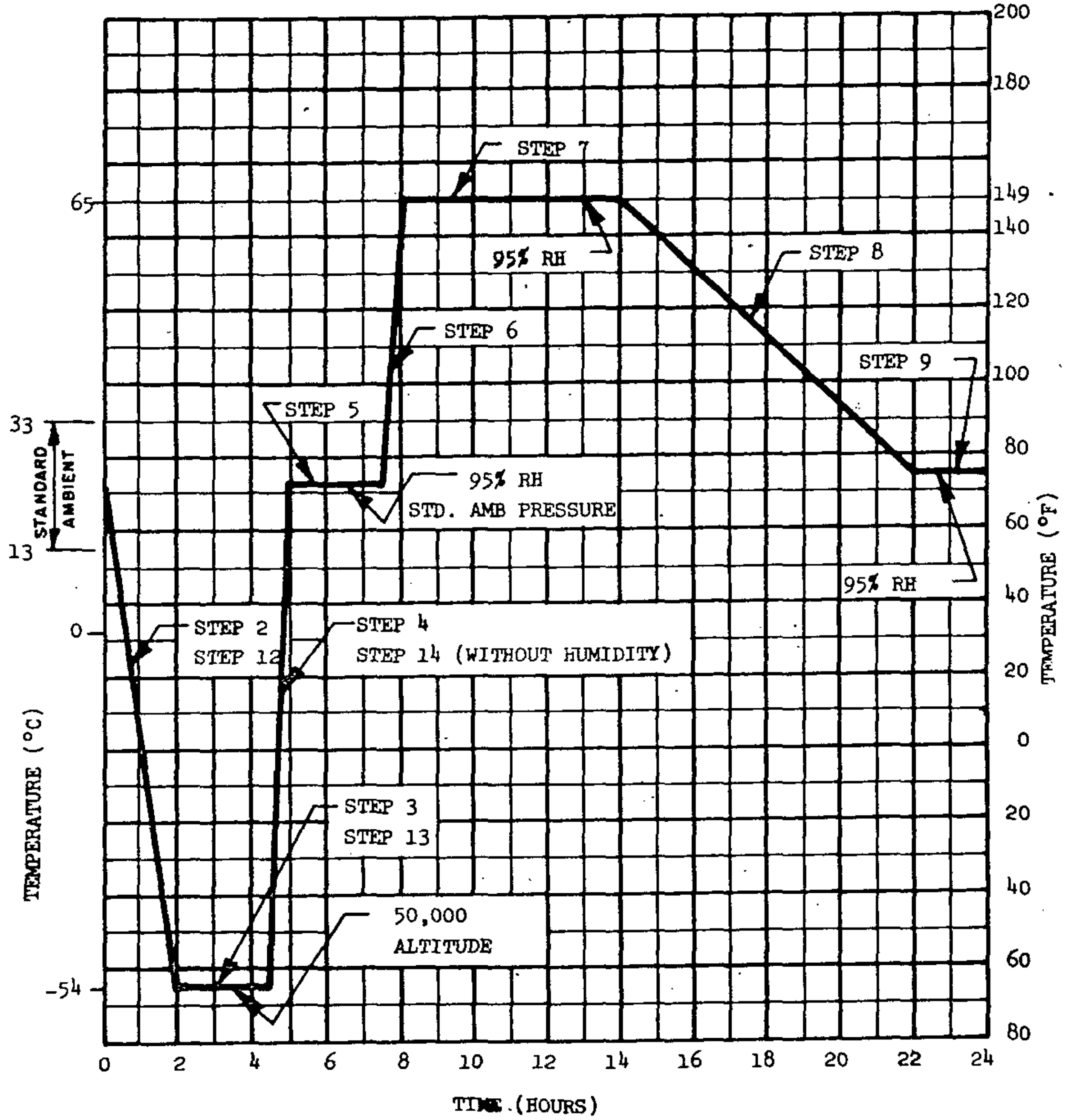


FIGURE 518-1. *Temperature-humidity-altitude cycle (Procedure I).*

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SPECIFICATION ANALYSIS SHEET

Form Approved Budget
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INSTRUCTIONS

This sheet is to be filled out by personnel either Government or contractor, involved in the use of the specification in procurement of products for ultimate use by the Department of Defense. This sheet is provided for obtaining information on the use of this specification which will insure that suitable products can be procured with a minimum amount of delay and at the least cost. Comments and the return of this form will be appreciated. Fold on lines on reverse side, staple in corner, and send to preparing activity.

SPECIFICATION MIL-STD-810B Environmental Test Methods

ORGANIZATION	CITY AND STATE

CONTRACT NO.	QUANTITY OF ITEMS PROCURED	DOLLAR AMOUNT $

MATERIAL PROCURED UNDER A

○ Direct Government Contract ○ Subcontract

1. HAS ANY PART OF THE SPECIFICATION CREATED PROBLEMS OR REQUIRED INTERPRETATION IN PROCUREMENT USE?
   A. GIVE PARAGRAPH NUMBER AND WORDING.
   B. RECOMMENDATIONS FOR CORRECTING THE DEFICIENCIES.

2. COMMENTS ON ANY SPECIFICATION REQUIREMENT CONSIDERED TOO RIGID.

3. IS THE SPECIFICATION RESTRICTIVE?

○ YES ○ NO IF "YES", IN WHAT WAY?

4. REMARKS (Attach any pertinent data which may be of use in improving this specification. If there are additional papers, attach to form and place both in an envelope addressed to preparing activity.)

SUBMITTED BY (Printed or typed name and activity) DATE

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