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MIL-STD-810A (USAF)
23 JUNE 1964
SUPERSEDING
MIL-STD-810 (USAF)
14 JUNE 1962

MILITARY STANDARD
ENVIRONMENTAL TEST METHODS
FOR AEROSPACE
AND
GROUND EQUIPMENT

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DEPARTMENT OF THE AIR FORCE

1. This standard has been approved by the Air Force and is published to establish environmental test methods for aerospace and ground equipment.

2. Use of this standard by activities under cognizance of the Air Force shall be mandatory effective on date of issue.

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

SEG, (SEPS)
Wright-Patterson AFB, Ohio 45433

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SECTION 1

SCOPE

1.1 PURPOSE. This standard establishes uniform methods for environmental tests for determining the resistance of aerospace and ground equipment to the deleterious effects of natural and induced environments peculiar to military operations. The test methods contained herein are intended to specify suitable conditions obtainable in the laboratory which give test results similar to actual service conditions, to obtain reproducibility of the results of tests, and to serve as a guide for those engaged in preparing the environmental test portions of individual equipment specifications. THIS STANDARD IS INTENDED FOR NEW ENGINEERING AND SHOULD NOT BE APPLIED IN RETROSPECT TO EXISTING GOVERNMENT CONTRACTS OR TO FUTURE CONTRACTS INTENDED FOR RE-PROCURING INVENTORY ITEMS WHICH ARE ALREADY QUALIFIED UNDER SOME OTHER SPECIFICATION.

1.2 APPLICATION OF TEST METHODS. The test methods contained in this standard apply broadly to all items of aerospace and ground equipment, except air frames and primary power plants, 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 INDIVIDUAL EQUIPMENT SPECIFICATION. Transition tables I, II, and III contained in the appendix of this standard give MIL-STD-810 (USAF) tests which may be used, *when authorized by the procuring activity,* in lieu of the tests given in the following specifications:

MIL-T-5422 (ASG) Environmental Testing for Aircraft Electronic Equipment.

MIL-E-5272 (ASG) Environmental Testing, Aeronautical and Associated Equipment.

MIL-E-4970 (USAF) Environmental Testing, Ground Support Equipment. (This specification has been canceled for new design.)

1.3 NUMBERING SYSTEM. The test methods are designated by the numbers 500 through 599 inclusive. The test methods are serially numbered in the order in which they are introduced into this standard.

1.3.1 *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 500.2, etc. Any such revisions are contained in the last page of this standard. It is intended that each test method be independently revised, either totally or in part, when the need arises.

1.4 IDENTIFICATION OF TEST METHODS. The test methods contained in this standard are identified as follows:

Test Method No.	*Method Title*
500	Low Pressure
501	High Temperature
502	Low Temperature
503	Temperature Shock
504	Temperature-Altitude (Cycling)
505	Sunshine
506	Rain
507	Humidity (Cycling)
508	Fungus
509	Salt Fog
510	Sand and Dust
511	Explosive Atmosphere
512	Immersion (Leakage) (Discontinued)
513	Acceleration
514	Vibration
515	Acoustical Noise
516	Shock
517	Low Pressure-Solar Energy

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SECTION 2

APPLICABLE DOCUMENTS

The issues of the following documents in effect on the date of invitation for bids, form a part of this standard to the extent specified herein.

Specifications
Military

MIL-G-5572	Gasoline, Aviation: Grades 80/87, 91/96, 100/130, 115/145
MIL-J-5624	Jet Fuels, Grades JP-4, and JP-5
MIL-F-8261	Fungus Resistance Tests, Aeronautical and Associated Materials, General Specification for
MIL-C-8811	Chamber, Rain Testing
MIL-C-9435	Chamber, Explosion-Proof Testing
MIL-C-9436	Chamber, Sand and Dust Testing
MIL-C-9452	Chamber, Fungus Resistance Testing

OTHER PUBLICATIONS. The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated the issue in effect on the date of invitation for bids shall apply.

U. S. Standard Atmosphere, 1962

(Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20325)

S1. 1-1960

American Standard Acoustical Terminology (Including Mechanical Shock and Vibration)

(American Standards Association Inc., 10 East 40th Street, New York 16, New York)

Method D880

The Incline Impact Test for Shipping Containers
(American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pennsylvania)

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SECTION 3

GENERAL REQUIREMENTS

3.1 FORMULATION OF TEST. The test shall be performed in the manner and sequence or combination specified in the individual equipment specification. When the test sequence is not specified it is SUGGESTED that the test sequence for the test item and its intended use be selected from table I. When selecting tests the anticipated environmental conditions should be carefully considered. Only those conditions that reflect actual service usage, including shipping and ground handling, should be taken into account. Those conditions which would adversely affect or most probably induce a malfunction of the test item should be given emphasis.

3.2 PERFORMANCE OF TEST.

3.2.1 *Pretest Performance Record.* Prior to conducting any of the tests the test item shall be operated under standard ambient conditions 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 during or at the conclusion of the test.

3.2.2 *Installation Of Test Item In Test Facility.* The test item shall be installed in the test facility at room temperature in a manner that will simulate service usage. Plugs, covers, and inspection plates used in service shall remain in place. When mechanical or electrical connections are not used the connections normally protected in service shall be adequately covered. The test item shall then be operated to determine that no malfunction or damage was caused due to faulty installation or handling. The requirement for operation following installation of the test item in the test facility is applicable only when operation is required during exposure to the specified test.

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

3.2.4 *Inspection and Failure Criteria.* When specified herein the test item shall be visually inspected and a record made of any damage resulting from the test. Normally the test item shall be removed from the test facility prior to inspection as stated in the various test methods. However, in those instances where the installation of the test item in or on the test facility is complex, costly, or time consuming, the performance of the inspection may be accomplished with the test item inside or on the test facility providing all inspection criteria can be met as stated herein. (If a test chamber is used for the test and the inspection is performed inside the test chamber, the test chamber shall be returned to conditions of room ambient temperature, atmospheric pressure, and relative humidity before proceeding with the inspection.) Deterioration, corrosion, or change in tolerance limits of any internal or external components which could in any manner prevent the test item from meeting operational requirements shall provide reason to consider the test item as having failed to withstand the conditions of the test.

3.3 TEST CONDITIONS. Unless otherwise specified herein, or in the individual equipment specification, all measurements and tests shall be made at room ambient temperature, atmospheric pressure, and relative humidity. Whenever these conditions must be closely controlled in order to obtain reproducible results a reference temperature of 23°C (73°F), a relative humidity of 50 percent, and an atmospheric pressure of 30 inches of mercury respectively shall be used together with whatever tolerances are required to obtain the desired precision of measurement. Actual ambient test conditions should be recorded periodically during the test period.

3.3.1 *Measurements of Test Conditions.* All measurements of test conditions shall be made with instruments of the accuracy specified in 3.3.3.

3.3.2 *Tolerance of Test Conditions.* The maximum allowable tolerances of test conditions (exclusive of accuracy of instruments), except as stated in any one of the test methods of this standard or as stated in the individual equipment specification, shall be as follows:

a. Temperature: plus or minus 2°C (3.6°F).

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TABLE I

Suggested Test Sequence for Aerospace and Ground Equipment

Test Method	Test (Note 1)	Ground (Note 2)					Aerospace (Note 3)									
		A	B	C	D	E	a	b	c	d	e	f	g	h	i	j
	Temperature & Pressure															
500	Low Pressure	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}	${}^{2}3^{1}$	${}^{2}5^{1}$	${}^{2}5^{1}$	${}^{2}5^{1}$	${}^{2}3^{1}$	${}^{2}5^{1}$	2	4	${}^{3}5^{1}$	${}^{2}5^{1}$
504	Temperature—Altitude (Cycling)	—	—	—	—	—	5^{5}	4^{5}	4^{5}	4^{5}	${}^{3}5^{51}$	4^{5}	5^{5}	5^{5}	4^{5}	4^{5}
505	Sunshine	3^{1}	3^{1}	4^{1}	4^{1}	4^{1}	—	—	—	—	—	—	6^{3}	—	—	—
	Corrosion & Erosion															
506	Rain	7^{1}	7	6	10^{1}	10	—	6^{1}	7^{1}	7^{1}	${}^{3}6^{1}$	—	—	${}^{3}6^{1}$	—	—
507	Humidity (Cycling)	8	8	7	11	11	7	7^{1}	8	8	7	6	9	7	6^{1}	11
508	Fungus	9	9	8	12	12	8	8^{1}	9	9	${}^{3}8^{1}$	7	10	8	${}^{3}7^{1}$	12
509	Salt Fog	10^{1}	10	9	13^{1}	13	9^{1}	9^{1}	10^{1}	10^{1}	${}^{3}9^{1}$	8^{1}	11^{31}	9^{3}	${}^{3}8^{1}$	13^{31}
510	Sand & Dust	6^{1}	6	10	6^{1}	6	6	10^{3}	11^{3}	6	10	9	7	10	9^{3}	6
	Dynamics															
511	Explosive Atmosphere	—	—	11	7^{1}	7^{1}	11^{3}	—	—	12^{3}	—	11^{3}	13^{31}	12	11^{21}	8^{21}
512	Immersion (Discont'd)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
513	Acceleration	—	—	—	—	—	10	11	12	11	11	10	12	11	10	7
514	Vibration	12	12	13	9	9	13	13	14	14	13	13	14	14	13	10
515	Accoustical Noise	—	—	—	—	—	14^{41}	14^{41}	15^{41}	15	14	14	16^{1}	15	14	14
516	Shock	11	11	12	8	8	12	12	13	13	12	12	15	13	12	9
517	Low Pressure—Solar Energy (See Note 3)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

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 missiles in addition to those tests not marked with a superscript.
3. Test not generally applicable to airborne or ground launched missiles.
4. Test not generally applicable to aircraft or helicopters.
5. Test not generally applicable to ground launched missiles.

Note 2: *Ground Equipment.*

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: *Aerospace Equipment.*

Equipment installed in airplanes, helicopters, air launched and ground launched missiles. 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. All aerospace still and motion picture cameras and optical devices.
j. Electronic and Communications Equipment. All such equipment.

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b. Pressure: When measured by devices such as manometers, plus or minus 5 percent or 0.06 inches of mercury, whichever provides the greatest accuracy. When measured by devices such as ion gauges, plus or minus 10 percent to 1×10^{-5} torr.

c. Relative Humidity: plus 5 percent R.H., minus 0 percent.

d. Vibration Amplitude: Sinusoidal plus or minus 10 percent. Random plus or minus 30 percent.

e. Acceleration: plus or minus 10 percent.

3.3.3 *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 or MIL-Q-9858 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-fifth 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 environmental conditions concerned.

3.3.4 *Stabilization of Test Temperature.* Unless otherwise specified, temperature stabilization will have been attained when the temperature of a centrally located component or part of the test item having the largest mass does not change more than 2°C per hour.

3.4 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.

3.4.1 *Test Chamber.*

3.4.1.1 *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.

3.4.1.2 *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.

3.4.1.3 *Location of Temperature Sensors.* Unless otherwise specified, thermocouples or equivalent temperature sensors utilized to determine the specified ambient chamber temperature shall be centrally located within the test chamber where possible and baffled or otherwise protected so as to prevent the direct impingement of conditioned air.

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

Copies of this standard for military use may be obtained as indicated in the foreword to, or the general provisions of, the Index of Military Specifications and Standards.

The title and identifying symbol should be stipulated when requesting copies of military standards.

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METHOD 500.1

LOW PRESSURE

1. PURPOSE. The low pressure test is conducted to determine the deleterious effects of reduced pressure on aerospace and ground 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 material tend to sublime and many 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. The test procedures described are intended to serve several purposes. Procedure I is applicable to ground equipment. The test is conducted to determine the ability of ground equipment to withstand the reduced pressure encountered during shipment by air and for satisfactory operation under those pressure conditions found at high ground elevations. Procedure II is applicable to installed aerospace equipment. This test is performed to determine the ability of equipment to operate satisfactorily following exposure to both reduced pressure and temperature conditions encountered during flight.

2. PROCEDURE.

Procedure I. Ground Equipment. The test item shall be placed in the test chamber in accordance with section 3.2.2. The internal chamber temperature shall be uncontrolled during the test. The chamber internal pressure shall be reduced to 3.44 inches of mercury (50,000 feet above sea level) and maintained for a period of not less than 1 hour. The chamber pressure shall then be increased to 20.58 inches of mercury (10,000 feet above sea level) and the test item operated. The results shall be compared with the data obtained in accordance with section 3.2.1. The chamber shall then be returned to room pressure and the test item inspected in accordance with section 3.2.4.

Procedure II. Aerospace Equipment. The test item shall be placed in the test chamber in accordance with section 3.2.2. The test chamber internal temperature shall be reduced to —54°C (—65°F). The test chamber internal pressure shall then be reduced to the lowest pressure condition for which the test item is designed to operate while maintaining the specified temperature. (When performance requirements are specified in altitude in feet the equivalent pressure can be obtained from the U.S. Standard Atmosphere, 1962). The conditions of pressure and temperature shall be maintained for a period of not less than 1 hour. At the conclusion of this time period and while at the specified pressure and temperature the test item shall be operated and the results compared with the data obtained in accordance with section 3.2.1. With the test item still operating, the test chamber internal pressure shall be gradually increased to room pressure. The rate of pressure change shall be as specified in the individual equipment specification. During this period special attention shall be given to electrical and electronic test items for erratic operation or malfunction resulting from arcing or corona. The test item shall then be removed from the test chamber and inspected as specified in section 3.2.4.

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METHOD 501.1

HIGH TEMPERATURE

1. PURPOSE. The high temperature test is conducted to determine the resistance of aerospace and ground 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. The minimum temperature of 52°C (125°F) is established as representing the maximum temperature of the ambient air. The temperature of 71°C (160°F) results from the addition of 19.4°C or 35°F due to solar radiation. Higher temperatures can result from the operation or confinement within cases or enclosures of equipment which generate heat as a by-product.

2. PROCEDURE.

Procedure I. The test item shall be placed in the test chamber in accordance with section 3.2.2. The internal chamber temperature shall be raised to 71°C (160°F) and maintained for a period of not less than 48 hours. The internal chamber relative humidity shall not exceed 15 per cent. At the conclusion of the exposure period the internal chamber temperature shall then be adjusted to the highest operating temperature under which the test item is designed to operate and maintained until temperature stabilization of the test item is reached. The test item shall then be operated and the results compared with the data obtained in accordance with section 3.2.1. The test item shall then be removed from the test chamber, returned to room temperature and inspected as specified in section 3.2.4.

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METHOD 502.1

LOW TEMPERATURE

1. PURPOSE. The low temperature test is conducted to determine the effects of low temperature on aerospace and ground 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. The following conditions are established as standard: —62°C (—80°F) for surface transportation and storage, —54°C (—65°F) for world wide operation, —40°C (—40°F) for operation in Continental United States, and 2°C (35°F) for equipment operated in temperature controlled areas.

2. PROCEDURES.

Procedure I. The test item shall be placed in the test chamber in accordance with section 3.2.2. The internal chamber temperature shall be lowered to —62°C (—80°F) and maintained for a period of not less than 48 hours. At the conclusion of the exposure period the test item may be removed from the test chamber and inspected in accordance with section 3.2.4. The internal chamber temperature shall then be adjusted to the lowest temperature under which the test item is designed to operate and maintained until temperature stabilization of the test item is reached. The test item shall then be operated and the results compared with the data obtained in accordance with section 3.2.1. The test item shall then be removed from the test chamber, returned to room temperature and inspected as specified in section 3.2.4.

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METHOD 503.1

TEMPERATURE SHOCK

1. PURPOSE. The temperature shock test is conducted to determine the effects on aerospace and ground equipment of sudden changes in temperature of the surrounding atmosphere. Cracking or rupture of materials due to sudden dimensional changes by expansion or contraction is the principal difficulty to be anticipated. This could occur in service to aerospace equipment during rapid altitude changes and to ground equipment being moved from heated storage buildings to low temperature outdoor areas, or vice versa.

2. PROCEDURE.

Procedure I. The test item shall be placed in the test chamber in accordance with section 3.2.2 and the internal chamber temperature raised to 85°C (185°F), and maintained for a period of not less than 4 hours. At the conclusion of this time period the test item shall, within 5 minutes, be transferred to a cold chamber with an internal temperature of —40°C (—40°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.) The test item shall be exposed to this temperature for a period of not less than 4 hours. At the conclusion of this time period the test item shall, within 5 minutes, be returned to the high temperature chamber maintained at 85°C (185°F). This constitutes one cycle. The number of continuous cycles shall be three. The duration of exposure at each extreme temperature shall not be less than that specified and may be extended to overnight exposure to prevent interruption of the transfer sequence. At the conclusion of the low temperature portion of the third cycle, the test item shall be removed from the test chamber and stabalized at room temperature. The test item shall then be operated and the results compared with the data obtained in accordance with section 3.2.1. The test item shall then be inspected as specified in section 3.2.4.

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METHOD 504.1

TEMPERATURE-ALTITUDE (CYCLING)

1. PURPOSE. The temperature-altitude test is intended primarily for electronic equipment installed in aircraft capable of operation from sea level to 100,000 ft. Before applying this test to other types of aerospace equipment, the test conditions and procedures specified in this test method should be carefully analyzed for applicability. Aerospace 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, high and low temperature and high relative humidity. 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. 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.

TABLE 504-I

ENVIRONMENTAL CONDITIONS

Equipment Class *	Equipment Mode: Continuous	Equipment Mode: Non-operating	Temperature	Altitude
1	x		—54 to 55°C	Sea level to 50,000 feet
		x	—62 to 85°C	
1A	x		—54 to 55°C	Sea level to 30,000 feet
		x	—62 to 85°C	
2	x		—54 to 71°C	Sea level to 70,000 feet
		x	—62 to 95°C	
3	x		—54 to 95°C	Sea level to 100,000 feet
		x	—62 to 125°C	
4	x		—54 to 125°C	
		x	—62 to 150°C	

* Equipment classes, as used in this test method are established for illustrating the equipment operaing mode vs. the temperature altitude relationship and are not intended to be analogous to equipment categories used elsewhere within this standard.

3. PROCEDURE.

Procedure I. The test item shall be placed in the test chamber in accordance with section 3.2.2 making connections and attaching instrumentation as necessary. In general, the testing schedule outline 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. Alternate temperature-altitude conditions and test item operating modes are given in figures 504-1 through 504-4. When changing chamber conditions from those required for one step to those required for any other step, the sequence given in table 504-II or in any sequence, the rates of temperature and pressure changes shall be the maximum permitted 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 the 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 for 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

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Table 504-II. Test chamber conditions for temperature-altitude tests

Class*	Step	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Temp	-62°C	-54°C	-54°C	-10°C	85°C	55°C	71°C	omit	30°C	47°C	20°C	35°C	Omit	Room amb-ient
	Alt (in ft)	Atm	Atm	50,000	Atm	Atm	Atm	Atm		40,000	40,000	50,000	50,000		
	Time	2 hrs				16 hrs	4 hrs	30 min		4 hrs	30 min	4 hrs	30 min		
1A	Temp	-62°C	-54°C	-54°C	-10°C	85°C	55°C	71°C	omit	48°C	64°C	40°C	57°C	Omit	Room amb-ient
	Alt (in ft)	Atm	Atm	30,000	Atm	Atm	Atm	Atm		20,000	20,000	30,000	30,000		
	Time	2 hrs				16 hrs	4 hrs	30 min		4 hrs	30 min	4 hrs	30 min		
2	Temp	-62°C	-54°C	-54°C	-10°C	95°C	71°C	95°C	omit	36°C	60°C	10°C	35°C	Omit	Room amb-ient
	Alt (in ft)	Atm	Atm	70,000	Atm	Atm	Atm	Atm		50,000	50,000	70,000	70,000		
	Time	2 hrs				16 hrs	4 hrs	30 min		4 hrs	30 min	4 hrs	30 min		
3	Temp	-62°C	-54°C	-54°C	-10°C	125°C	95°C	125°C	125°C	60°C	90°C	20°C	50°C	75°C	Room amb-ient
	Alt (in ft)	Atm	Atm	80,000	Atm	Atm	Atm	Atm	Atm	50,000	50,000	100,000	100,000	100,000	
	Time	2 hrs				16 hrs	4 hrs	30 min	10 min	4 hrs	30 min	4 hrs	30 min	10 min	
4	Temp	-62°C	-54°C	-54°C	-10°C	150°C	125°C	150°C	150°C	90°C	115°C	50°C	75°C	185°C	Room amb-ient
	Alt (in ft)	Atm	Atm	80,000	Atm	Atm	4 hrs	Atm	Atm	50,000	50,000	100,000	100,000	100,000	
	Time	2 hrs				16 hrs	Atm	30 min	10 min	4 hrs	30 min	4 hrs	30 min	10 min	

*For class of equipment see figures 504-1 through 504-4 and table 504-I

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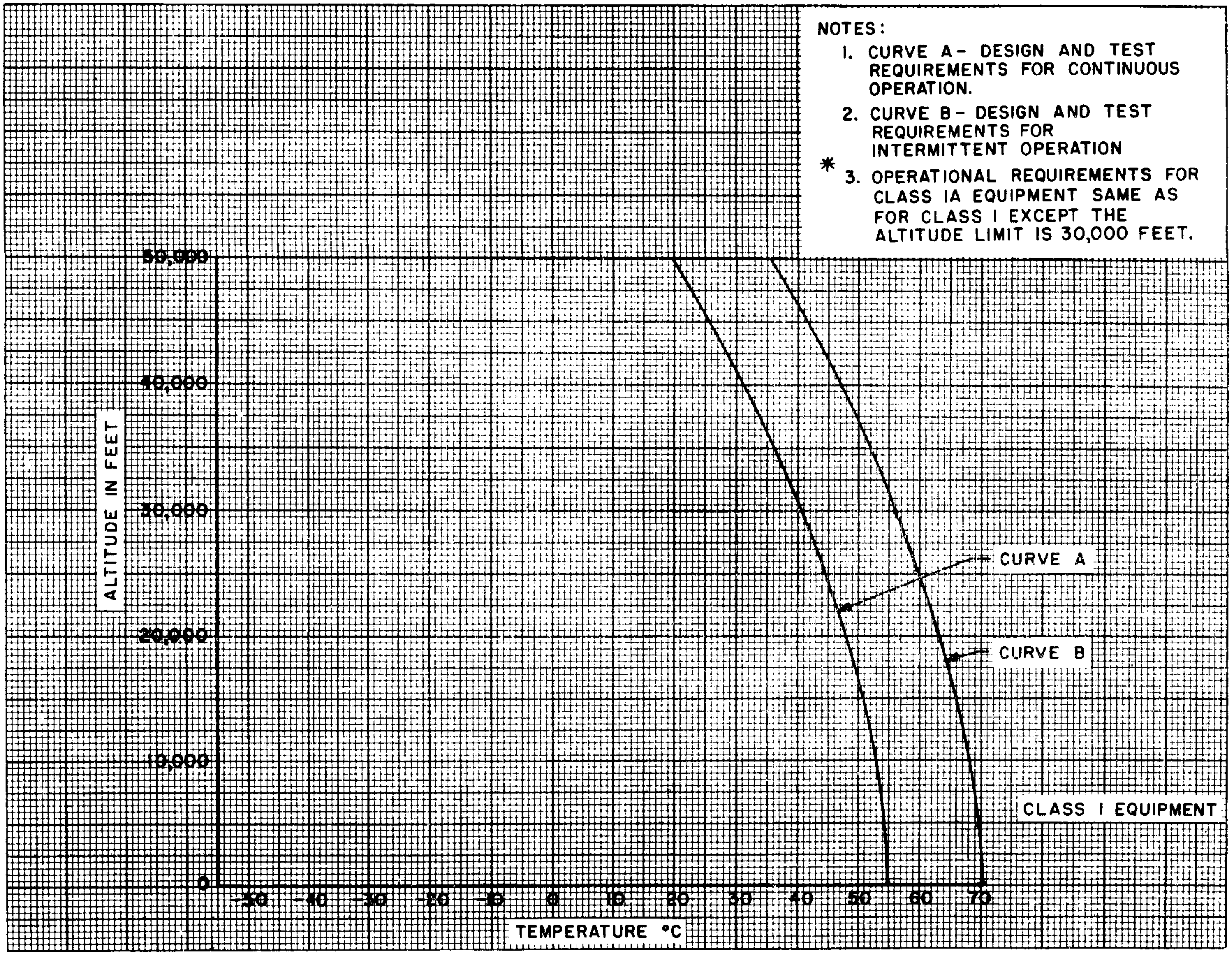

*Figure 504-1. Operational requirements for class 1 and 1A aerospace equipment. Temperature vs. altitude.**

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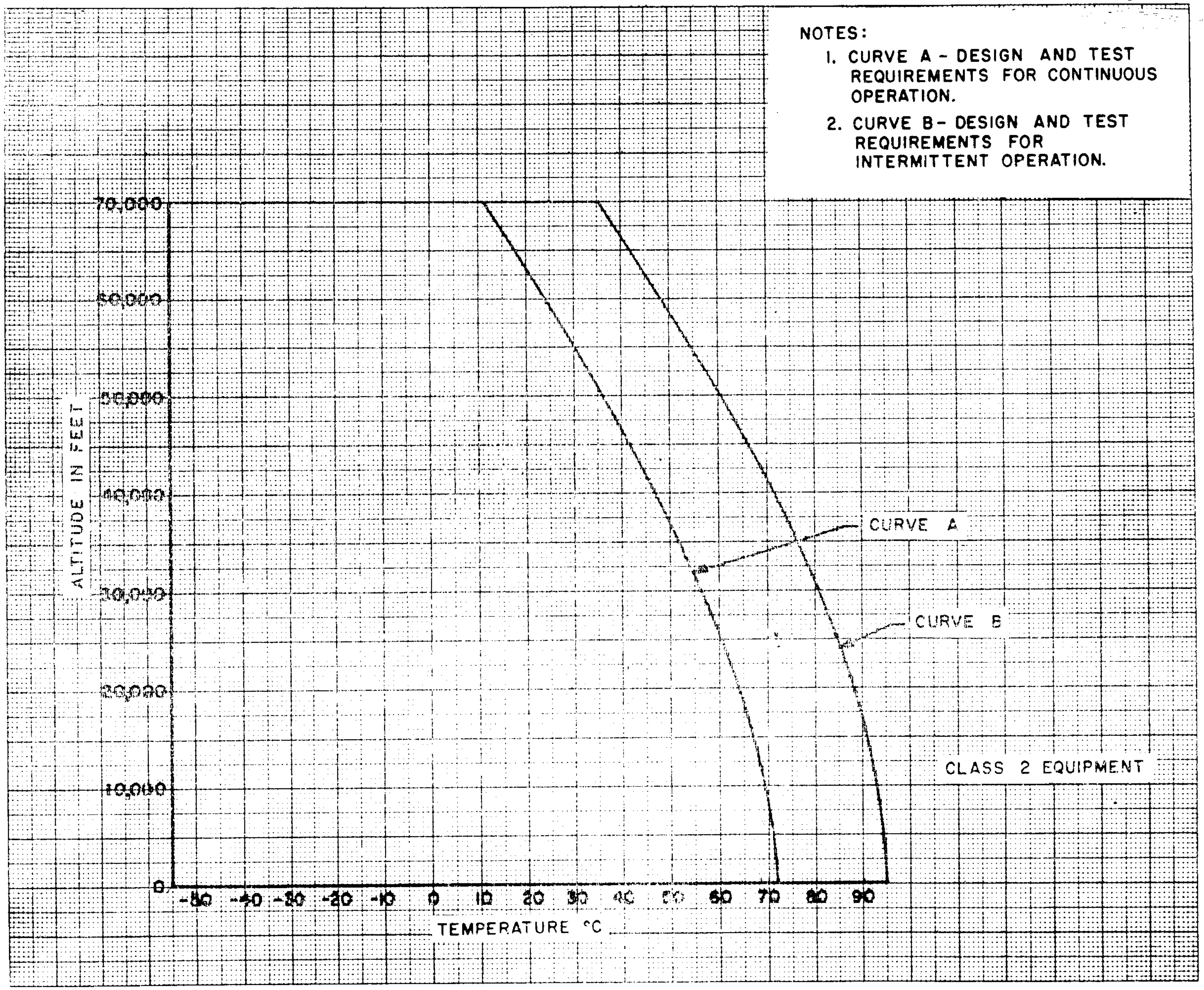

Figure 504-2. Operational requirements for class 2 aerospace equipment. Temperature vs. altitude.

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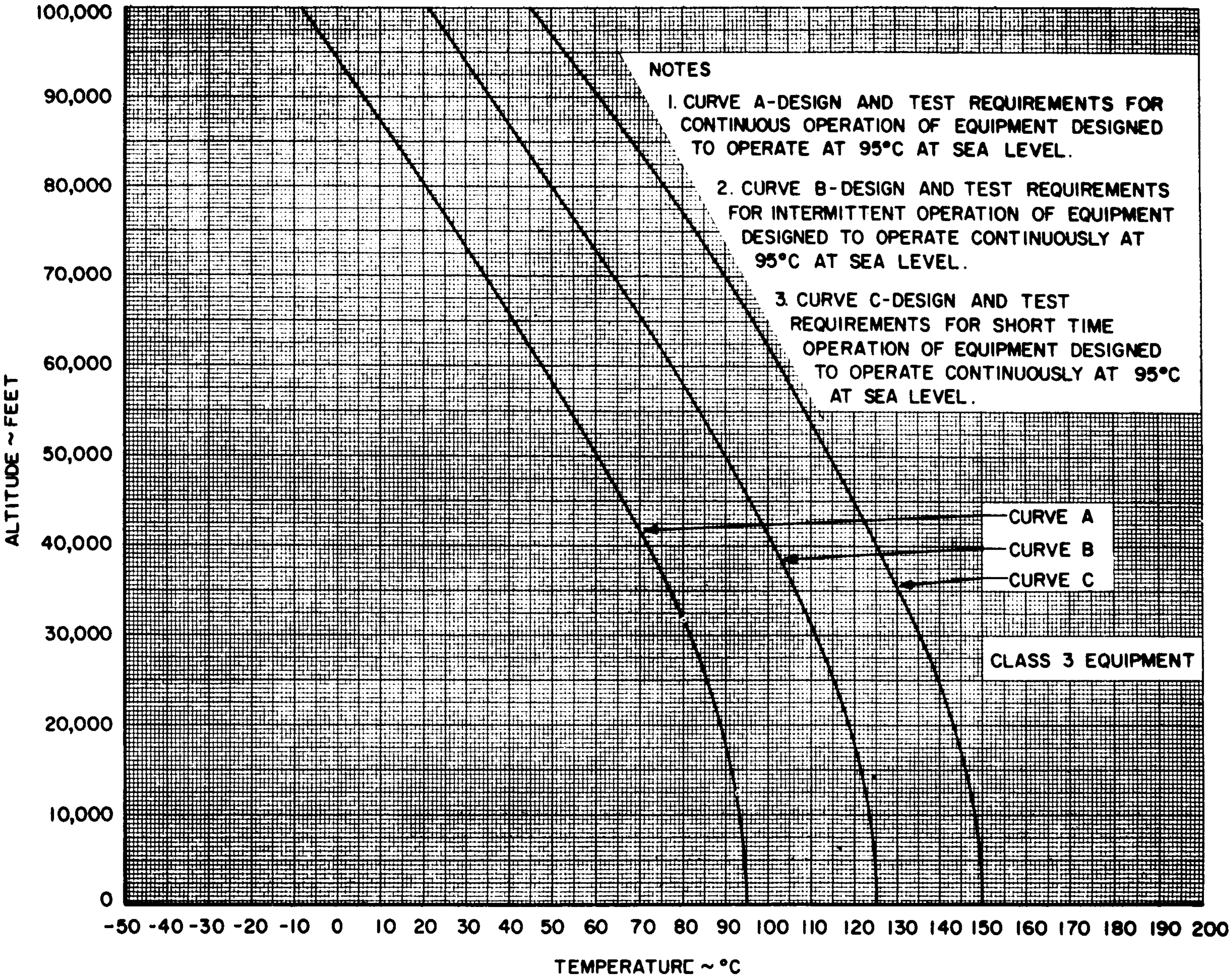

Figure 504-3. Operational requirements for class 3 aerospace equipment. Temperature vs. altitude.

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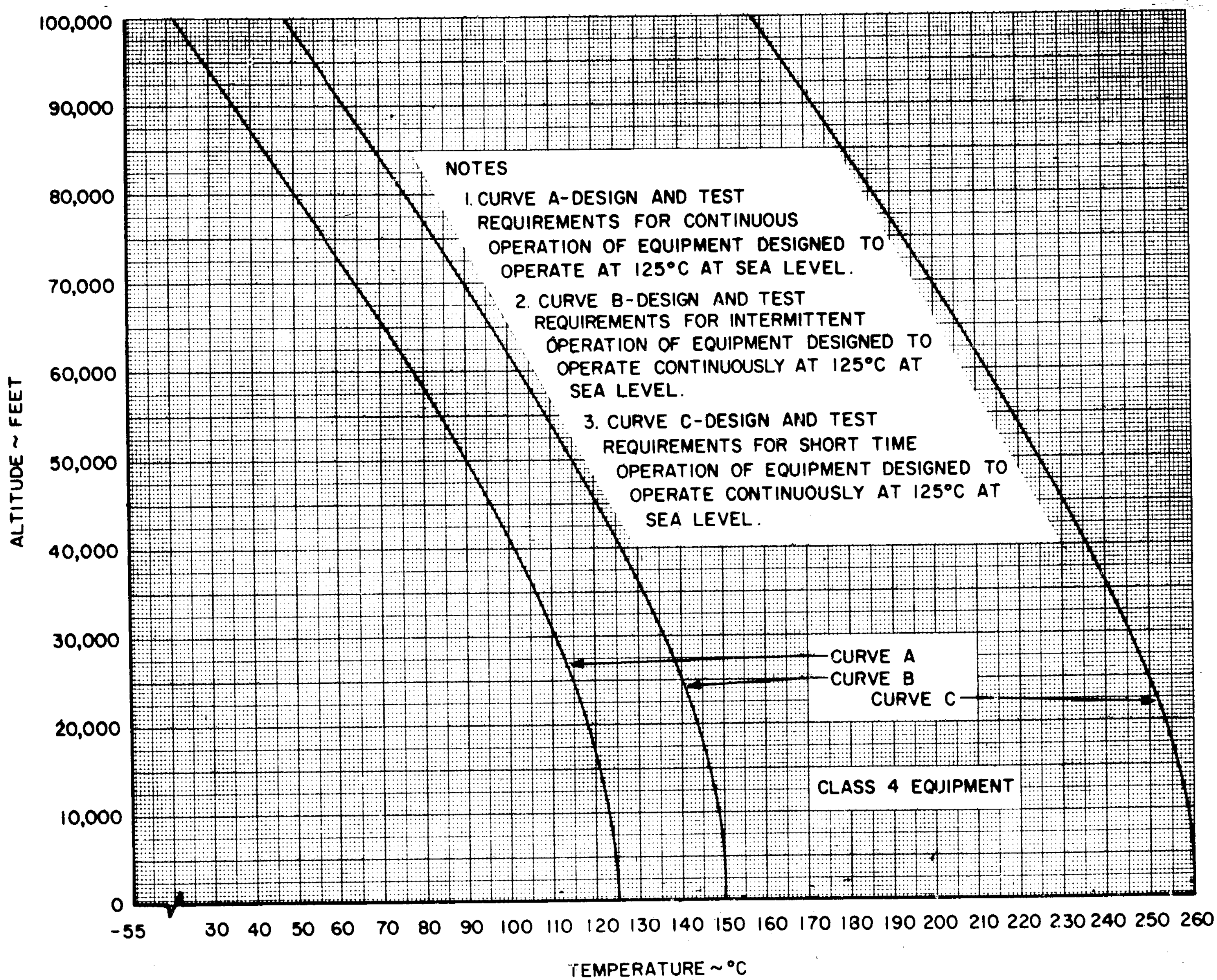

Figure 504-4. Operational requirements for class 4 aerospace equipment. Temperature vs. altitude.

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time. The test item shall then be turned off and restabilized at —54°C (—65°F). This constitutes 1 cycle. The operation cycle shall be repeated 2 more times (see notes (a) and (b)). The ambient temperature shall be maintained at —54°C (—65°F).

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 —54°C (—65°F) 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 3.2.1. 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 chamber conditions and the test item temperature have stabilized, turn the test item on the highest specified input voltage and permit it to operate continuously for the period of time specified in table 504-II. Thermocouple readings 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 7 in table 504-II. After chamber conditions and the test item temperature have stabilized, the test item shall be operated at the highest specified input voltage for 4 cycles, each cycle consisting of the period of operation specified in table 504-II, 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 shall be recorded every 10 minutes.

Step 8—With the test item nonoperating, adjust the chamber condition to those specified for step 8 in table 504-II. After the chamber conditions and test item temperature have been stabilized, the test item shall be operated at the highest specified input voltage for 4 cycles. Each cycle shall consist of the period of operation specified in table 504-II followed by 15-minute off period. The test item shall be checked for satisfactory operation during each period of operation and the results recorded. Thermocouple readings 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 and the altitude adjusted to that specified. Following chamber and test item temperature stabilization the test item shall be operated at the highest specified input voltage for that period of time specified in table 504-II. Thermocouple readings shall be recorded every 30 minutes.

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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 chamber and test item temperatures have stabilized, operate the test item at the highest specified input voltage for 4 cycles, each cycle consisting of the period of operation specified 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 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 the period of time specified in table 504-II. Thermocouple readings 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 the chamber conditions and test item temperature have stabilized, operate the test item at the highest specified input voltage for 4 cycles, each cycle consisting of the period of operation specified in table 504-II 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 shall be recorded for every 10 minutes of operation.

Step 13—With the test item nonoperating, stabilize the chamber and test item to those conditions specified for step 13 in table 504-II. Following stabilization the test item shall be operated at the highest specified input voltage for 4 cycles, each cycle consisting of the period of operation specified followed by a 15-minute off period. The test item shall be checked for satisfactory operation during each period of operation and thermocouple readings 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 3.2.1.

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 individual 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.

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METHOD 505.1

SUNSHINE

1. PURPOSE The sunshine test is conducted to determine the effect of heat resulting from solar energy on aerospace and ground equipment. For the purpose of this test, only the terrestrial portion of the solar spectrum is considered. The limits and energy levels given in Procedure I provide the simulated effects of natural sunshine. The ultraviolet portion simulates natural sunshine in a general way and is considered to be representative for wide area irradiation. 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 test is applicable to any item of equipment which may be exposed to solar radiation during survice at the Earth's surface or in the lower atmosphere.

2. PROCEDURE.

Procedure I. The test item shall be placed in the test chamber in accordance with section 3.2.2 and exposed to radiant energy at the rate of 100 to 140 watts per square foot. Fifty to eighty-four watts per square foot shall be in wavelengths above 7,800 angstrom units and 4 to 8 watts per square foot shall be in wavelengths below 3,800 angstrom units. (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.) The period of the test shall not be less than 48 hours, during which time the chamber temperature shall be maintained at 45°C (113°F). At the conclusion of the exposure period, and with the temperature maintained as specified, the test item shall be operated and the results compared with the data obtained in accordance with section 3.2.1. The test item shall then be returned to room temperature and inspected in accordance with section 3.2.4.

1 watt hour = 3.413 btu

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METHOD 506.1

RAIN

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1. PURPOSE. The rain test is conducted to determine the efficiency of protective covers or cases designed to shield equipment from the elements. This test is applicable to all items of aerospace and ground 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. PROCEDURE.

Procedure I. The test item shall be placed in a rain chamber, equal to that specified in MIL-C-8811, and installed as specified in section 3.2.2. The rain chamber temperature shall be uncontrolled, except as regulated by water introduced as rain, throughout the test period. The test item shall be exposed to a simulated rainfall of 4 ± 1 inches per hour as measured at the surface of the test item by a U.S. Weather Bureau type gauge. The rainfall shall be produced by means of a water spray nozzle of such design that the water is emitted in the form of droplets having a minimum diameter of 1.5 millimeters. The temperature of the water shall be uncontrolled provided the water supply temperature is between 11° and 35°C (51.8° and 95°F). The direction of rainfall shall be 45° from the vertical. The rainfall shall be dispersed uniformly over the test area within the limits specified above. Each of the major sides of the test item shall be exposed to the simulated rainfall for a period of 30 minutes, for a total test duration of not less than 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 3.2.1. The protective cover or case shall, where possible, then be removed and the test item inspected for compliance with section 3.2.4 with particular attention to evidence of water penetration, such as free water, swelling, or other deterioration.

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METHOD 507.1

HUMIDITY (CYCLING)

1. *PURPOSE.* The humidity test is applicable to all items of aerospace and ground 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 force behind the moisture migration and penetration. Corrosion is one of the principal effects of humidity. Hygroscopic materials are sensitive to moisture and deteriorate rapidly under humid conditions. Absorption of moisture by many materials results in swelling, which destroys their functional utility and causes loss of physical strength and changes in other important mechanical properties. Insulating materials which absorb moisture may suffer degradation of their electrical properties.

2. 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 vented to the atmosphere to prevent the buildup of vapor pressure. Relative humidity shall be determined from the dry bulb wet bulb thermometer comparison method. The air velocity flowing across the wet bulb shall be not less than 900 feet per minute. Provisions shall be made for controlling the flow of air throughout the internal test chamber area where the velocity of air shall not exceed 150 feet per minute. Distilled, demineralized, or deionized water at 25°C (77°F) shall be used to obtain the specified humidity. Prior to starting the test the pH of the water shall be measured. The pH of the water shall not be less than 6.5 or greater than 7.5. If the pH is other than that specified, the pH shall be adjusted as necessary.

3. PROCEDURE.

Procedure I. Humidity Cycling. The test item shall be placed in the test chamber in accordance with section 3.2.2. Prior to starting the test the chamber temperature shall be between 20° and 38°C (68° and 100°F) with uncontrolled humidity. The temperature and relative humidity shall then be gradually raised to 71°C (160°F) and 95 percent respectively over a period of 2 hours. These conditions shall be maintained for a period of not less than 6 hours. With the relative humidity maintained at 95 percent the chamber temperature shall then be gradually reduced to 20° to 38°C (68° to 100°F) over a period of not less than 16 hours. This constitutes 1 cycle. The number of continuous cycles shall be 10 for a total test time of not less than 240 hours. At the conclusion of the test, the test item shall be removed from the chamber and returned to room ambient conditions. Excess moisture may be removed by turning the test item upside down or by wiping external surfaces only. The test item shall then be operated, the results compared with the data obtained in accordance with section 3.2.1, and inspected in accordance with section 3.2.4 within 1 hour.

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METHOD 508.1

FUNGUS

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

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

Cotton	Leather
Wood	Paper and Cardboard
Linen	Cork
Cellulose Nitrate	Hair and Felts
Regenerated Cellulose	Lens Coating Materials

2. PREPARATION OF SPORE SUSPENSION. Four groups of fungi are listed in table 508-I. One species of fungus from each group shall be used.

TABLE 508-I

Group	Organism	American Type Culture Collection Number Note 1	Quartermaster Number Note 2
I	Chateomium globosum Myrothecium verrucaria	6205 9095	459 460
II	Memneniella echinata Aspergillus niger	9597 6275	1225 458
III	Aspergillus flavus Aspergillus terreus	10836 10690	1223 82j
IV	Penicillium citrinum Penicillium ochrochloron	9849 9112	1226 477

Note 1. Source. American Type Culture Collection
2112 M Street, N.W.
Washington 6, D.C.

Note 2. Source. Mycology Laboratory, PRD, Quartermaster Research and Engineering Center
Natick, Massachusetts

In preparing the spore suspension, sterile distilled water having a pH value between 5.8 and 7.2 at a temperature between 22° and 32°C (72° and 89°F) shall be utilized. Approximately 10ml. of sterile distilled water shall be introduced directly into each tube culture of the fungus and the fungal spores brought into suspension by vigorously shaking or by gentle rubbing of the spore layer with an inoculating loop without disturbing the agar surface. This process shall be repeated for each species of fungus. The separate spore suspensions from the four types of fungi shall be mixed together to provide a composite suspension. Actively growing cultures between 7 to 21 days old after initial inoculation shall be used for the preparation of the spore suspension. After preparation, the spore suspension will not be kept for more than a 24-hour period at temperatures from 22° to 32°C (72° to 89°F) or not more than 48 hours at temperature from 2° to 7°C (35° to 45°F).

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3. PROCEDURE.

Procedure I. This procedure shall be used for complete assemblies or large pieces of material which cannot be cut or reduced to sample size. The test item shall be placed in a mold chamber, equal to that specified in MIL-C-9452, and installed as specified in section 3.2.2. The internal test chamber temperature shall be raised to 30° ± 2°C (86° ± 3.6°F) at 95 ± 5 percent relative humidity and maintained throughout the test period. The test item shall be sprayed with the suspension of mixed spores. To insure viability of the organism, a known nutrient material inoculated with the same spore suspension used to spray the test item shall be placed in the test chamber. The test period shall be not less than 28 days. At the end of this period the test item shall be removed from the test chamber and inspected in accordance with section 3.2.4. If so specified in the individual equipment specification the test item shall be operated and the results compared with those obtained in accordance with section 3.2.1.

Procedure II. This procedure shall be used for materials which can be cut or reduced to a size suitable for testing in a petri dish. The test shall be performed in accordance with Specification MIL-F-8261, except that the spore suspension shall be prepared as specified in paragraph 2 of this test method. A test period of not less than 14 days shall be used.

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METHOD 509.1

SALT FOG

1. PURPOSE. The salt fog test is conducted to determine the resistance of aerospace and ground 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 metals or coating combination, 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 a constant 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 such as 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

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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 requirement for operating temperature.

3. 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 ± 0.1 percent solution shall be prepared by dissolving 5 ± 0.1 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 of from 1.023 to 1.037. In order to determine if the percent of sodium chloride in the solution falls within the specified range refer to figure 509-1 utilizing the measured temperature and density of the salt solution.

3.1 *Adjustment of pH.* The pH of the salt solution shall be so maintained that the solution atomized at $35^{\circ}\text{C}\,^{+1^{\circ}}_{-2^{\circ}}\text{C}$ ($95\,^{+2^{\circ}}_{-4^{\circ}}\text{F}$) and collected by the method specified in paragraph 4.3 of this test method will be in the pH range of 6.5 to 7.2. Only diluted C. P. hydrochloric acid or C. P. sodium hydroxide shall be used to adjust the pH. The 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 paragraph 4.4 of this test method.

3.2 *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.

4. TEST CHAMBER OPERATING CONDITIONS.

4.1 *Temperature.* The test shall be conducted with a temperature in the exposure zone maintained at $35^{\circ}\,^{+1^{\circ}}_{-2^{\circ}}\text{C}$ ($95^{\circ}\,^{+2^{\circ}}_{-4^{\circ}}\text{F}$). 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.

4.2 *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.

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

4.4 *Measurement of Salt Solution.* The solution, collected in the manner specified in paragraph 4.3 of this test method shall have the sodium chloride content and pH specified in paragraph 3 of this test method when measured at a temperature of $35^{\circ}\,^{+1^{\circ}}_{-2^{\circ}}\text{C}$ ($95^{\circ}\,^{+2^{\circ}}_{-4^{\circ}}\text{F}$). The salt solution from all collection receptacles used can be combined to provide that quantity required for the measurements specified.

4.4.1 *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.

4.4.2 *Measurement of pH.* The pH shall be measured as specified in paragraph 3.1 of this test method.

4.4.3 *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.

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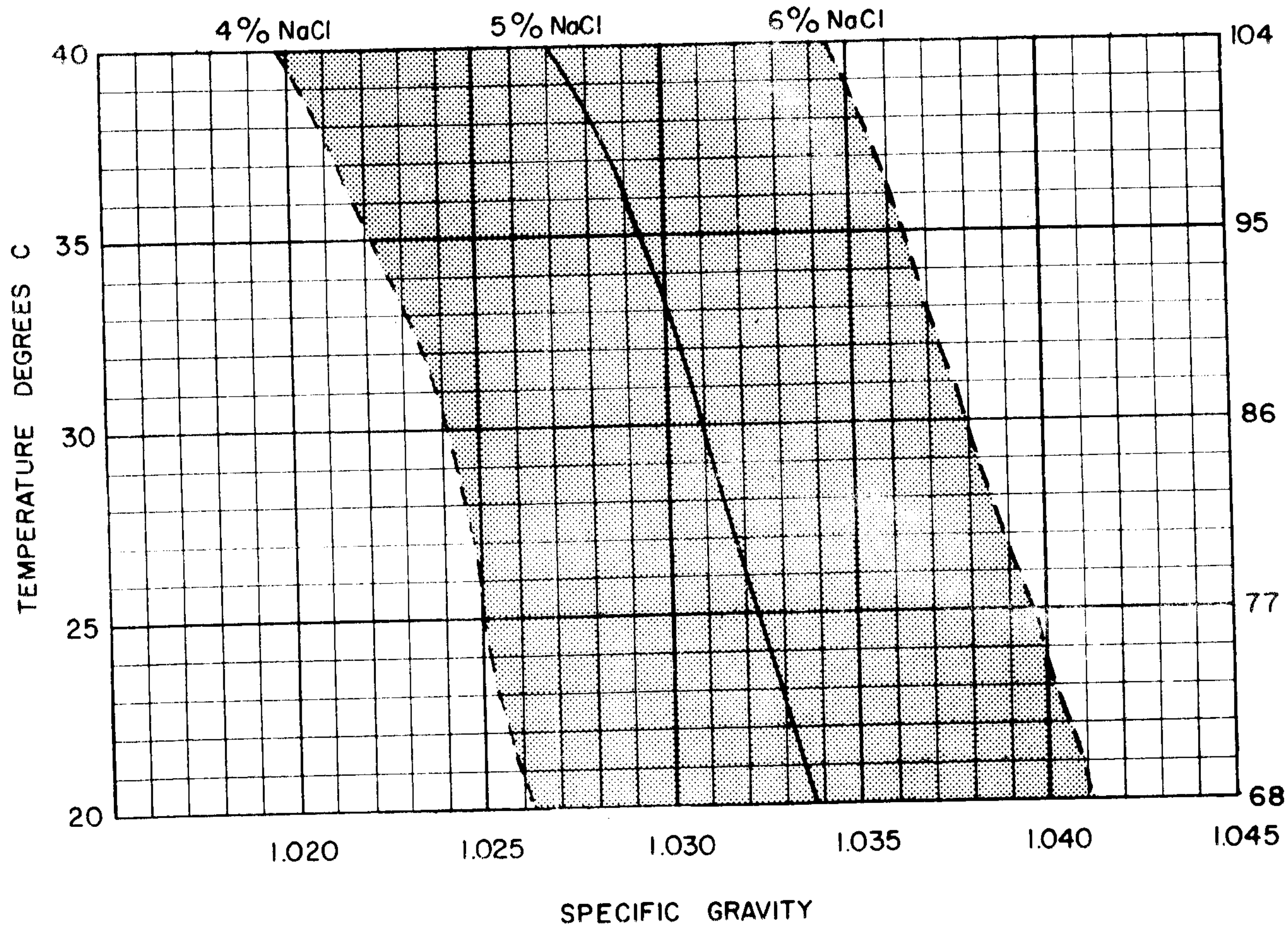

Figure 509-1. Variations of specific gravity of salt (NaCl) solution with temperature.

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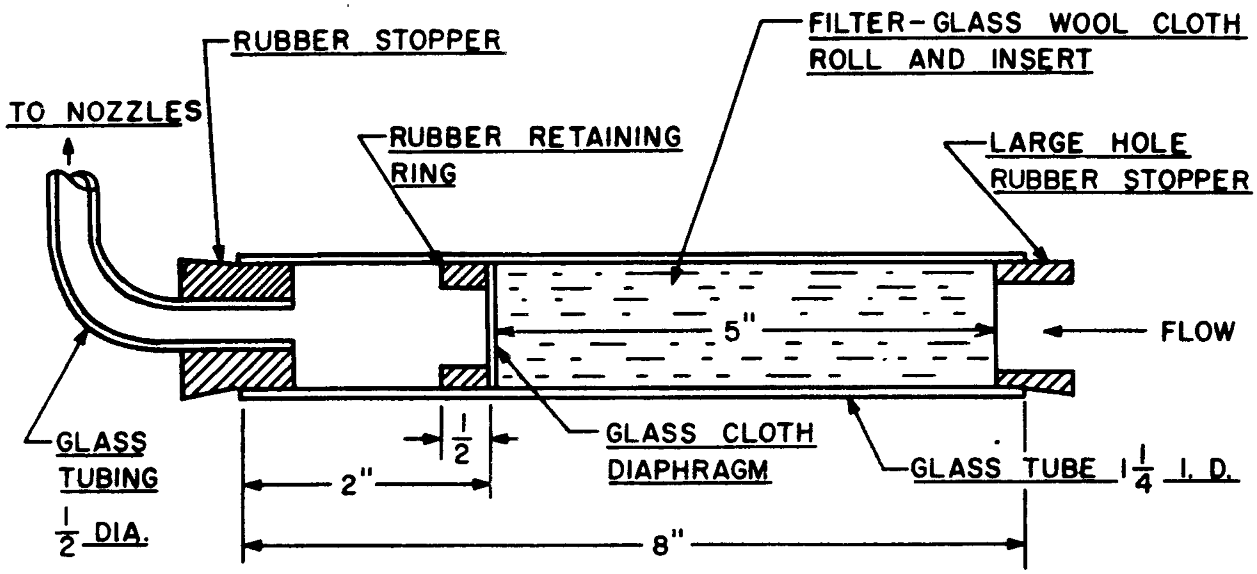

Figure 509-2. Salt Solution Filter.

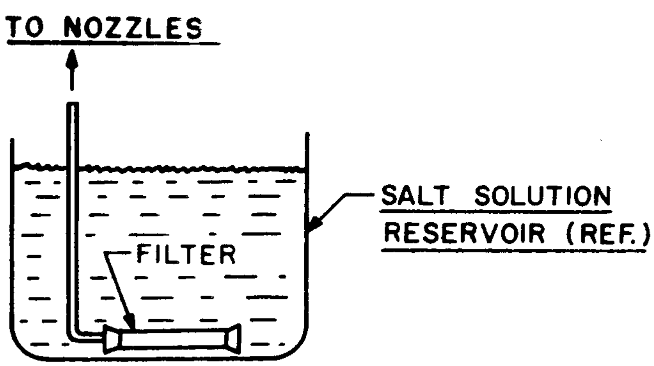

Figure 509-3. Locaton of salt solution filter.

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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.

6. PROCEDURE.

Procedure I. The test item shall be placed in the test chamber in accordance with section 3.2.2 and exposed to the salt fog for a period of not less than 48 hours. At the end of the test period the test item shall be operated and the results compared with the data obtained in accordance with section 3.2.1. Salt deposits resulting from the test may be removed by such methods specified in the individual equipment specification prior to operation of the test item. The test item shall then be inspected in accordance with section 3.2.4.

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METHOD 510.1

SAND AND DUST

1. PURPOSE. The sand and dust test is conducted to determine the resistance of aerospace and ground equipment to blowing fine sand and dust particles. Because of its abrasive character, sand and dust may affect items having moving parts where sand may enter. It may also cause the parts to bind, and may interfere with electrical contacts. Dust particles may also form nuclei for condensation of moisture, thus aiding in corrosion. Equipment may malfunction due to clogging of air filters.

2. CHARACTERISTICS OF SAND AND DUST. Sand and dust used in the test shall be of angular structure and shall have characteristics as follows:

a. 100 percent of the sand and dust shall pass through a 100-mesh screen, U.S. Standard Sieve Series.

b. 98 ± 2 percent of the sand and dust shall pass through a 140-mesh screen, U.S. Standard Sieve Series.

c. 90 ± 2 percent of the sand and dust shall pass through a 200-mesh screen, U.S. Standard Sieve Series.

d. 75 ± 2 percent of the sand and dust shall pass through a 325-mesh screen, U.S. Standard Sieve Series.

e. Chemical analysis of the dust shall be as follows:

SUBSTANCE	PERCENT BY WEIGHT
SiO_2	97 to 99
Fe_2O_3	0 to 2
Al_2O_3	0 to 2
TiO_2	0 to 2
MgO	0 to 1
Inorganic Losses	0 to 1

The sand and dust is commercially known as "140-mesh silica flour." Sand and dust (140-mesh silica flour) 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. PROCEDURE.

Procedure I. The test item shall be placed in a test chamber equal to that specified in MIL-C-9436, in accordance with section 3.2.2. The sand and dust density shall be raised to and maintained at 0.1 to 0.25 gram per cubic foot as measured at least three different locations within the test area utilizing collection devices such as impinger flasks. The relative humidity shall not exceed 30 percent at any time during the test. The internal temperature of the test chamber shall be maintained at 25°C (77°F) for a period of not less than 2 hours with the air velocity through the test chamber at 100 to 500 feet per minute. Following this 2-hour period the temperature shall be raised to and maintained at 71°C (160°F). These conditions shall be maintained for not less than 2 hours. At the end of this exposure period, the test item shall be removed from the test chamber and allowed to cool to room temperature. Accumulated dust shall be removed from the test item by brushing, wiping, or shaking, care being taken to avoid introduction of additional dust into the test item. Under no circumstances shall dust be removed by either air blast or vacuum cleaning. The test item shall then be operated, the results compared with those obtained in accordance with section 3.2.1, and inspected in accordance with section 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 sand and dust deposits.

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METHOD 511.1

EXPLOSIVE ATMOSPHERE

1. PURPOSE. The explosive atmosphere test is conducted to determine the ability of aerospace and ground equipment to operate in the presence of an explosive atmosphere without creating an explosion or to contain an explosion occurring inside the equipment. Since aerospace equipments are operating in ever changing potentially explosive atmospheres due to the flight profile of the aerospace vehicle, 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. The test procedures described herein are intended to serve several purposes. Procedure I is intended for determining the explosion producing characteristics of aerospace equipment not hermetically sealed and not contained in cases designed to prevent flame and explosion propagation. Ground equipment used in or near aerospace vehicles shall also be tested in accordance with this procedure except that the specified altitude survey need be conducted only to 10,000 feet. Procedure II is intended for determining the explosion and flame arresting characteristics of equipment cases designed for that purpose.

2. APPARATUS. An explosion-proof test chamber equal to that specified in MIL-C-9435 shall be used.

3. FUEL. The types of fuel selected shall be determined from the operational use and requirements of the equipment. Gasoline fuel shall be as specified in MIL-G-5572. Jet fuel shall be as specified in MIL-J-5624.

3.1 *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:

$$AAV = \frac{AV\ (\text{desired})}{1.04\left(\frac{P}{14.696}\right) - .04} = \frac{13}{1.04\left(\frac{6.75}{14.696}\right) - .04} = 29.68$$

Where —

AVA = 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 (60°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}).

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

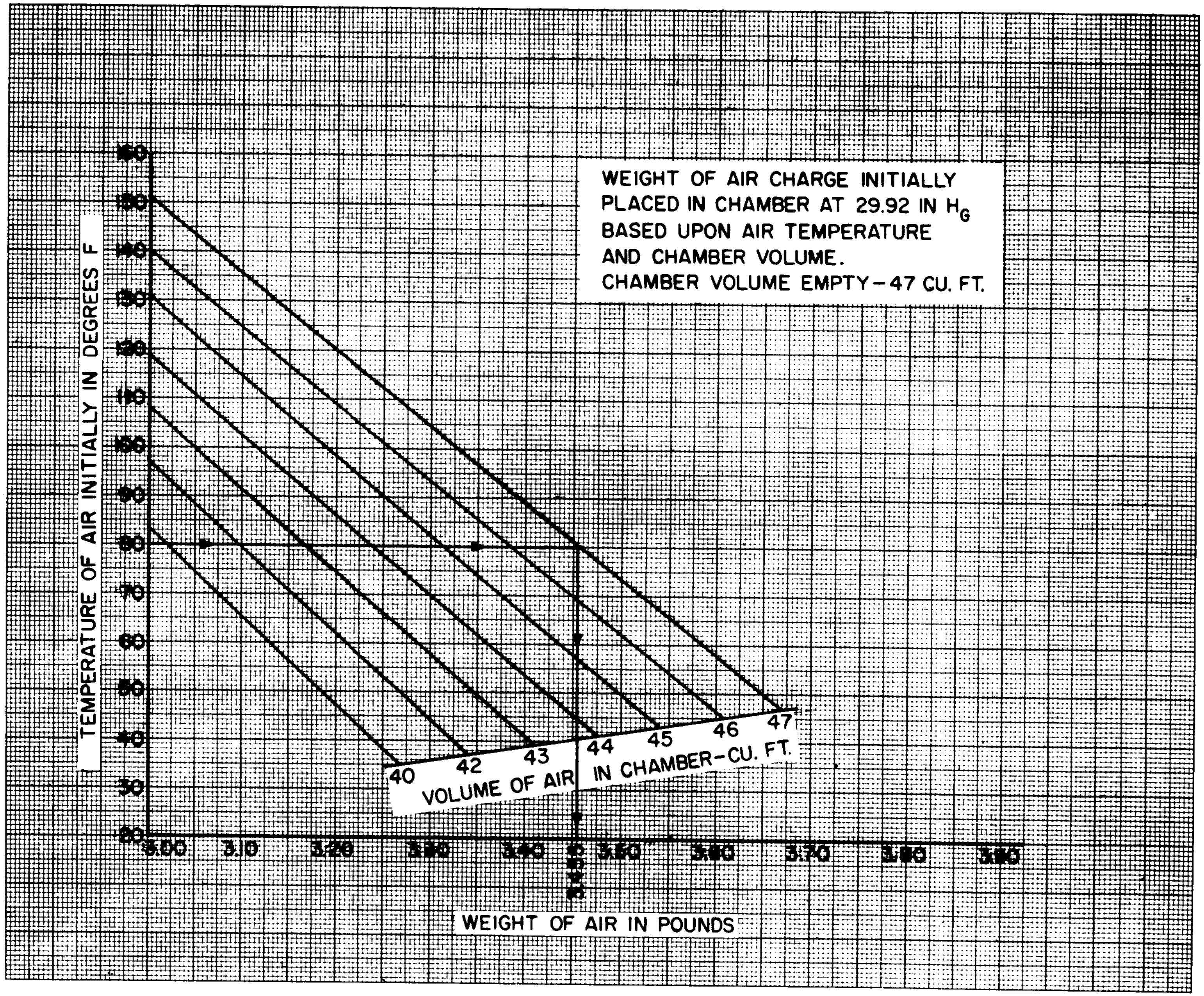

Figure 511-1. Weight of air.

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Figure 511-1 pertains to a specific test chamber and may not be used for all such 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 temperature and specific gravity at 16°C (60°F) use figure 511-2 to determine specific gravity at given temperature.

Step 4. Using figure 511-3 read from specific gravity determined under Step 3 for the correction factor k. Apply factor to obtain weight of fuel corrected (W_{FC}).

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

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

---

4. PROCEDURE.

Procedure I.

Preparation for Test.

a. The test item shall be installed in the test chamber in accordance with section 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.

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 ± 5°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 or 20°F of that of the chamber ambient air, prior to introduction of the explosive mixture.

Step 2. The internal test chamber pressure shall be reduced sufficiently to simulate an altitude approximately 10,000 feet above the desired test altitude. The weight of fuel necessary to produce an air-vapor ratio of 13 to 1 at the desired test altitude shall be determined from consideration of chamber volume, fuel temperature and specific gravity, chamber air and wall temperature, test altitude, etc. (see para. 3.1 of this test method). 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 thi time be commenced, all making and breaking electrical contacts being actuated. If high temperature components are present, a warmu time of 15 minutes shall be permitted. If n explosion results, air shall be admitted into th chamber so as to steadily reduce the altitud down past the desired test altitude to an eleva tion 5,000 feet below that altitude. The opera tion of the test item shall be continuo throughout this period of altitude reductio and all making and breaking electrical co tacts shall be operated as frequently as deeme practicable.

Step 4. If by the time the simulated altitude ha been reduced to 5,000 feet below the test alt tude, no explosion has ocurred as a result operation of the test item, the potential expl siveness of the air-vapor mixture shall be ver fied by igniting a sample of the mixture wi a spark gap or glow plug. At pressure altitud of 20,000 feet or higher the attainment of igr tion at any altitude shall be sufficient eviden that the mixture was ignitable even though i nition was not obtained at some other point

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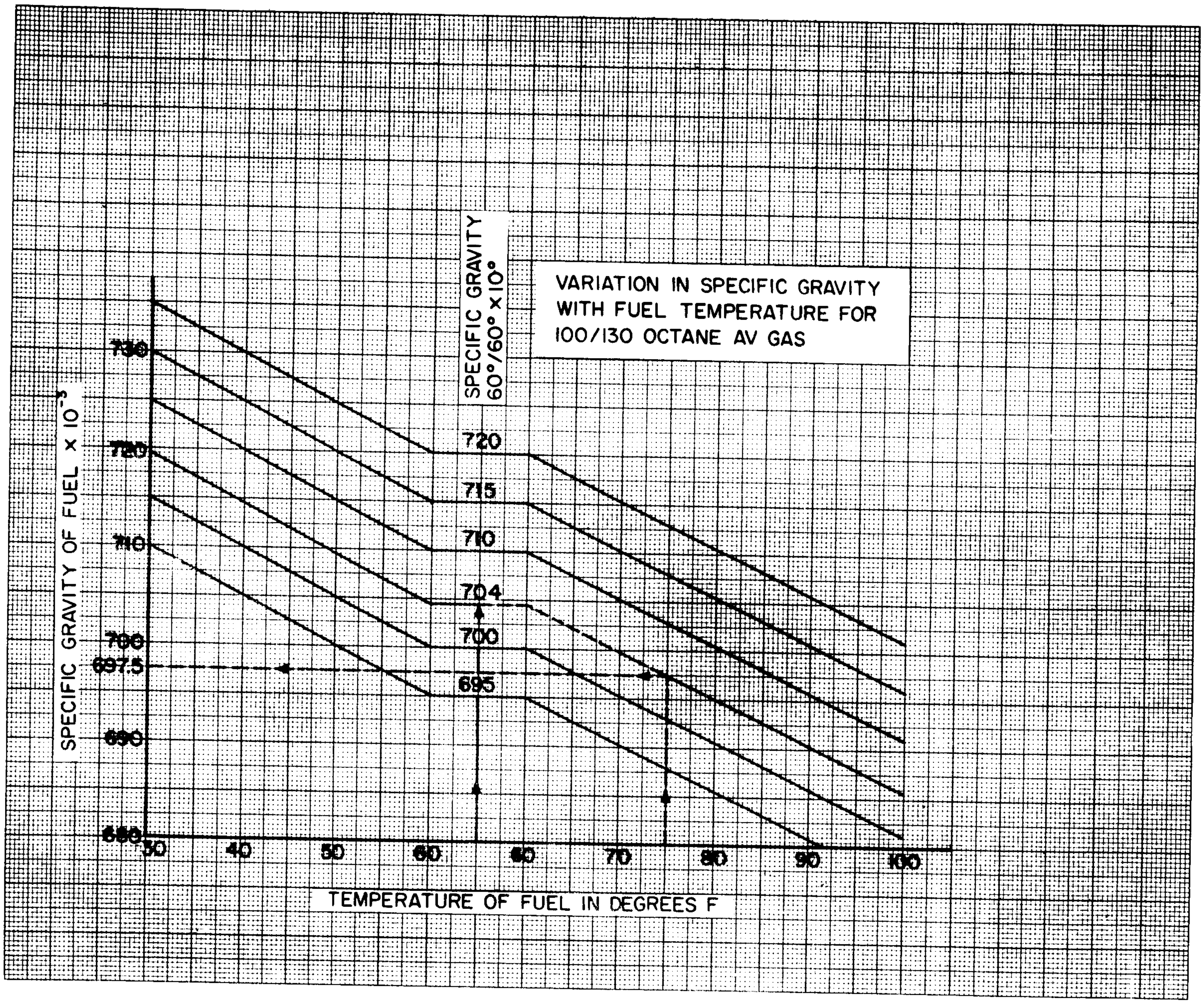

Figure 511-2. Specific gravity of fuel at a given temperature.

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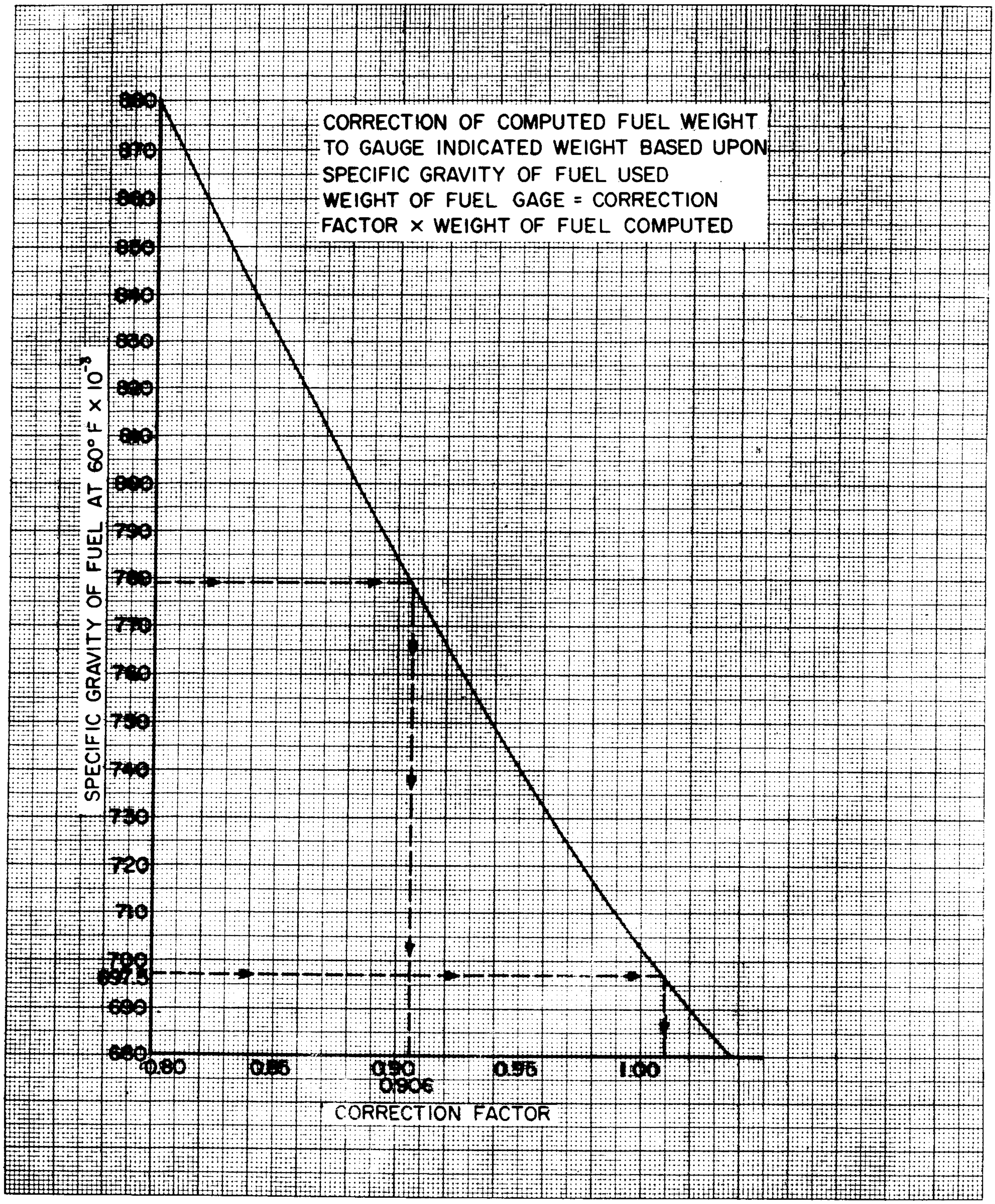

Figure 511-3. Correction factor.

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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.

Failure Criteria

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

Procedure II

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 must 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 3.2.2.

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 of this test method.

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 must 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.

Failure Criteria

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

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METHOD 512

IMMERSION (LEAKAGE)

1. The Immersion (Leakage) Test is Discontinued. This test was intended to determine the integrity of hermetic seals and gaskets employed by various devices. Such a test must be accomplished by the equipment vendor on each such device as part of his production line quality control. Requirements and methodology for this type of testing should be as specified in the individual equipment specification and as provided for in MIL-Q-9858, Quality Control System Requirements. This test, as originally included in this standard, can not be construed to be an environmental test.

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METHOD 513.1

ACCELERATION

1. PURPOSE. The acceleration test is conducted to determine structural soundness and satisfactory performance of aerospace equipment in a field of steady state acceleration other than gravity.

2. SCOPE. The test item shall be subjected to both the structural and the operational test unless otherwise specified by individual equipment specification.

3. 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. Procedure I of this test method is applicable to the centrifuge apparatus.

4. 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 increased until not less than 90 percent of the specified G level is obtained.

5. PROCEDURE.

Procedure I. Structural Test. The test item shall be installed on the acceleration apparatus in accordance with section 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 G level of the vehicle, and the orientation of the test item within the vehicle. When the forward acceleration G level of the vehicle *is known* and, when the position of the test item in the vehicle *is known*, the test level shall be determined as follows:

DIRECTION OF MOTION

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.

When the position of the test item in the vehicle *is unknown*, the test level should be determined as follows:

2.25 X A = G Test Level.

When the forward acceleration G level of the vehicle is *not known*, and the position of the test item in the vehicle *is known*, the test level shall be determined by the vehicle category as specified in table 513-I.

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

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When both the forward acceleration G level of the vehicle and the position of the test item in the vehicle are *unknown* the highest G level in table 513-I for the particular vehicle category selected shall be utilized. The test shall then commence. 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 one minute is usually sufficient to determine structural soundness, however, the test time may be increased at the option of the procuring activity. At the conclusion of the test the test item shall be operated and the results compared with the data obtained in accordance with section 3.2.1. The test item shall then be inspected as specified in section 3.2.4.

Procedure II. Operational Test. The test item shall be installed on the acceleration apparatus in accordance with section 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 G level of the vehicle, and the position of the test item within the vehicle. When the forward acceleration G level of the vehicle *is known* and, when the position 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.

When the position of the test item in the vehicle *is unknown*, the test level shall be determined as follows:

1.5 X A = G Test Level

When both the forward acceleration G level of the vehicle is *not known*, and the position of the test item in the vehicle *is known*, the test level shall be determined by the vehicle category as specified in table 513-II.

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

When both the forward acceleration G level of the vehicle and the position of the test item in the vehicle *are unknown*, 150 percent of the G level in the "fore" direction column of table 513-II for the particular vehicle category selected shall be utilized. The test shall then commence. 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 one minute is usually sufficient to determine proper operation, however, the test time may be increased at the option of the procuring activity. The test item shall be operated before, during and at the conclusion of the test, and the results compared with the data obtained in accordance with section 3.2.1. The test item shall then be inspected as specified in section 3.2.4.

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METHOD 514.1

VIBRATION

1. PURPOSE. The vibration test is conducted to determine that aerospace and ground equipment is constructed to withstand expected dynamic stresses at pronounced vibration susceptible frequencies and that performance degradations or malfunctions will not be produced by the service vibration environment.

2. SCOPE. The tests specified herein are established for equipment to be used in a variety of military applications. Table 514-I, Vibration Test Selection Chart, provides a convenient means for selecting test requirements. This table is divided into two major sections. The first section, captioned "Test Nomenclature," specifies the equipment class, the equipment mounting method, and a test curve or range of test curves. The second section, captioned "Mechanics of Test," specifies the test procedures to be employed and the test times of table 514-II.

3. EQUIPMENT CLASS. 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:

EQUIPMENT CLASS

1. Aircraft
2. Helicopters
3. Air Launched Missiles
4. Ground Launched Missiles
5. Ground Vehicles
6. Shipment by Common Carrier, Land, Sea, or Air
7. Ground Equipment (excluding ground vehicles)

4. EQUIPMENT MOUNTING METHODS.

A. Equipment rigidly mounted to supporting structure, without the use of vibration isolators.

B. Equipment normally mounted on vibration isolators.

C. Equipment normally installed on resiliently mounted racks or panels but requiring a test when the rack or panel is not available.

4.1 *Number of Tests to be Performed.* All tests shown in the applicable mounting method block in table 514-I shall be performed. For example, referring to table 514-I, Equipment Class 3, Mounting "B," four tests are specified as indicated by figures 514-1, -1, -3, and -4. All four tests shall be performed to evaluate equipment installed in an air launched missile for both the captive and flight phase.

5. SELECTION OF TEST CURVES. Test curves by equipment class are given in figures 514-1 through 514-6. In some instances several test curves are shown for one equipment class. The selection of test curves shall be made after 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. General guidance for the selection of vibration test curves for each equipment class by location is contained in the following paragraphs.

5.1 *Aircraft Equipment Test Curves*, see figure 514-1.

5.2 *Helicopters Equipment Test Curves*, see figure 514-2.

5.3 *Air Launched Missile Equipment Test Curves.* Items of equipment to be installed in air launched missiles shall be subjected to both a captive phase and a flight phase vibration test. The vibration test curve for the captive phase shall be selected from figure 514-1. The vibration test curve for the flight phase shall be selected from figure 514-3 (Sinusoidal Cycling) and figure 514-4 (Random Vibration) since both tests are required as specified in table 514-I. Suggested test curves are given in table 514-III.

5.4 *Ground Launched Missile Equipment Test Curves.* Items of equipment to be installed in ground launched missiles shall be subjected to sinusoidal cycling test and a random vibration test as specified in table 514-I. Sinusoidal test curves are shown in figure 514-3. Random vibration test curves are shown in figure 514-4. Guidance for the selection of vibration test curves is contained in table 514-III.

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TABLE 514-I

Vibration Test Selection Chart

TEST NOMENCLATURE, Para. 6				MECHANICS OF TEST, Para. 7				
Equip. Class Para. 3	Mounting Para. 4	Test Curve, Para. 5 Fig. 514-	Test Curve, Para. 5 Curve	Notes	Performance, Part I Cycling Sinusoidal	Performance, Part I Random	Resonance Dwell Part II	Time Table 514-II
1 Acft.	A	1	B, C, D, or E	- -	X	-	X	I
	B	1	B, C, D, or E	Step 1 Note 1	X	-	X	I
		1	A	Step 2 Note 1	X	-	X	II
	C	1	A	- -	X	-	X	I
2 Helicopters	A	2	B	- -	X	-	X	I
	B	2	B	Step 1 Note 1	X	-	X	I
		2	A	Step 2 Note 1	X	-	X	II
	C	2	A	- -	X	-	X	I
3 Air Launched Missiles	A	1	B or C	Captive Phase	X	-	X	V
		3	B, C, D, or E	Flight Phase	X	-	-	II
		4	B thru F	Flight Phase	-	X	-	II
	B	1	B or C	Captive Phase Step 1 Note 1	X	-	X	V
		1	A	Step 2 Note 1	X	-	X	II
		3	B, C, D, or E	Flight Phase	X	-	-	II
		4	B thru F	Flight Phase	-	X	-	II
	C	1	A	Captive Phase	X	-	X	V
		3	A	Flight Phase	X	-	-	II
		4	A	Flight Phase	-	X	-	II
4 Ground Launched Missiles	A	3	B thru G	- -	X	-	-	II
		4	A thru K	- -	-	X	-	II
	B	3	B thru G	- -	X	-	-	II
		4	A thru K	Step 1 Note 1	-	X	-	II
		3	A	Step 2 Note 1	X	-	-	II
	C	3	A	- -	X	-	-	II
		4	A	- -	-	X	-	II
5 Ground Vehicles	-	5	A or B	Note 2	X	-	X	III
6 Shipment by common carrier and 7 Ground Equip.	-	6	A	Note 3	X	-	X	IV

Note 1. Equipment normally provided with vibration isolators shall first be tested with the isolators in place in accordance with step 1. The isolators shall then be removed, the equipment rigidly mounted and subjected to the lower G level in accordance with step 2 in order to demonstrate minimum structural resistance to vibration.

Note 2. For ground vehicle equipment weighing more that 143 pounds, the upper frequency limit of figure 514-5 shall be reduced according to the frequency vs. weight requirement of figure 514-7.

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 items of equipment weighing more than 100 pounds, the upper frequency limit of figure 514-6 shall be reduced according to the weight vs. frequency requirement of figure 514-8.

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TABLE 514-II

Time Table

(Times shown refer to one axis of vibration)

Time Schedule	RESONANCE DWELL		PERFORMANCE	
	Number of Resonances	Total Time at Resonance	Total Cycling Time	Random Time (When Required by Table 514–I)
I	0	—	3 Hr.	—
	1	½ Hr.	2½ Hr.	—
	2	1 Hr.	2 Hr.	—
	3	1½ Hr.	1½ Hr.	—
	4	2 Hr.	1 Hr.	—
	Dwell 30 minutes at each resonance			
II	0	—	↑	↑
	1	10 min.		
	2	20 min.	30 min.	30 min.
	3	30 min.		
	4	40 min.	↓	↓
	Dwell 10 minutes at each resonance			
III	0	—	4 Hr.	—
	1	¾ Hr.	3¼ Hr.	—
	2	1½ Hr.	2½ Hr.	—
	3	2¼ Hr.	1¾ Hr.	—
	4	3 Hr.	1 Hr.	—
	Dwell 45 minutes at each resonance			
IV	0	—	↑	—
	1	½ Hr.		—
	2	1 Hr.	Note 4	—
	3	1½ Hr.		—
	4	2 Hr.	↓	—
	Dwell 30 minutes at each resonance			
V	0	—	2 Hr.	—
	1	½ Hr.	1½ Hr.	—
	2	1 Hr.	1 Hr.	—
	3	1½ Hr.	½ Hr.	—
	4	2 Hr.	0	—
	Dwell 30 minutes at each resonance			

Note 4. Perform three complete cycles from minimum frequency of figure 514–8 and return to minimum frequency.

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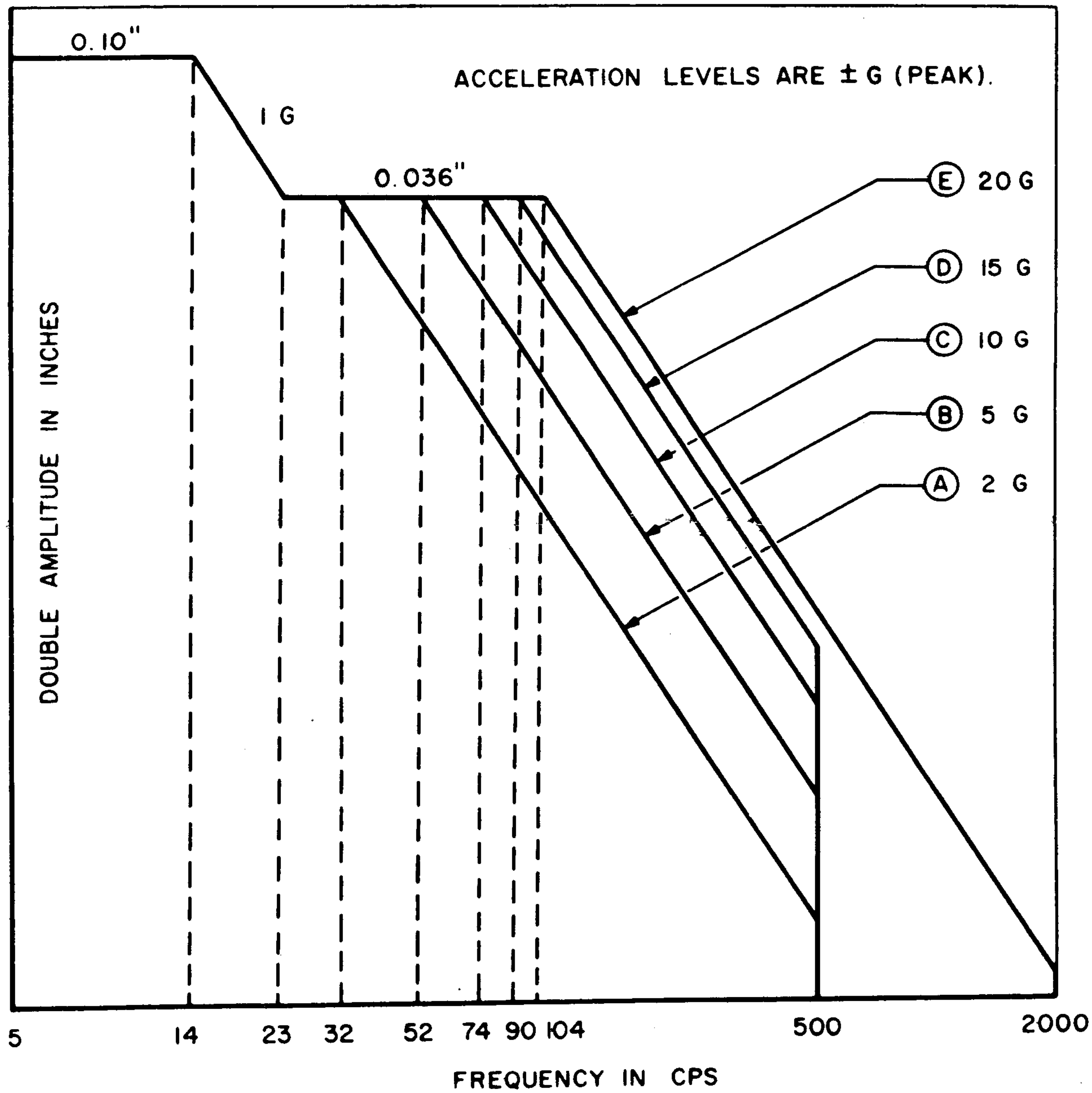

Curve	Aircraft Equipment Location
A	Equipment installed on vibration isolated panels and racks when the panel or rack is not available for test and when specified in table 514-I.
B	Equipment in forward half of fuselage or equipment in wing areas of aircraft with engines at rear of fuselage.
C	Equipment in rear half of fuselage or equipment in wing areas of aircraft with wing mounted engines.
D	Equipment located in the engine compartment or pylon.
E	Equipment mounted directly on aircraft engine.
	Air Launched Missile (captive phase)
B	Equipment in missile attached to wing of aircraft with engine in rear of fuselage.
C	Equipment in missile carried in aircraft fuselage or attached to wing in aircraft with wing mounted engines.

Figure 514-1. Vibration test curves, aircraft equipment and air launched missile (captive phase) equipment.

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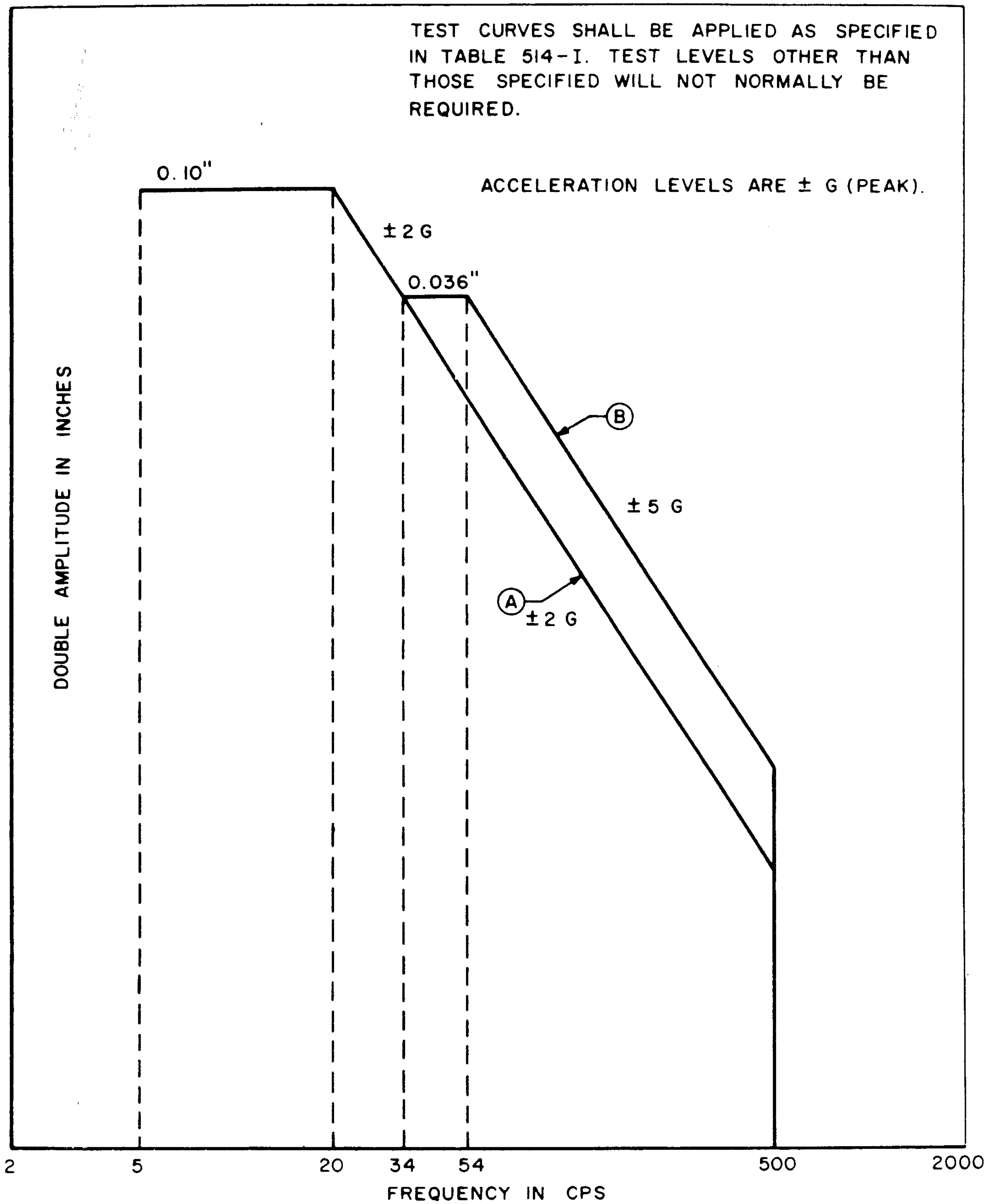

Figure 514-2. Vibration test curves, helicopter equipment.

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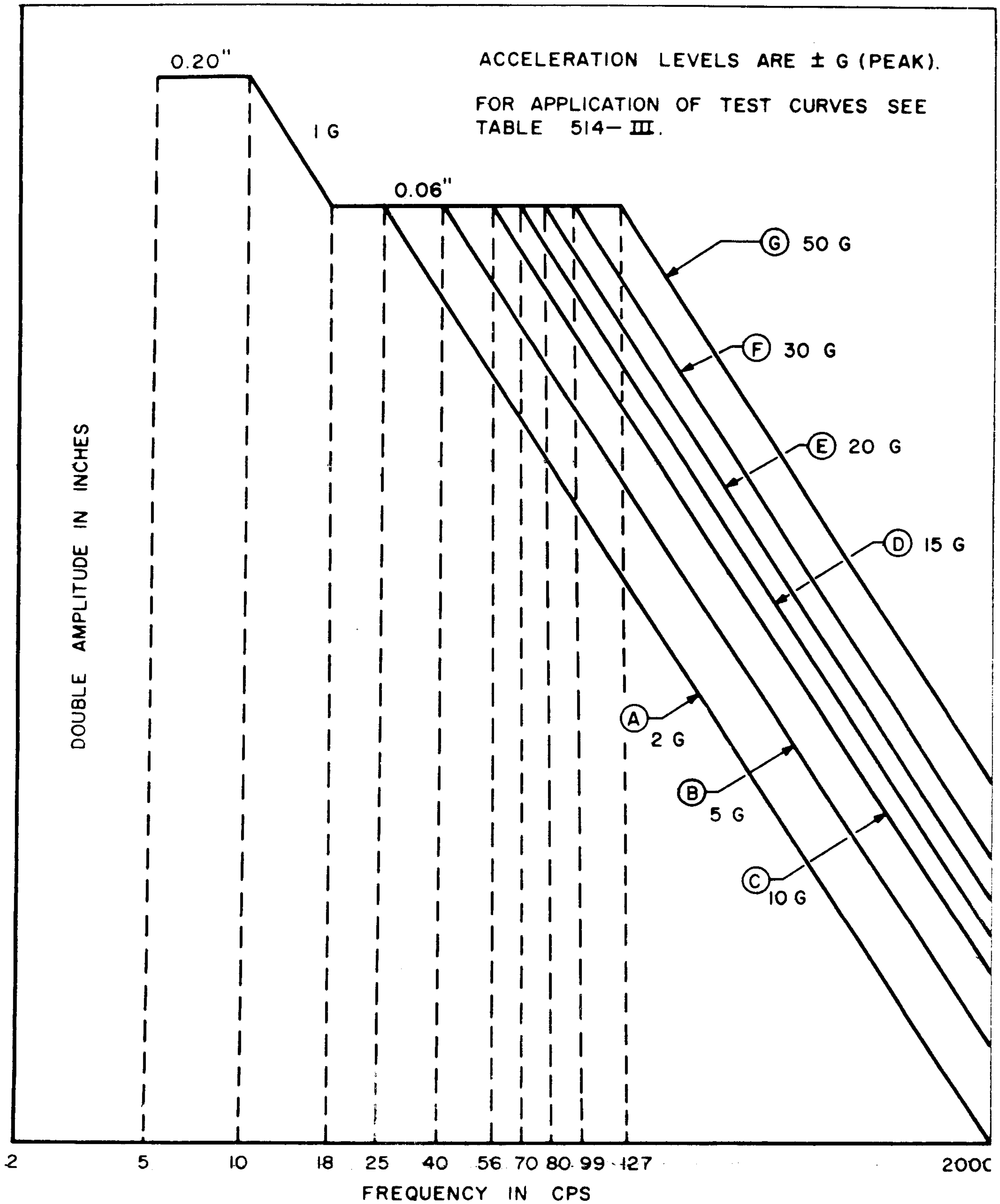

Figure 514-3. Vibration test curves, (sinusodial), air launched missile (flight phase) and ground launched missile equipment.

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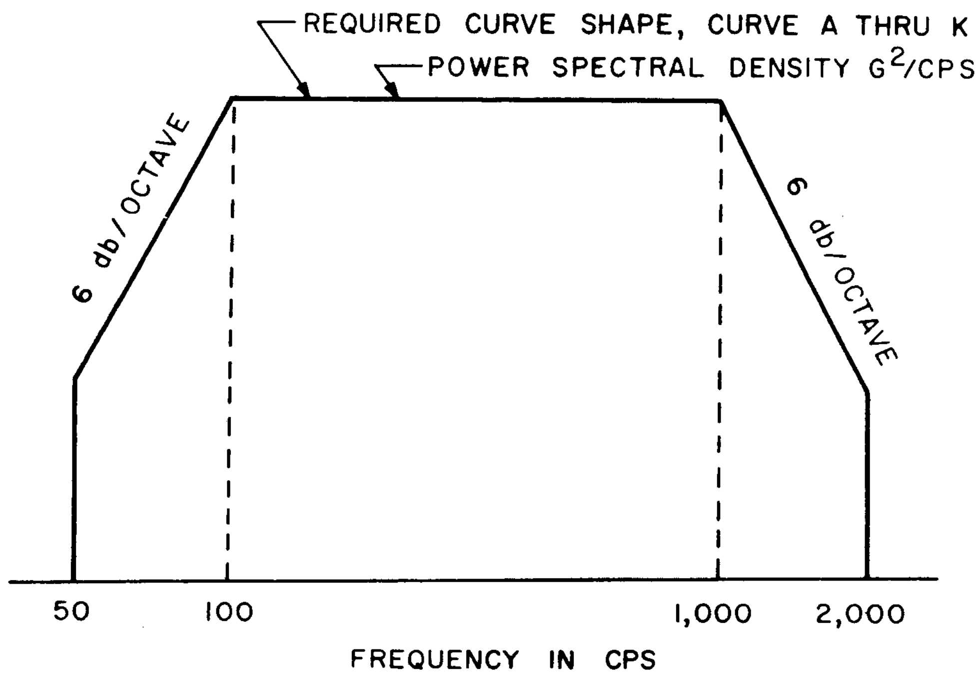
RANDOM VIBRATION TEST CURVE ENVELOPE



TEST CURVE	POWER SPECTRAL DENSITY	OVERALL RMS G MINIMUM
A	0.02	5.3
B	0.04	7.5
C	0.06	9.3
D	0.1	11.9
E	0.2	16.9
F	0.3	20.7
G	0.4	23.9
H	0.6	29.3
J	1.0	37.8
K	1.5	46.3

Figure 514-4. Random vibration test curves, air launched missiles (flight phase) and ground launched missiles.

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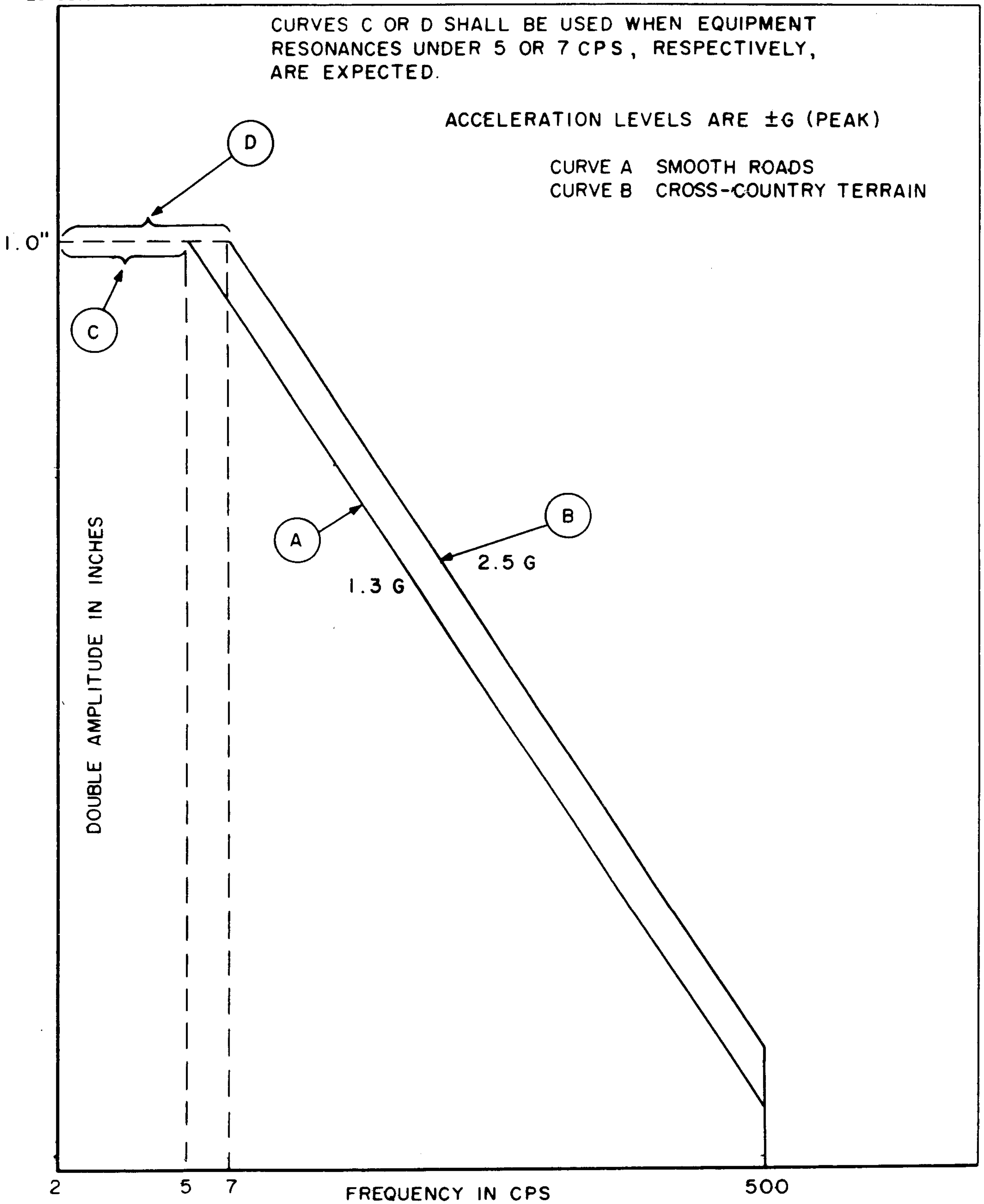

Figure 514-5. Vibraton test curves, equipment installed in ground vehicles.

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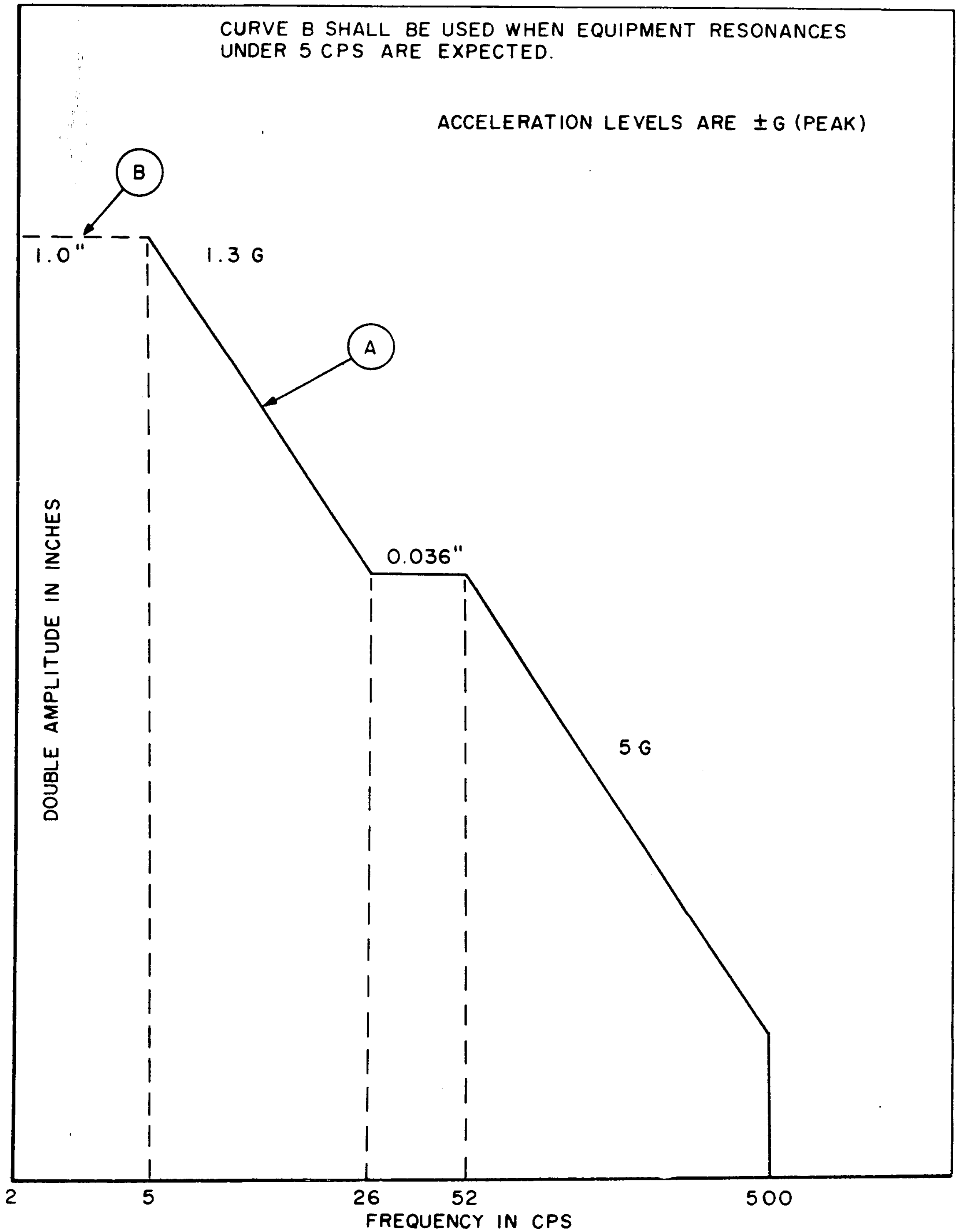

Figure 514-6. Vibration test curves, equipment transported by common carrier.

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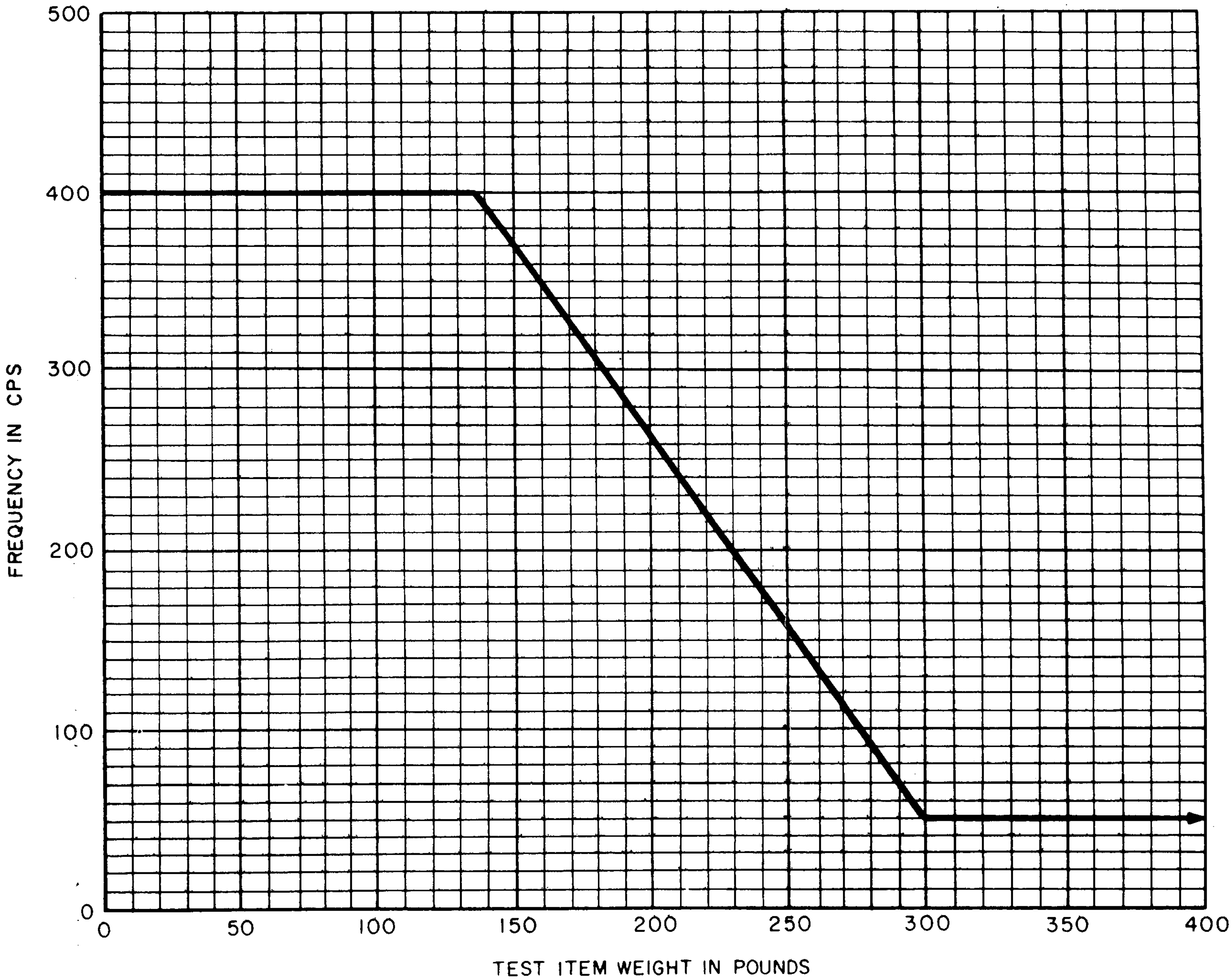

Figure 514-7. Weight vs. frequency. Equipment installed in ground vehicles.

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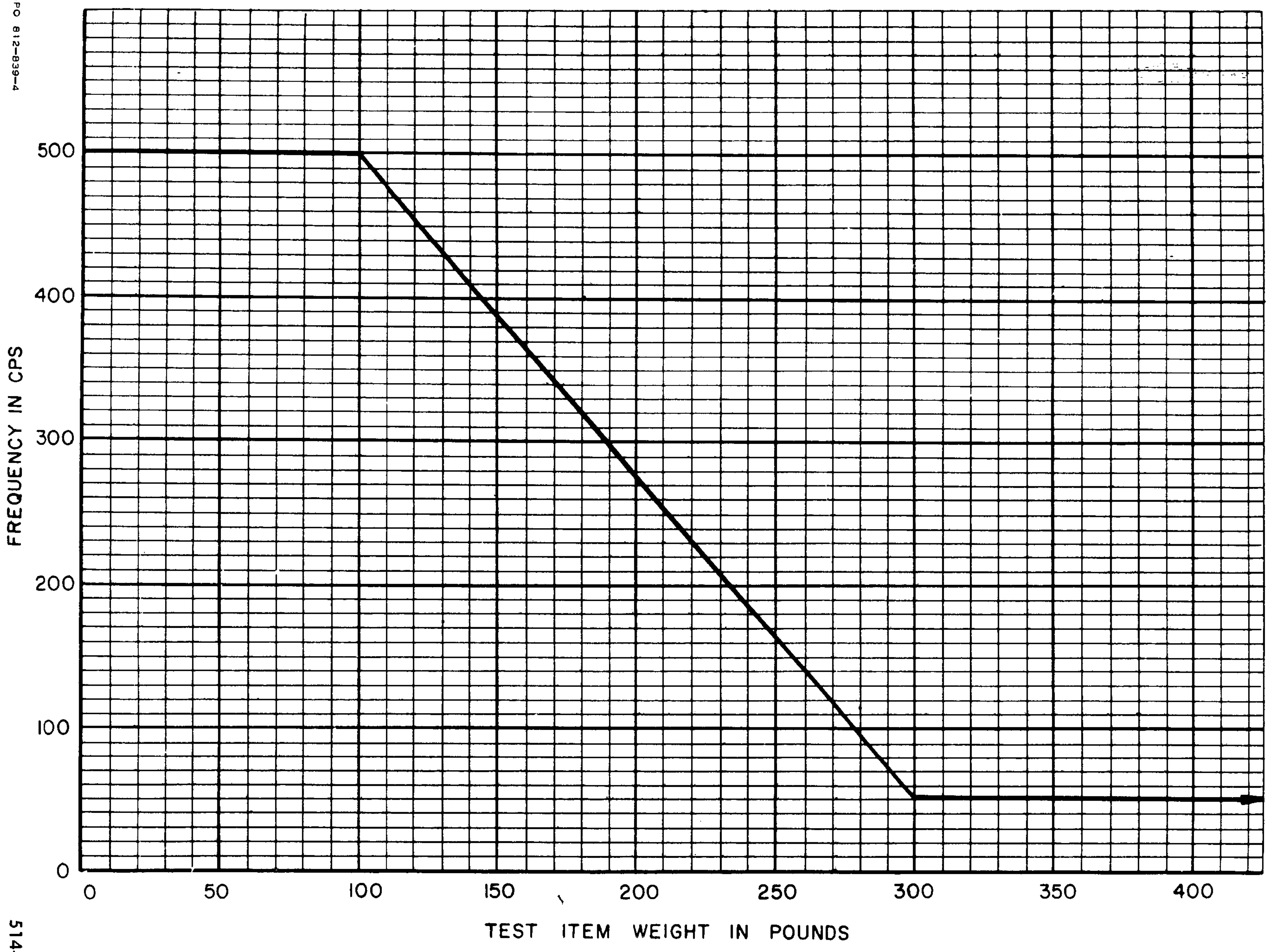

Figure 514-8. Weight vs. frequency. Equipment shipped by common carrier.

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TABLE 514-III

Suggested Vibration Test Curves				
Missile Type	Vibration Test Curves: Sinusoidal Fig. 514-3	Vibration Test Curves: Random Fig. 514-4	Approx. Thrust to Weight Ratio or Thrust in Pounds	Equipment Location by Missile Section
Air Launched (Flight phase)	E	F	20/1 or greater	Booster
	D	E	5/1 thru 15/1	
	C	D	3/1 or less	
	C	C	15/1 or greater	All locations except Booster
	B	B	Less than 15/1	
Ground Launched	B or C	A, B, or C	—	All except Booster
	C or D	D, E, or F	250,000 lb. or less	By Individual Booster Stage
	D or E	F, G, or H	250,000 lb. to 500,000 lb.	
	F or G	H, J, or K	Over 500,000 lb.	

5.5 *Ground Vehicle Equipment Test Curves.* Items of equipment to be installed in ground vehicles shall be subjected to a sinusoidal resonance and cycling test as specified in table 514-I. Sinusoidal test curves are shown in figure 514-5.

5.6 *Shipment by Common Carrier, Land, Sea or Air.* All items of equipment shipped by common carrier shall be subjected to a sinusoidal resonance and cycling test as specified in table 514-I. Sinusoidal test curves are shown in figure 514-6.

5.7 *Ground Equipment (excluding ground vehicle equipment).* Unless otherwise specified ground equipment shall be tested for shipment by common carrier only.

6. FORMULATION OF VIBRATION TEST NOMENCLATURE. The sequence of requirements in table 514-I are arranged in a manner which provides the means for formulating a vibration test nomenclature. The vibration test nomenclature shall be formulated from table 514-I, following the selection of requirements, in accordance with the following examples:

EXAMPLE NO. 1

Equipment Class	Mounting	Test Curve Figure 514-	Test Curve Curve
1	A	1	D

Referring to table 514-I, the above nomenclature specifies a test for equipment installed in an aircraft; equipment which is rigidly mounted; and, tested in accordance with figure 514-1, Curve "D."

EXAMPLE NO. 2

Equipment Class	Mounting	Test Curve Figure 514-	Test Curve Curve
3	A	1	C
3	A	3	D
3	A	4	F

Referring to table 514-I, since all tests shown for any one mounting method must be performed, it is necessary to specify a three part nomenclature number to completely identify the requirement. For equipment class 3, mounting method B, it is necessary to specify a four part nomenclature number etc.

7. MECHANICS OF TEST. A test shall be performed in accordance with the procedure as indicated by an "X" in the applicable block under the caption "Mechanics of Test" in table 514-I. The duration of the test shall be as specified in time schedule table 514-II in accordance with the time schedule designated by a Roman numeral.

8. *Procedure.* The vibration environment specified 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. The test item shall be installed in accordance with section 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. Wherever possible, the test load shall be distributed uniformly on the vibration exciter table in order to minimize effects of unbalanced loads.

Procedure I

Performance, Part I.

The performance test may be sinusoidal cycling, random, or a combination of both. For guidance in performing a combined test see paragraph 9.1 of this test method. The test to be applied is dependent on the vehicle in which the equipment is installed and shall be as specified in table 514-I. The test item shall be operating throughout the sinusoidal

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cycling and or random test. The test item performance during and following the test shall meet the requirements of the individual equipment specification. When the test item is packaged for transportation, operational monitoring of the test item during the test is not applicable.

Sinusiodal Cycling.

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 test curve. Logarithmic cycling rates shall be in accordance with figure 514-9 and the specified time schedule of table 514-II. A linear cycling rate may be substituted for logarithmic cycling when performed in accordance with paragraph 9.2 of this test method. When it is specified that a resonance dwell test follow the cycling test, significant resonant modes of the test item shall be determined during the cycling test. The initial frequency sweep cycling rate shall be decreased when necessary to facilitate the establishment of resonant frequencies. The frequency sweep shall be repeated for portions of the test curve when necessary to precisely locate narrow resonant modes. 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 3.2.1 and shall meet the requirements of the individual equipment specification. The test item shall then be inspected in accordance with section 3.2.4.

Random Vibration.

Random vibration, having a Gaussian distribution. shall be applied according to the specified test curve and time schedule. Instantaneous acceleration peaks may be limited to three times the rms acceleration level. Resonant modes of the moving mass (test item or substitute equivalent mass, fixture, vibration exciter moving element) shall be equalized or compensated for within the frequency range of the test curve. Control and analysis of random vibration are specified in paragraph 9.3 of this test method. 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 3.2.1 and shall meet the requirements of the individual equipment specification. The test item shall then be inspected in accordance with section 3.2.4.

Resonance Dwell, Part II.

The test item shall be operating during the test so that functional effects caused by internal resonances may be observed; however, compliance with tolerances specified in the individual equipment specification is not mandatory. The test item shall be vibrated along each axis at the most severe resonant frequencies according to the specified time schedule and according to the applicable double amplitudes or accelerations of the specified test curve. 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, the frequency shall be adjusted to maintain the resonance condition. For all test items weighing more than 50 pounds (except ground equipment and equipment shipped by common carrier) the vibratory accelerations may 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 test curve level. At the conclusion of the test, the test item shall be operated and the results compared with the data obtained in accordance with section 3.2.1. The test item shall then be inspected in accordance with section 3.2.4.

9. TEST DETAILS AND TECHNIQUES.

9.1 *Combined Sinusoidal Cycling and Random Vibration Test.* The sinusoidal cycling and 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 r.m.s 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.

9.2 *Substitution of Linear Cycling for Logarithmic Cycling.* When a 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 514-9. The frequency bands and linear cycling rates shown in table 514-IV shall be used for the 5 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.

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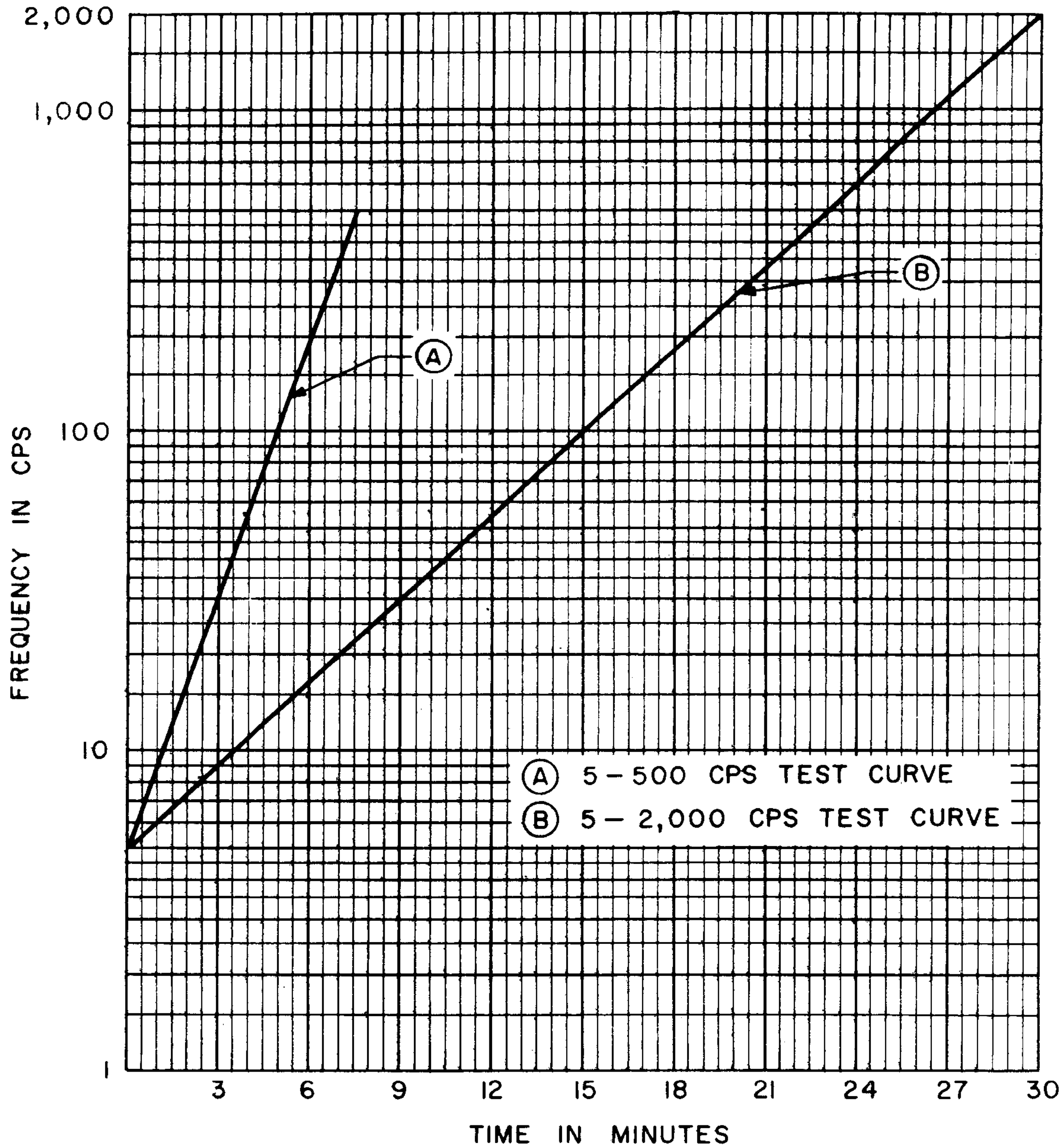

NOTE : FOR CYCLING TESTS OF LESS THAN 500 CPS MAXIMUM FREQUENCY, THE FREQUENCY RANGE SHALL BE CYCLED LOGARITHMICALLY FROM MINIMUM TO MAXIMUM IN 7.5 MINUTES FOR THE TOTAL TIME PERIOD SPECIFIED.

Figure 514-9. Logarithmic cycling rates.

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TABLE 514-IV

Linear Cycling Rates

Total Frequency Range	Frequency Bands cps	Cycling Time in Minutes	Linear Cycling Rate cps/min
5 to 500 cps	5.0 to 22.5	2.5	7
	22.5 to 100	2.5	31
	100 to 500	2.5	160
5 to 2000 cps	5.0 to 22.5	7.5	2.33
	22.5 to 100	7.5	10.33
	100 to 450	7.5	46.67
	450 to 2000	7.5	206.67

9.3 *Control and Analysis of Random Vibration.* The applied vibration spectrum shall normally be within the tolerances of +40, —30% between the frequencies of 50 and 1,000 cps, and within + 100, —50% between 1,000 and 2,000 cps. For a power spectral density analysis of the test spectrum, these tolerances may be expressed as ± 1.5 db and ± 3 db respectively. Tolerance levels in terms of db are defined as:

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

$$\text{db} = 20 \log \frac{G_1}{G_0}$$ where $G_1{}^2/\text{cps}$ = acceleration power spectral density and G_1 = G rms (over the analyzer bandwidth.) The term G_0 defines the specified level.

A wave analyzer shall be used to assure the specified equalization tolerances.

The following characteristics shall be reported for the analyzer for each test.

a. Filter bandwidths

b. Integrator time constant

c. Amplitude accuracy

9.4 *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 test curve. For massive test items and fixtures and large force exciters or multiple vibration exciters, the input control level may be an average of at least three or more inputs. Transverse motion measured at the test item attachment points shall be limited to 100% of the applied vibration.

9.5 *Transducer Mounting.* The monitoring transducer or transducers shall be rigidly attached to and located on or near the attachment point or points of the test item.

9.6 *Combined Temperature-Vibration Test.*

Tests shall be conducted under room ambient conditions unless the individual 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 individual equipment specification.

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METHOD 515

ACOUSTICAL NOISE

1. PURPOSE. The acoustical noise test is conducted to determine the effects on aerospace 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 acoustical noise test is not intended to be a substitute for the conventional sinusoidal or random vibration test when specified in the individual equipment specification. The test described herein should be considered only as a supplement to the specified shock and vibration tests.

2. CRITERIA FOR APPLICATION OF ACOUSTIC TEST. 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 possible that high frequency resonances of some responding equipment elements may be overlooked during the vibration test due to 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.

2.1 *Assessment of Equipment.* Of importance is the fact that some equipments may possess both sensitive and insensitive properties, and, that in some equipments 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.

2.1.1 *Insensitive Properties.* Equipments with insensitive properties are those having small surface areas (several square feet or less), 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 board 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.

2.1.2 *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. SELECTION OF TEST GRADE. The noise levels and duration of exposure are divided into four intensity categories as listed in table 515-I. The grades are in order of increasing severity (overall sound pressure level) from A through D. The grade should be selected as appropriate for the expected acoustic level. Normally grade 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 grade B may be required. Grades C and D represent the intense sound fields generated by large rocket thrust vehicles. Grade C is recommended for equipment locations forward of the booster compartment extending to the forward or nose cone regions. Grade D is recommended for locations in the booster compartment near the thrust source and may include instrument pods externally mounted on the booster sides.

4. APPARATUS. The reverberation test enclosure shall be a 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.

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TABLE 515-I

Sound Test Schedule		
Grade	Test Overall Sound Pressure Level—db*	Exposure Time
A	140	30 minutes
B	150	30 minutes
C	160	30 minutes
D	165	30 minutes

*Ref. 2 X 10^{-4} dynes/cm2

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5. MOUNTING OF TEST ITEM. The test item shall be suspended in the test chamber by means of soft suspension cords such as soft springs or elastic cord, and in accordance with section 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.

6. PROCEDURE.

Procedure I

Step 1—Measurement of sound pressure field. The sound pressure field shall be measured with the test item mounted in the test chamber. Measurements shall be made by using a microphone (more than one if desired) to measure the test item sound field in proximity to each major dissimilar surface. The overall sound pressure level desired or selected from table 515-I, reduced by 5 db, shall then be introduced into the test chamber and adjusted to conform with the octave band spectrum specified in figure 515-1. The time required to conduct the survey should not be comparable to the final test time. The sound pressure level and the survey time are reduced to avoid possible premature damage to the test item. The microphone shall be moved over the test item surface and at least 18 inches distant from the test item surface. The measurements made within this volume shall then be averaged.

Step 2—Performance of test. When step 1 is accomplished the overall noise level shall be raised to the value desired or selected from table 515-I and the test shall commence. The average sound pressure distribution around the test item should be uniform within 0 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 individual equipment specification.

When measurements are made during or following the test they shall be compared with the data obtained in accordance with section 3.2.1. At the conclusion of the test the test item shall be inspected in accordance with section 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 1, step 1. 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.

7. DEFINITIONS AND TERMS. A comprehensive list of standard terminology is contained in American Standards Association documents S 1.1-1960 titled "Acoustical Terminology (Including Mehanical Shock and Vibration)."

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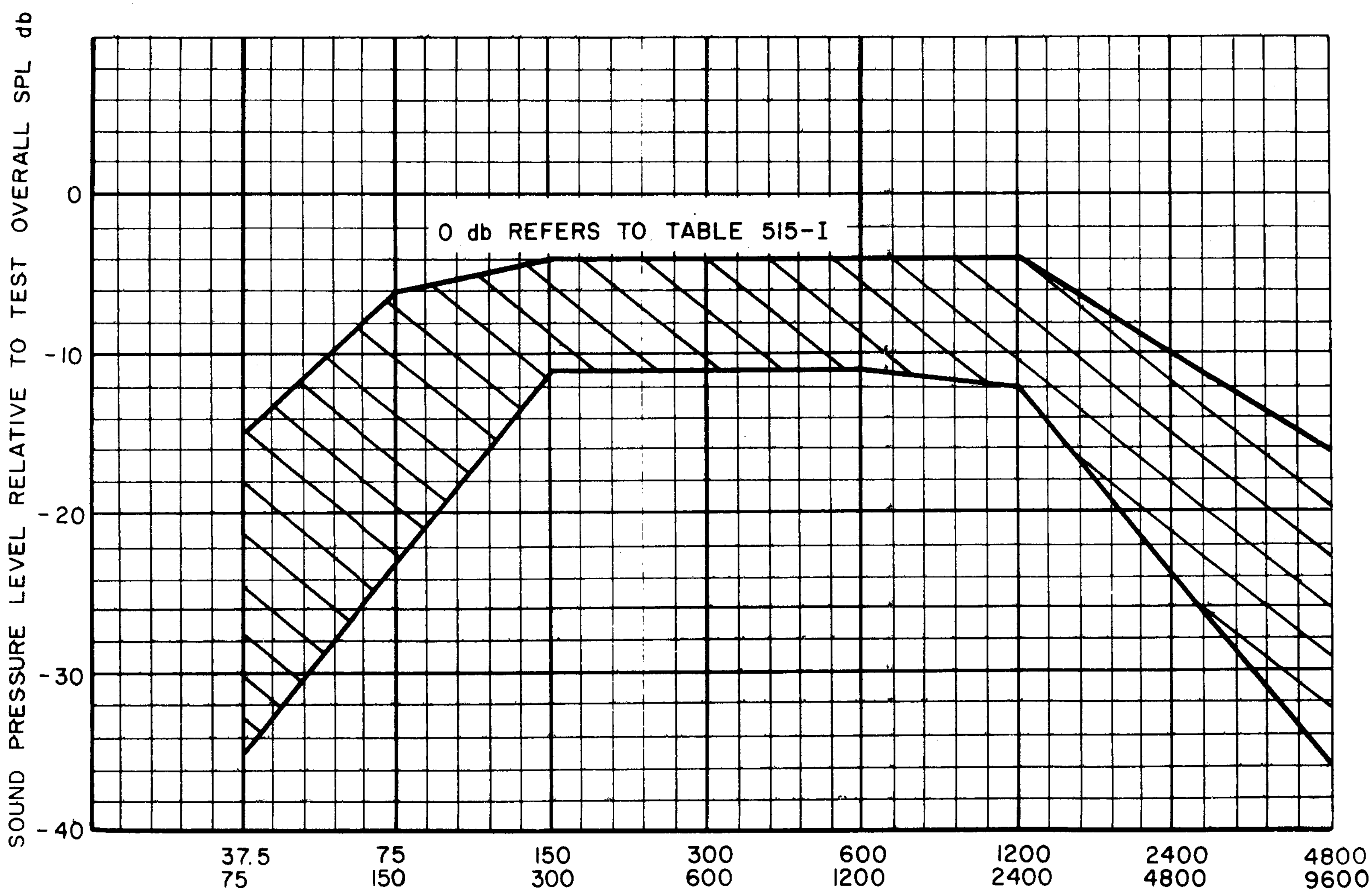

Figure 515-1. Continuous spectrum for noise test.

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METHOD 516.1

SHOCK

1. PURPOSE. The shock test is conducted to determine that structural integrity and performance of aerospace and ground 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 shall be capable of producing the specified input shock pulse shown in figure 516-1. 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 or a dummy load which may be either a rejected item or a rigid dummy mass may be used to calibrate the shock machine. (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 intended for the test item.) The shock machine shall then be calibrated for conformance with the specified wave form. The dummy 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 dummy load, the test shall be considered to meet the requirements of the specified wave form. (Except in the case where the test item itself is used for calibration, the waveform during the actual test will be somewhat different than that observed during calibration. It is therefore 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 transducer through the readout instrument, shall be as specified by figure 516-2. 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 *Transducer, 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:

$$RC \geq 0.2$$

Where R = Load resistance (ohms)
C = transducer capacitance plus shunt capacitance of cable and load (farads)

2.2.3 *Transducer, Strain Gage.* Strain gage transducers 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. (Resonant frequencies greater than 1,500 cps are recommended).

2.2.4 *Transducer Calibration.* Transducers shall be calibrated against a standard transducer or by optical means, either of which shall have an accuracy of ± 5 percent.

2.2.5 *Transducer Mounting.* The monitoring transducer shall be rigidly attached to the test item support fixture at or near the attachment point or points of the test item.

3. SHOCK PULSE. The shock pulse shall be as shown in figure 516-1. The highest point on the curve (peak acceleration value) shall lie on line BC. If more than one point can be judged to be the highest point on the curve, that highest point which occurs latest in time shall lie on line BC. Line BC shall be perpendicular to the base line (zero g) of the pulse. All points of the acceleration wave form shall lie within the area enclosed by the tolerance limit lines. The acceleration shall drop to a value of 1 gravity in a time equal to or less than 1 millisecond later than line BC.

4. PROCEDURE. The test item shall be rigidly attached to the shock machine table for procedures I, IV, and V in accordance with section 3.2.2. Wherever possible the test load shall be distributed uniformly on the test platform in order to minimize effects of unbalanced loads.

Procedure I.

Basic Design Test

This procedure shall be used for shock testing individual equipment assemblies (mechanical, electrical, hydraulic, electronic, etc.) of medium size including items of equipment which mount on vibration isolators and equipment racks. Three shocks in each direction shall be applied along the three mutually perpendicular

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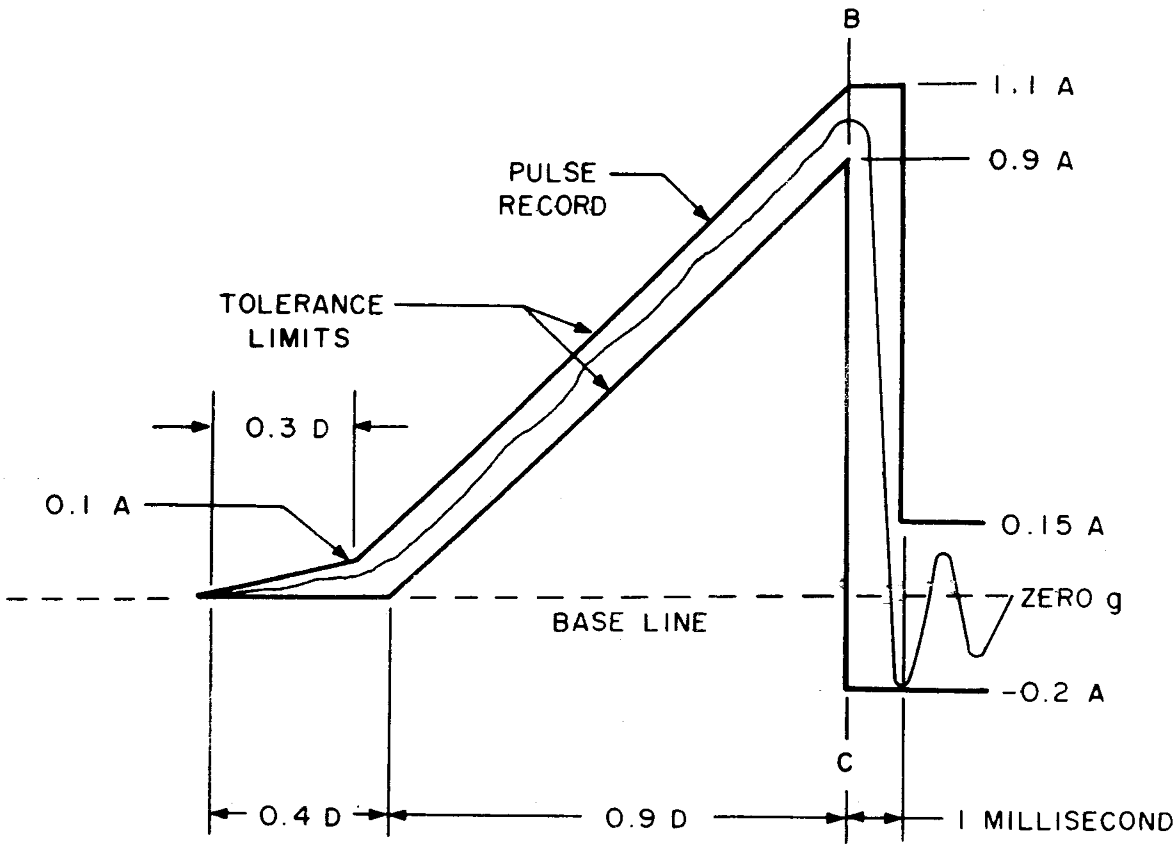

D = NOMINAL DURATION IN MILLISECONDS

A = SPECIFIED PEAK ACCELERATION IN GRAVITIES (g'S)

g = ACCELERATION OF GRAVITY ON EARTH 386 IN./SEC./SEC.

PROCEDURE	TEST	PEAK VALUE A	NOMINAL DURATION D
I	BASIC DESIGN	20 g	10 ms
IV	CRASH SAFETY	40 g	10 ms
V	HIGH INTENSITY	100 g	6 ms

Figure 516-1. Sawtooth Shock Pulse Configuration.

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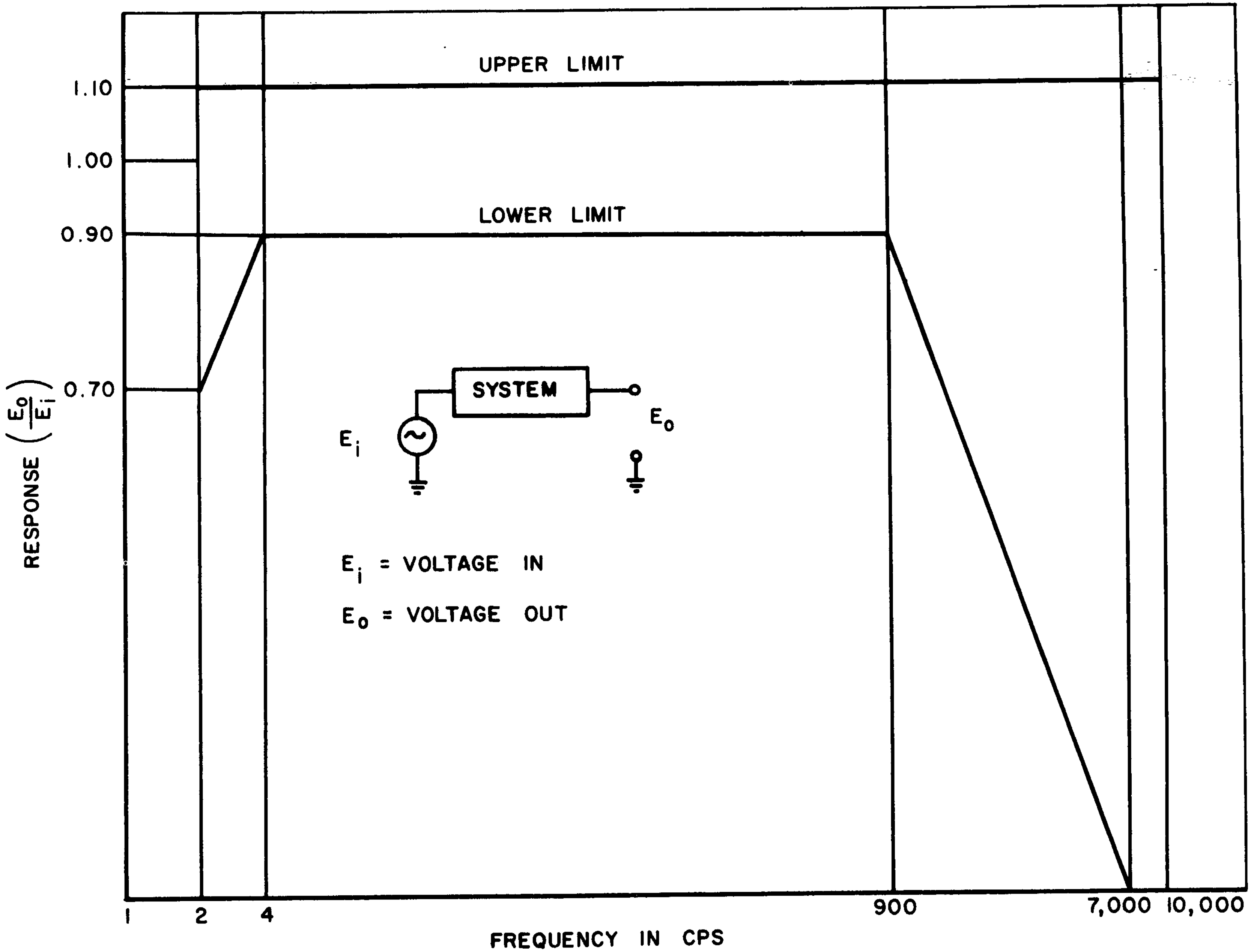

Figure 516-2. System Frequency Response.

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axes of the test item (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 figure 516-1 and shall have a peak value (A) of 20g and a nominal duration of 10 milliseconds. The test item shall be operating during and after the test if required by the individual 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 3.2.1. The test item shall then be inspected as specified in section 3.2.4.

Procedure II.

Transit Test

Discontinued, use Procedure III.

Procedure III.

Transit Test

This procedure is applicable to equipment transported by land, sea, or air and should be used when no other transit shock test is specified in the individual equipment specification or the packaging specification. The transit test is applied to determine the ability of equipment to resist damage from shock due to handling associated with transportation. This test is applicable to equipment in the package in the nonoperating condition. In the performance of this test, step "a" through step "c" shall be performed where applicable as specified in table 516-I, followed by step "d".

Step a. Free fall Drop Test. The packaged test item of the applicable gross weights and dimensions specified in table 516-I shall be dropped cornerwise onto a hard, level, concrete floor or equal surface on each of its eight corners, falling freely through the vertical distances specified in table 516-I. Prior to each drop, the package shall be suspended with its center of gravity vertically above the striking corner.

Step b. Edgewise Drop Test. The packaged test item of the applicable gross weight specified in table 516-I shall be tested as follows: One end of the base of the package shall be supported on a sill 5 to 6 inches in height. The opposite end shall be raised and allowed to fall freely to a hard level concrete floor or equal surface from the height of drop specified in table 516-I. The test shall be applied once to each end of the package. If the size of the package and the location of the center of gravity are such that this drop cannot be made from the prescribed height, the greatest height attainable shall be substituted.

TABLE 516-I

Drop Test

Gross Weight Not Exceeding	Dimensions on Any Edge or Diameter Not Exceeding	Free Fall Drop Test (Height of Drop)	Edgewise Drop Test (Height of Drop)	Cornerwise Drop Test (Height of Drop)
Pounds	Inches	Inches	Inches	Inches
50	36	30	—	—
100	48	21	—	—
150	60	18	—	—
200	60	16	—	—
600	72	—	36	36
3000	No Limit	—	24	24
No Limit	No Limit	—	12	12

Step c. Cornerwise Drop Test. The packaged test item having the applicable gross weight specified in table 516-I shall be tested as follows: One corner of the base of the package 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 package shall be raised and allowed to fall freely to a hard level concrete floor or equal surface from the heights specified in table 516-I. This test shall be applied once to each of two diagonally opposite corners of the base. If the size of the package and the location of the center of gravity are such that this drop cannot be made from the prescribed height,

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the greatest height attainable shall be substituted. When the proportions of width and height of the package are such to cause instability in the cornerwise drop test, edgewise drops shall be subtituted. In such instances two edgewise drops on each end shall be conducted.

Step d. Impact Test. Packaged equipment having a gross weight exceeding 200 pounds or any dimension more than 60 inches, closed as for transport, shall be subjected to one of the following impact tests. The test shall be applied once to each side and end that has dimensions of less than 9.5 feet.

(1) Pendulum Impact Test. The packaged test item shall be suspended above the floor by 4 or more ropes, chains or cables which are 16 feet long or longer.

The test item shall be pulled back so that the center of gravity has been raised 9 inches, and then shall be released and permitted to swing freely into a barrier. The barrier shall be a flat rigid wood, concrete or masonry wall or other equally unyielding flat obstacle that is oriented perpendicular to the line of swing.

(2) Incline Impact (Conbur) Test. The packaged test item shall be made to strike a flat rigid surface at a velocity of 7 feet per second. The procedure shall conform to ASTM Standard Method D 880, "The Incline Impact Test for Shipping Containers" suitably modified to accommodate the package.

At the conclusion of the test the test item shall be operated and the results compared with the data obtained in accordance with section 3.2.1. The test item shall then be inspected as specified in section 3.2.4.

Procedure IV.

Crash Safety Test

This test is conducted to determine the structural integrity of equipment mounting means. If no mounting base or vibration insolators are used, the test item shall be attached by its normal points of attachment. The test item shall be subjected to two shocks in each direction along the three mutually perpendicular axes of the equipment (12) shocks.

The shock pulse shape shall be in accordance with figure 516-1 and shall have a peak value (A) of 40g and a nominal duration (D) of 10 milliseconds. Bending and distortion shall be permitted. There shall be no failure of the mounting attachment and the test item or dummy load shall remain in place.

Procedure V.

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 aeropace 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 (12 shocks). The shock pulse shape shall be in accordance with figure 516-1 and shall have a peak value (A) of 100g and a nominal duration (D) of 6 milliseconds. The test item shall be operating during and after the test if required by the individual 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 3.2.1. The test item shall then be inspected as specified in section 3.2.4.

Procedure VI.

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 solid bench top. The test shall be performed, as follows, in a manner simulating shocks liable to occur during servicing.

Step a. Using one edge as a pivot, tilt the opposite edge of the assembly until the horizontal axis forms an angle of 45° with the table, or the opposite edge is 4 inches above the table, whichever occurs first, and permit the assembly to drop freely to the horizontal. Repeat, using other practicable edges of the same horizontal face as pivots, for a total of four drops.

Step b. Repeat step a, with the assembly resting on other faces until it has been dropped for a total of four times on each face on which the assembly 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 3.2.1. The test item shall then be inspected as specified in section 3.2.4.

5. RELATED SHOCK TESTS.

5.1 *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.

5.2 *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.

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METHOD 517.1

LOW PRESSURE-SOLAR ENERGY

1. PURPOSE. The low pressure solar energy test is conducted to determine whether aerospace vehicles such as satellites, external instrumentation packages, spacecraft, and space stations, with associated equipment, can withstand the deleterious effects of combined space environments. Such environments and conditions include solar radiation, low pressure, temperature gradients, and natural heat sink conditions. Damaging effects include sublimation and deterioration of materials, change in friction co-efficients, and change in operating characteristics of equipment. Conditions and effects related to zero gravity, micrometeorite hits, and high energy particle radiation are recognized but, because of inadequate simulation techniques, are not included in this test method. 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 aplication of heat. Individual components, equipments, and sub-systems which will operate under sufficiently well known ambient temperatures may be tested in accordance with Method 500, Procedure II of this standard providing the effect of solar radiation on materials involved is considered negligible.

2. SCOPE. The tests described in this test method are intended for the evaluation of complete aerospace vehicles including installed equipment.

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 emitted and reflected thermal radiation from planets or moons.

b. Rotational modes and attitude orientation, as applicable.

c. Programming of solar electromagnetic energy in accordance with the mission. (Day and night orbiting periods for satellites, instrumentation packages, etc.)

d. Equipment operation duty cycles.

e. Duration of test. (Number of orbits, time in flight, etc.)

f. Method for monitoring equipment 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. Omission of fuels and oxidizers.

l. Statement of reliability and failure criteria.

m. Other applicable requirements.

3.1 *Test Discipline.*

3.1.1 *Reflected and Emitted Thermal Radiation.* 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 will vary by more than 10°C from the temperature it would have if no planet or moon were present, simulation of reflected radiation (albedo) and emitted thermal radiation (planet radiation) from the planet or moon should be attempted in addition to direct solar radiation. Solar radiation shall be applied to the test item in the direction corresponding to that of the Sun in space. The solar electromagnetic energy distribution specified in table 517-I, knowledge of the flight path, and the planet radiation specified in table 517-II shall be used in determining the needed thermal radiation. Total solar energy shall be equal to the applicable value from the Incident Solar Radiation Intensity column of table 517-II with a tolerance of plus or minus 3 percent. The total energy tolerance and the variations of table 517-I shall be met over each 1/100 or 0.1 square feet, whichever is greater, of the area of the test space which is intended to be illuminated by simulated solar energy.

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TABLE 517-I

Solar Electromagnetic Energy Distribution

Wavelength Band (Angstroms)	Percent of Total Energy	Allowable Variation of Band Energy
*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%

*Due to the cost involved and difficulties in simulation, the need for simulating the 1800 to 2500 angstrom wavelength band should be carefully analyzed.

TABLE 517-II

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

The simulated planet or moon albedo and thermal radiation should be conducted for at least two portions of the trajectory sufficiently near the planet or moon and separated from each other by a distance corresponding to a change of at least 90 degrees in the direction of the radius vector from the planet or moon to the test item. Tolerances on the planet or moon radiation should be such that the resulting temperature variation on the test item is less than 5°C. For simulated solar electromagnetic radiation and other thermal sources uniformity and collimation must be considered. A collimation angle greater than 6 degrees should not be permitted for solar radiation unless a larger angle is justified by special test conditions.

3.1.2 *Time-Low Pressure.* 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 1×10^{-5} torr for not less than 24 hours. Test items with intended flight times of less than 24 hours should be exposed to low pressure for a time equal to or longer than the actual intended flight time. A pressure of 1×10^{-8} torr or lower should be employed where changes in physical properties of materials, outgassing, cold welding, etc. are of concern.

4. PROCEDURE.

Procedure I. The test item shall be placed in the test chamber in accordance with section 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 3.2.1. All equipment shall be operated (excluding any propulsion system) and measurements made as specified during the test under the conditions and duty cycles specified in the individual vehicle or equipment specifi-

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cation. The test chamber shall then be reduced to that pressure determined through compliance with paragraph 3.1.2 of this test method and the chamber walls cooled to —195°C (—320°F). Thermal energy corresponding to the applicable value and manner of exposure determined through compliance with paragraph 3.1.1 of this test method shall then be applied to the test item. The normal rotational mode of the test item along with other requirements and conditions shall then be established and maintained throughout the test. Measurements made during the test shall be compared with the data obtained in accordance with section 3.2.1. At the conclusion of the test the test chamber shall be returned to standard ambient conditions and the test item inspected in accordance with section 3.2.4.

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APPENDIX

Transition tables I, II, and III give those tests in this standard which may be used, *when authorized by the procuring activity,* in lieu of the tests given in the following specifications.

MIL-T-5422 (ASG) Environmental Testing for Aircraft Electronic Equipment

MIL-E-5272 (ASG) Environmental Testing, Aeronautical and Associated Equipment

MIL-E-4970 (USAF) Environmental Testing, Ground Support Equipment (This specification has been cancelled for new design)

TABLE I

Transition from MIL-T-5422 to MIL-STD-810

MIL-T-5422		MIL-STD-810
Para. Nr.	Environment	Method, Procedure, or Table
4.1	Temp. — Altitude	Method 504
4.2	Vibration Part I (designer must select G level) Vibration Part II	Method 514, Table 514-I, 1B1, Step 1 (designer must select G level) Method 514, Table 514-I, 1B1, Step 2
4.3 4.3.2.1 4.3.2.2	Shock Equipment Mounting (crash safety)	Method 516 Procedure I (basic design test) Procedure IV (crash safety test)
4.4	Humidity	Method 507
4.5	Salt Spray	Method 509
4.6	Explosion	Method 511
4.7	Sand and Dust	Method 510
4.8	Fungus	Method 508

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TABLE II

Transition from MIL-E-5272 to MIL-STD-810

MIL-E-5272		MIL-STD-810
Para. Nr.	Environment	Method, Procedure, or Table
4.1	High Temperature	Method 501
4.2	Low Temperature	Method 502
4.3	Temperature Shock	Method 503
4.4	Humidity	Method 507
4.5	Altitude	Method 500, Procedure II
4.6	Salt Spray	Method 509
4.7	Vibration	Method 514
4.7.1	Discont'd. Use Proc. XII	N/A
4.7.2	Proc. II	Table 514-I, 1A1E to 500 cps only
4.7.3	Proc. III discont'd. Use Proc. XIII	N/A
4.7.4	Proc. IV	Table 514-I, 1C1A
4.7.5	Proc. V	Table 514-I, 1C1A
4.7.6	Proc. VI discont'd.	N/A
4.7.7	Proc. VII	Table 514-I, 1A1E
4.7.8	Proc. VIII	Table 514-I, 1A1E
4.7.9	Proc. IX discont'd. Use Proc. XII	N/A
4.7.10	Proc. X discont'd. Use Proc. XII	N/A
4.7.11	Proc. XI discont'd. Use Proc. XII	N/A
4.7.12	Proc. XII	Table 514-I, 1A1, B, C, D, or E 1B1, B, C, D, or E 1B1A
4.7.13	Proc. XIII	Table 514-I, 1C1A
4.7.14	Proc. XIV	
	Aircraft	Table 514-I, 1A1E
	Rocket (test now obsolete)	See criteria for Air Launched & Ground Launched Missiles Table 514-I, Equip Class 3 & 4
4.8	Fungus	Method 508
4.9	Sunshine	Method 505
4.10	Rain	Method 506
4.11	Sand and Dust, Proc. I, II, and III	Method 510
4.12	Immersion	Method 512, Discontinued

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TABLE II (Cont.)

MIL-E-5272		MIL-STD-810
Para. Nr.	Environment	Method, Procedure, or Table
4.13	Explosion	Method 511
4.14	Temperature-Altitude, Proc. I and II	Method 504
4.15	Shock	
4.15.1	Proc. I discont'd. Use Proc. IV	N/A
4.15.2	Proc. II discont'd. Use Proc. V	N/A
4.15.3	Proc. III	Obsolete, not carried forward in MIL-STD-810
4.15.4	Proc. IV	Method 516, Proc. V
4.15.5	Proc. V	Method 516 as below
4.15.5.1	Equipment	Method 516, Proc. I (basic design)
4.15.5.2	Equipment, Crash Safety	Method 516, Proc. IV (crash safety)
4.16	Acceleration	
4.16.1	Proc. I	Method 513, Proc. I and II
4.16.2	Proc. II discont'd. Use Proc. III	N/A
4.16.3	Proc. III	Method 513, Proc. I and II

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TABLE III

Transition from MIL-E-4970 to MIL-STD-810

MIL-E-4970		MIL-STD-810
Para. Nr.	Environment	Method, Procedure, or Table
4.1	High Temperature	
4.1.1	Proc. I	Method 501
4.1.2	Proc. II	Method 501
4.1.3	Proc. III	Method 501
4.2	Low Temperature	
4.2.1	Proc. I	Method 502
4.2.2	Proc. II	Method 502
4.2.3	Proc. III	Method 502
4.3	Humidity	
4.3.1	Proc. I	Method 507
4.4	Low Pressure	
4.4.1.1	Proc. I	Method 500, Proc. I
4.4.1.2	Proc. II	Method 500, Proc. I
4.5	Salt Fog	Method 509
4.6	Vibration	
4.6.1	Proc. I discont'd. Use Proc. IV	N/A
4.6.2	Proc. II discont'd. Use Proc. V	N/A
4.6.3	Proc. III discont'd. Use Proc. VI	N/A

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REVISIONS TO TEST METHODS

METHOD NO.	DATE	TITLE
500.1	23 June 1964	Low Pressure
501.1	23 June 1964	High Temperature
502.1	23 June 1964	Low Temperature
503.1	23 June 1964	Temperature Shock
504.1	23 June 1964	Temperature—Altitude (Cycling)
505.1	23 June 1964	Sunshine
506.1	23 June 1964	Rain
507.1	23 June 1964	Humidity (Cycling)
508.1	23 June 1964	Fungus
509.1	23 June 1964	Salt Fog
510.1	23 June 1964	Sand and Dust
511.1	23 June 1964	Explosive Atmosphere
512	Discontinued	Immersion (Leakage)
513.1	23 June 1964	Acceleration
514.1	23 June 1964	Vibration
515	14 June 1962	Acoustical Noise
516.1	23 June 1964	Shock
517.1	23 June 1964	Low Pressure—Solar Energy