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19 July 1983
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10 March 1975

MILITARY STANDARD

ENVIRONMENTAL TEST METHODS AND ENGINEERING GUIDELINES

FSC ENVR

AMSC Number F3208

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ENVIRONMENTAL TEST METHODS AND ENGINEERING GUIDELINES

MIL-STD-810D

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

2. Recommended corrections, additions, or deletions shall be addressed to Commander, Aeronautical Systems Division, Attn: ASD/ENESS, Wright-Patterson AFB, Ohio 45433.

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FOREWORD

MIL-STD-810D has been revised to require more careful attention to environments throughout the development process. A course of action for determining and assessing the environments to which an item will be exposed during its service life has been added to section 4, General Requirements. The additional General Requirements aid in preparation for design and preparation for test. Documentation requirements for the design and testing process have also been added to section 4.

The bulk of the standard remains devoted to test methods. Each individual method has been revised to encourage more accurate determination of the environmental stresses that an equipment will encounter during its service life. Guidance for accelerated or aggravated testing during the design process is included in some cases. Each test method has been divided into two sections: Section I provides guidance for choosing and tailoring a particular test procedure; Section II includes step-by-step test procedures. In some methods, not only the test values, but also the sequence of steps is tailorable.

The result of this revision will be that this standard cannot be called out or applied as a fixed, relatively simple routine. Instead, an environmental engineering specialist will have to choose and alter the test procedures to suit a particular combination or sequence of environmental conditions for a specific equipment application.

The methods of this standard are not intended to satisfy all safety compliance testing requirements. Safety compliance testing may require tests not covered herein.

Technical questions may be addressed to the following offices:

Air Force Wright Aeronautical Laboratories
AFWAL/FIEE
Wright-Patterson AFB, Ohio 45433
Telephone: Commercial (513) 255-5082
Autovon 785-5082

Hq US Army Test and Evaluation Command
DRSTE-AD-M
Aberdeen Proving Ground, MD 21005
Telephone: Commercial (301) 278-3677
Autovon 283-3677

Naval Air Engineering Center
ESSD Code 9313
Lakehurst, NJ 08733
Telephone: Commercial (201) 323-7458
Autovon 624-7458

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1. SCOPE

1.1 Purpose. This standard provides:

a. Guidelines for conducting environmental engineering tasks to tailor environmental tests to end-item equipment applications.

b. Test methods for determining the effects of natural and induced environments on equipment used in military applications.

1.2 Application. Application of this standard early in the development phase of the acquisition process is encouraged. Selected application at other points in the acquisition process may be appropriate. The methods of this standard are not all-inclusive. Additional environments or combinations of environments should be included in the environmental test specification when appropriate. The test methods of this standard are intended to be applied in support of the following objectives:

a. To disclose deficiencies and defects and verify corrective actions.

b. To assess equipment suitability for its intended operational environment.

c. To verify contractual compliance.

1.3 Limitations. This standard purposely does not address the following:

a. Electromagnetic interference (EMI).

b. Lightning and magnetic effects.

c. Nuclear weapons and nuclear weapons' effects.

d. Piece parts, such as bolts, wires, transistors, and integrated circuits.

e. Tests of basic materials.

f. Certain aspects of the safety testing of munitions, such as rough handling tests.

2. REFERENCED DOCUMENTS

2.1 Government documents

2.1.1 Specifications, standards, and handbooks. The following documents of the issue listed in the current Department of Defense Index of Specifications and Standards (DODISS) and the supplement thereto (if applicable), form a part of this standard to the extent specified herein.

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SPECIFICATIONS

MILITARY

MIL-S-901	Shock Tests, H.I. (High Impact), Ship Machinery, Equipment And Systems

STANDARDS

MILITARY

MIL-STD-167	Mechanical Vibrations Of Shipboard Equipment
MIL-STD-210	Climatic Extremes For Military Equipment
MIL-STD-781	Reliability Testing For Engineering Development, Qualification And Production
MIL-STD-1165	Glossary Of Environmental Terms
MIL-STD-1540	Test Requirements For Space Vehicles
MIL-STD-1670	Environmental Criteria And Guidelines For Air-Launched Weapons
MIL-STD-45662	Calibration System Requirements

PUBLICATIONS

AR 70-38	Research, Development, Test And Evaluation Of Materiel For Extreme Climatic Conditions
STANAG 2831	Climatic Environmental Conditions Affecting The Design Of Materiel For Use By NATO Forces Operating In A Ground Role
STANAG 3518AE	Environmental Test Methods For Aircraft Equipment And Associated Ground Equipment

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

2.2 Order of precedence. In the event of a conflict between the text of this standard and the references cited herein, the text of this standard shall take precedence.

3. DEFINITIONS

3.1 The following definitions shall apply:

a. Accelerated test. A test designed to shorten the test time by increasing the frequency or duration of environmental stresses that would be expected to occur during field use.

b. Aggravated test. A test in which one or more conditions are set at a more stressful level than the test item will encounter in the field in order to reduce test time, reduce sample sizes, or assure a margin of safety.

c. Ambient environment. The conditions (e.g., temperature and humidity) characterizing the air or other medium that surrounds materiel.

d. Environmental conditions. (see Forcing function).

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e. Environmental engineering specialist. One whose principal work assignment lies in the technical area of natural and induced environments and their relation to military equipment. A person who has expertise in measuring and analyzing field environmental conditions, formulating environmental test criteria, specifying laboratory simulation of environments, and evaluating the effects of environments on equipment.

f. Forcing function. A climatic or mechanical environmental input to an item of equipment that affects its design, service life, or ability to function. (Also referred to as an environmental condition or an environmental stress.)

g. Hermetic seal. A permanent air-tight seal.

h. Induced environment. A local environmental condition that is predominantly man-made or equipment-generated. Also refers to any internal condition that results from the combination of natural forcing functions and the physical/chemical characteristics of the equipment.

i. Life cycle history. A time history of events and conditions associated with an item of equipment from its release from manufacturing to its ultimate removal from service. The life cycle should include the various phases that an item will encounter in its life, such as: handling, shipping, and storage prior to use; mission profiles while in use; phases between missions, such as stand-by or storage, transfer to and from repair sites and alternate locations; and geographical locations of expected deployment.

j. Mission profile. That portion of the life cycle associated with a specific operational mission.

k. Platform. Any vehicle, surface, or medium that carries the equipment. For example, an aircraft is the carrying platform for internally installed avionics equipment and externally mounted stores. The land is the platform for a ground radar set, and a man for a hand-carried radio.

l. Platform environment. The environmental conditions an equipment experiences as a result of being attached to or loaded onto a platform. The platform environment is a result of forcing functions induced or modified by the platform and any on-board environmental control systems.

m. Tailoring. The process of choosing or altering test procedures, conditions, values, tolerances, measures of failure, etc., to simulate or exaggerate the effects of one or more forcing functions to which an item will be subjected during its life cycle. The tailoring process, broadly speaking, also includes the engineering tasks and preparation of planning documents to assure proper consideration of environments throughout the life cycle.

n. Test level. The value at which a test condition is set.

o. Test method. The criteria and procedures used to formulate an environmental test. Test methods are identified by environment (or combinations) in section 5 of this document.

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p. Test procedure. A sequence of actions, the correct performance of which will result in a valid test of an item's response to a particular forcing function or combination of functions. Within each test method there are one or more test procedures.

4. GENERAL REQUIREMENTS

4.1 General. This standard describes a series of engineering tasks and supporting documentation to assure the tailoring of environmental test conditions to individual equipment applications. An environmental engineering specialist should be utilized to effectively apply this standard.

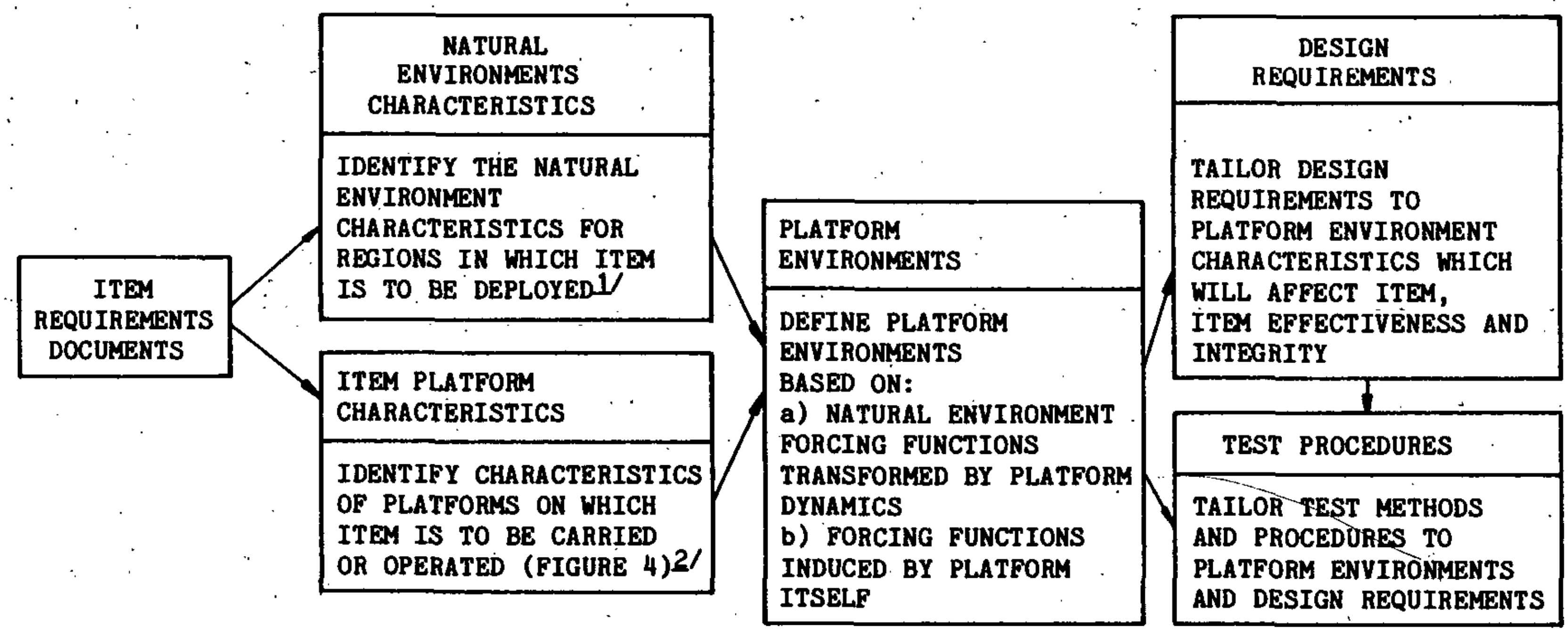
4.2 Tailoring

4.2.1 Objective of tailoring. The objective of tailoring, as applied in this standard, is to assure that military equipment is designed and tested for resistance to the environmental stresses it will encounter during its life cycle. Figure 1 illustrates the environmental tailoring process. Figure 2 shows generalized enviromental life cycle histories that may be used in developing a life cycle profile.

4.2.2 Tailoring tasks. It is necessary to give proper consideration to environments throughout the development process in order to obtain a quality product. To assure such consideration, environmental management plans shall be formulated that require the following engineering tasks: determination of life cycle environmental conditions; establishment of environmental design and test requirements, including a test plan; and collection and analysis of field data for verification of environmental design and test criteria. Proper attention to each of these tasks insures that the correct environments are identified for test, that engineering development as well as qualification tests are phased properly into the item's acquisition program, that environmental test conditions are traceable to life cycle conditions realistically encountered, and that testing is appropriate for the item application. The following plans, tasks, and documentation are established to facilitate the tailoring process. Each shall be prepared directly by the procuring activity or by the contractor as directed by the procuring activity.

4.2.2.1 Environmental Management Plan. The overall purpose of this plan is to develop a viable and cost effective program to assure that military equipment will be designed and tested for all pertinent environmental conditions to which it will be subjected during its life cycle. The overall management of the environmental program shall include consideration of manpower requirements, scheduling, life-cycle environmental conditions, test tailoring, test performance, analysis of results, corrective actions, and collection of data about, and analysis of, actual field environments. Plans for monitoring, assessing, reporting and implementing the entire environmental program shall be addressed. The environmental management plan shall be documented according to DID DI-R-7123.

4.2.2.2 Life Cycle Environmental Profile. A life cycle history of events and associated environmental conditions for an item from its release from manufacturing to its retirement from use shall be determined. The life cycle shall include the various phases an item will encounter in its life, such as: handling, shipping or storage prior to use; phases between missions, such as stand-by or storage or transfer to and from repair sites; geographical



1/ CONVENTIONAL METEOROLOGICAL DATA ARE NOT COLLECTED WITH MILITARY HARDWARE IN MIND. GREAT CARE MUST BE TAKEN TO ENSURE THAT THE METEOROLOGICAL DATA USED ARE RELEVANT TO THE SPECIFIC HARDWARE ITEMS.

2/ IN THIS CONTEXT, A PLATFORM IS ANY VEHICLE, SURFACE, OR MEDIUM THAT CARRIES THE HARDWARE. FOR EXAMPLE, AN AIRCRAFT IS THE CARRYING PLATFORM FOR AN AVIONICS POD, THE LAND ITSELF FOR A GROUND RADAR, AND A MAN FOR A HAND-CARRIED RADIO.

FIGURE 1. Environmental tailoring process for military hardware.

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locations of expected deployment; and platform environments. The environments and combination of environments the equipment will encounter at each phase shall be determined. All potential deployment scenarios should be described. Figure 2 shows generalized environmental life cycle profiles that may be used as a baseline to identify the environments most likely to be associated with each life cycle phase. The information presented in the figure does not necessarily include all environments or combinations of environments to which materiel will be exposed. The following factors should also be taken into account:

a. Configuration of the hardware.

b. Environment that is encountered.

c. Platform with which the hardware interfaces.

d. Interfaces with other equipment.

e. Absolute and relative duration of exposure phase.

f. Number of times phase will occur; intermittency of phase.

g. Probability of occurrence of environmental conditions.

h. Geographical location.

i. Any other information which will help identify any environmental conditions which may act upon the item.

The life cycle environment profile shall be documented according to DID DI-R-7124.

4.2.2.3 Environmental Design Criteria and Test Plan. This plan shall define the specific environmental design and test requirements and include an environmental test plan. Data obtained under provisions of 4.2.2.2 above shall be utilized, along with the individual environmental test methods listed in section 5 of this document. Consideration should be given to the following:

a. Probability of environmental occurrence, alone or in combination.

b. Expected effects and failure modes.

c. Effect on hardware performance and mission success.

d. Likelihood of problem's disclosure by the test methods.

e. Occurrence of similar environmental stress in more than one life profile phase.

f. Experience gained from other equipment similarly deployed.

This plan shall be documented under DID DI-R-7125.

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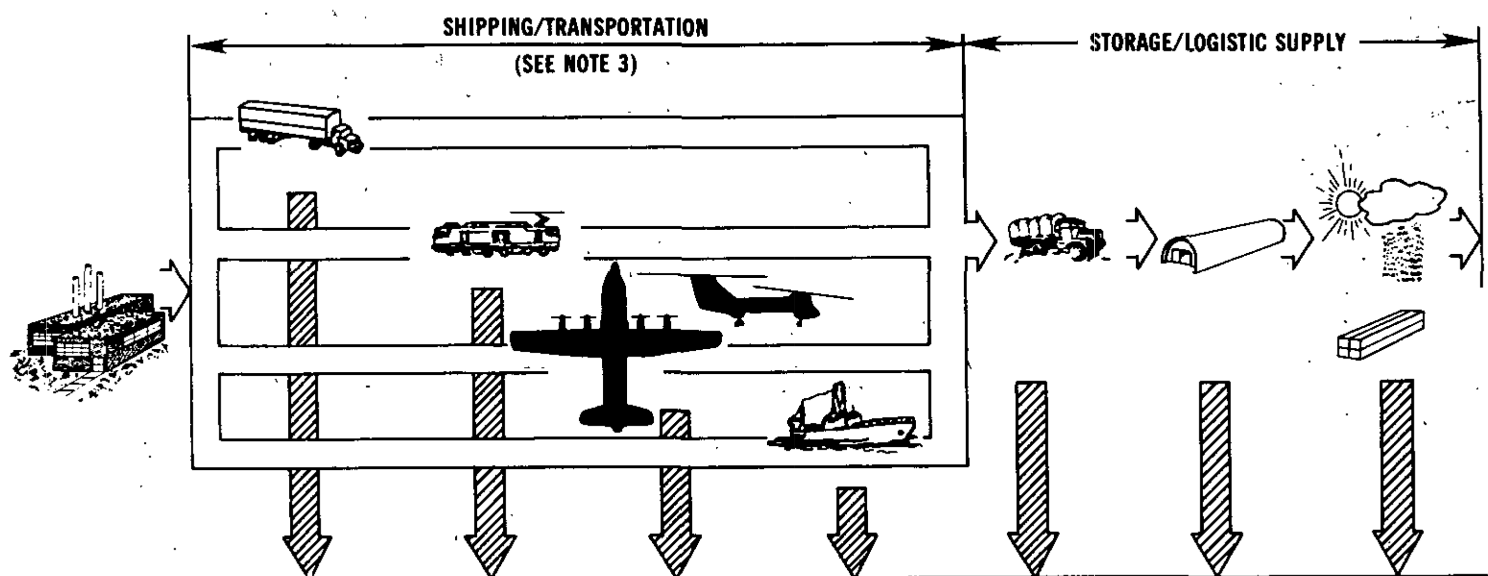

	Handling & Road Transportation	Handling & Rail Transportation	Handling & Air Transport	Handling & Ship Transport	Handling & Logistics Transport (Worst Route)	Storage, Sheltered (Tent, Shed, Igloo)	Storage, Open
Environmental Stress Generation Mechanisms (Induced)	Road Shock (Large Bumps/Potholes) Road Vibration (Random) Handling Shock (Dropping/ Overturning)	Rail Shock (Humping) Rail Vibration Handling Shock (Dropping/Overturning)	In-Flight Vibration (Engine/ Turbine Induced) Landing Shock Handling Shock (Dropping/Overturning)	Wave-Induced Vibration (Sinusoidal) Wave Sine Shock Mine/Blast Shock Handling Shock (Dropping/Overturning)	Road Shock (Large Bumps/Holes) Road Vibration (Random) Handling Shock (Dropping/Overturning) Thermal Shock (Air Drop)	None	None
Environmental Stress Generation Mechanisms (Natural)	High Temperature Dry/Humid) Low Temperature Rain/Hail Sand/Dust	High Temperature (Dry-Humid) Low Temperature Rain/Hail Sand/Dust	Reduced Pressure Thermal Shock (Air Drop Only)	High Temperature (Humid) Low Temperature Rain Temporary Immersion Salt Fog	High Temperature (Dry/Humid) Low Temperature/Freezing Rain/Hail Sand/Dust Salt Fog Solar Radiation Reduced Pressure	High Temperature (Dry/Humid) Low Temperature/ Freezing Salt Fog Fungus Growth Chemical Attack	High Temperature (Dry/Humid) Low Temperature/ Freezing Rain/Hail Sand/Dust Salt Fog Solar Radiation Fungus Growth Chemical Attack

(See Note 5)

FIGURE 2. Generalized life cycle histories for military hardware.

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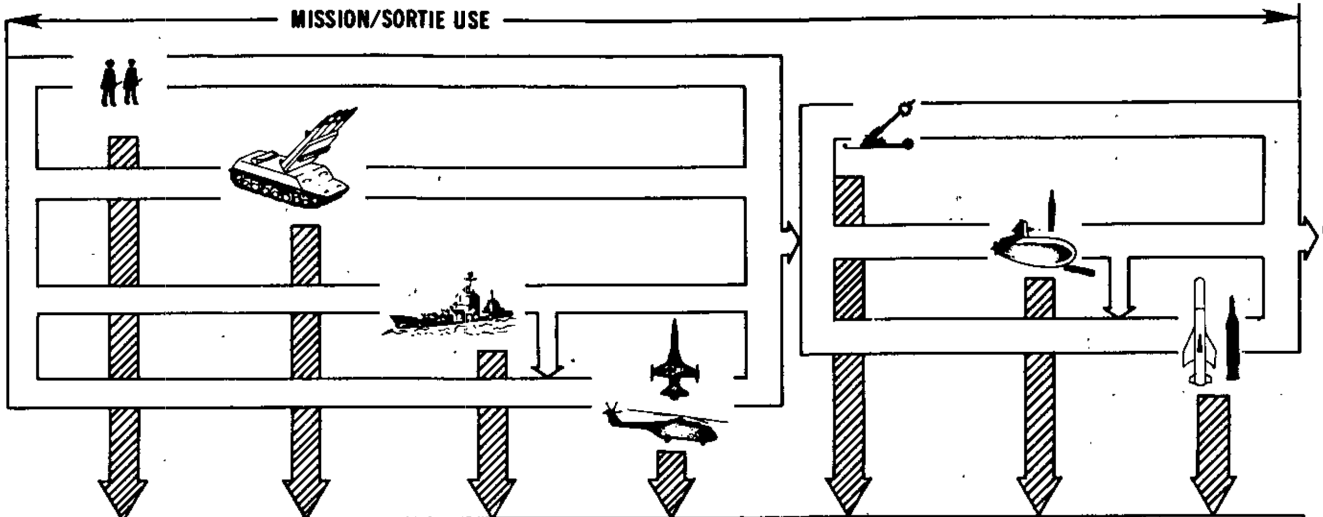

Deployment & Use by Foot Soldiers/Ground Personnel	Deployment & Use on Land Vehicles (Wheeled/ Tracked)	Deployment & Use Aboard Ships	Deployment & Use on Aircraft Including Captive Stores (Fixed/ Rotary Wing)	Delivery to Target Projectile	Delivery to Target Torpedo/Underwater Launched Missile	Delivery to Target Missile/Rocket
Handling Shock (Dropping/ Slamming/Overturning Firing/Blast Shock Acoustic Noise Explosive Atmosphere Electromagnetic Interference	Road/Off-Road Vibration (Surface Irregularities/ Tread Laying) Engine-Induced Vibration Acoustic Noise Handling Shock (Including Bench) Road/Off-Road Shock (Large Bumps/Holes) Land Mine/Blast Shock Weapon Firing Shock/ Vibration Explosive Atmosphere Electromagnetic Interference	Wave Induced Vibration (Sinusoidal) Engine-Induced Vibration Acoustic Noise Wave-Slam Shock Mine/Blast Shock Weapon Firing Shock Explosive Atmosphere Electromagnetic Interference Increased Pressure (Submarine)	Runway-Induced Vibration Aerodynamic Turbulence (Random Vibration) Maneuver Buffet Vibration) Gunfire Vibration Engine-Induced Vibration Acoustic Noise Take-Off /Landing/ Maneuver Acceleration Air Blast Shock Catapult Launch/Arrested Landing Shock Handling Shock (Including Bench) Aerodynamic Heating Explosive Atmosphere Electromagnetic Interference	Firing Shock Firing Acceleration Handling/Loading Shock Acoustic Noise Aerodynamic Heating Explosive Atmosphere Electromagnetic Interference	Launch Acceleration Handling/Launch Shock Engine-Induced Vibration Acoustic Noise Pyrotechnic Shock (Booster Separation) Explosive Atmosphere Electromagnetic Interference	Launch/Maneuver Acceleration Handling/Launch Shock Engine-Induced Vibration Aerodynamic Turbulence (Random Vibration Acoustic Noise Aerodynamic Heating Explosive Atmosphere Electromagnetic Interference
High Temperature (Dry/Humid) Low Temperature/ Freezing Thermal Shock Storage to Use) Rain/Hail Sand/Dust/Mud Salt Fog Solar Radiation Fungus Growth Chemical Attack	High Temperature (Dry/Humid) Low Temperature/ Freezing Thermal Shock Storage to Use) Rain/Hail Sand/Dust/Mud Salt Fog Solar Radiation Fungus Growth Chemical Attack	High Temperature (Dry/Humid) Low Temperature/ Freezing Thermal Shock Storage to Use) Rain Salt Fog Solar Radiation Fungus Growth Chemical Attack	High Temperature (Dry/Humid) Low Temperature/ Freezing Thermal Shock (Storage to Use) Rain Salt Fog Solar Radiation Rain Impingement Sand/Dust Impingement Fungus Growth Chemical Attack	Thermal Shock (Storage to Use) Rain Impingement Sand/Dust Impingement	Immersion Thermal Shock	Rain Impingement Sand/Dust Impingement

Note 1:
The environmental stress events experienced by actual hardware may not always occur in the sequence shown in this profile. The generalized profile is intended to be used as a starting point for a tailored life cycle stress analysis and to provide confidence that all potentially significant environmental conditions have been considered.

Note 2:
The generalized profile provides only representative decision-making information. It does not impose or imply a specific test order although it can aid in suggesting potentially useful environmental test stress combinations or sequences.

Note 3:
Hardware may be subjected to any or all of the shipping/transportation modes shown. Therefore, in any life cycle stress analysis, the anticipated stresses experienced by the hardware in each mode should be evaluated and the most significant of these incorporated in the test program.

Note 4:
The generalized profile shows only areas of environmental concern and does not attempt to show operational use patterns. The relative frequency and duration of storage, shipping, and mission events must be considered in determining life cycle environmental test parameters. It should also be remembered that even one-shot devices (rockets, shells, etc) must endure combinations and repetitions of all these events before they are ultimately fired.

Note 5:
In the interest of completeness. Some environmental stress generating mechanisms have been included for which corresponding tests are not induced in this document. Their absence from this document does not imply a lack of importance; they should be given equal consideration in the life cycle stress analysis.

Fig 2. Generalized life cycle histories for military hardware.

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4.2.2.4 Operational Environmental Verification Plan. This document shall include plans for obtaining data on actual operating or field environments to which the test item will be exposed, for comparison with design and test criteria. It will provide the basis for the analysis of the adequacy of the environmental program. The Operational Environmental Verification Plan shall be documented according to DID DI-R-7126.

4.3 Use of field/fleet data. Field data used in these methods should meet all of the following:

a. Equipment similarity. Whenever practical, measurements shall be made on (a copy of) the test item or on the same platform type as that which will carry the equipment to be tested. This ideal situation is often unattainable early in the development of new equipment. Therefore, it is sometimes necessary to derive data from appropriately similar equipment or carrying platforms. Under such circumstances, exact equivalence shall not be expected or required. It is important to note that equipment may be functionally dissimilar and still be considered as similar for evaluating environmental stress conditions.

b. Data quality. The following minimum standards should be satisfied before field lata is considered suitable for substitution into the test procedures. Supporting information should include:

(1) A description of the equipment or the carrying platform.

(2) The location on the hardware or carrying platform at which the measurements were made.

(3) The environmental and operating conditions under which the measurements were made.

(4) The type and calibration status of data recording and analysis equipment and instrumentation.

In addition, the measured data should be analyzed and formatted to be compatible with the specific test procedure for which it is being considered.

c. Data quantity. Sufficient data is needed to adequately describe the conditions being evaluated, but the requirements for sufficiency will vary with the environmental conditions, physical and performance characteristics of the hardware type, and program needs. Consideration shall be given to:

(1) The number and nature of the data measurement points.

(2) The number and scope of trials conducted to record data.

Some engineering judgement may be required to assess the applicability of data when constraints limit the number and location of measurement points.

4.4 Test conditions. Unless otherwise specified herein or in the equipment specification, measurements and tests shall be made at the following conditions:

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a. Standard ambient. Ambient measurements and checks (e.g., pre- and post-test) are conducted at room ambient conditions as follows:

Temperature:	$25^{\circ}C \pm 10^{\circ}C$ ($77^{\circ}F \pm 18^{\circ}F$)
Relative humidity:	Uncontrolled room ambient
Atmospheric pressure:	Site pressure

b. Controlled ambient. When the ambient conditions must be closely controlled, the following shall be maintained:

Temperature:	$23^{\circ}C \pm 2^{\circ}C$ ($73^{\circ}F \pm 3.6^{\circ}F$)
Relative Humidity:	50 percent $\pm$ 5 percent
Atmospheric Pressure:	$96.45^{+6.6}_{-10.0}$ kPa
	(725^{+50}_{-70} mmHg)
	($28.5^{+2.0}_{-3.0}$ inHg)

4.4.1 Tolerances for test conditions. Unless otherwise specified, tolerances for test conditions shall be as follows:

a. Temperature. The test item shall be totally surrounded by an envelope of air (except at necessary support points). The temperature of the test section measurement system and the temperature gradient throughout this envelope, which is measured close to the test item, shall be within $\pm 2^{\circ}C$ ($\pm 3.6^{\circ}F$) of the test temperature and shall not exceed $1^{\circ}C$ per meter or a maximum of $2.2^{\circ}C$ total (equipment nonoperating).

b. Pressure. When pressure is 1.3×10^{-3} Pa or higher, it shall be measured with an accuracy of ±5 percent of the measured value.

c. Low pressure. When pressure is lower than 1.3×10^{-3} Pa it shall be measured with an accuracy of ±10 percent of the measured value.

d. Humidity. Relative humidity at the chamber control sensor shall be ±5 percent of the measured value.

e. Vibration amplitude

Sinusoidal: ±10 percent
Random: See method 514.3

f. Vibration frequency. Vibration frequency shall be measured with an accuracy of ±2 percent, or ±1/2 Hz below 25 Hz.

g. Acceleration. Acceleration shall be measured to within ±10 percent.

h. Time. Elapsed time shall be measured with an accuracy of ±1 percent.

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4.4.2 Accuracy of test instrumentation calibration. The accuracy of instruments and test equipment used to control or monitor the test parameters shall be verified prior to and following each test and then calibrated in predetermined intervals and shall meet the requirements of MIL-STD-45662 to the satisfaction of the procuring activity. All instruments and test equipment used in conducting the tests specified herein shall:

a. Be calibrated to laboratory standards whose calibration is traceable to the National Standards via primary standards.

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

4.4.3 Stabilization of test temperature

4.4.3.1 Test item operating. Unless otherwise specified, temperature stabilization is attained when the temperature of the operating part of the test item considered to have the longest thermal lag is changing no more than 2.0°C (3.6°F) per hour.

4.4.3.2 Test item nonoperating. Unless otherwise specified, temperature stabilization is attained when the temperature of the operating part of the test item considered to have the longest thermal lag reaches a temperature within test tolerances of the nominal test temperature, except that any critical component (e.g., battery electrolyte for engine starting test) will be within 1°C (1.8°F). Structural or passive members are not normally considered for stabilization purposes. When changing temperatures, for many test items, the temperature of the chamber air may be adjusted beyond the test condition limits to reduce stabilization time, provided the extended temperature does not induce response temperature in a critical component or area of the test item beyond the test temperature limits for the test item.

4.4.4 Test sequence. Experience has shown definite advantages to performing certain tests immediately before, in combination with, or immediately following other tests. Where these advantages have been identified, guidance has been put in I-3c of the test methods and shall be followed. Other sequences and combinations consistent with 1.2 and 4.2.1 of General Requirements may be used with the permission of the procuring agency.

4.4.5 Test procedures. Guidance for choosing among the procedures of a method is found in section I of each method.

4.4.6 Test conditions. Whenever practical, specific test levels, ranges, rates, and durations shall be derived from measurements made on actual or appropriately similar equipment (see 4.3). When specific measured data are not available, the test characteristics shall be tailored using the guidance found in section 5.

4.5 General test performance guidance

4.5.1 Pretest performance record. Before testing, the test item should be operated at standard ambient conditions (see 4.4) to obtain and record data for determining compliance with the requirements document(s) and for comparison

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with data obtained before, during, and after the environmental test(s). The identification and environmental test history of the specific test item(s) should be documented for failure analysis purposes.

4.5.1.1 Pre-test record. The pre-test record shall include (as applicable):

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

b. Additional evaluation criteria (in addition to 4.5.7).

4.5.2 Installation of test item in test facility. Unless otherwise specified, the test item shall be installed in the test facility in a manner that will simulate service usage, with connections made and instrumentation attached as necessary.

a. Plugs, covers, and inspection plates not used in operation, but used in servicing, shall remain in place.

b. Electrical connections normally used in service but not in test shall be provided with electrical connectors having dummy cables with protected terminations. Such mechanical connections shall also be protected.

c. For tests where temperature values are controlled, the test chamber shall be at standard ambient conditions when the test item is installed or as specified in the individual methods.

d. The test item shall be operated according to the applicable technical order or technical manual, when available, to determine that no malfunction or damage has resulted from faulty installation or handling. The requirement to operate the test item after its installation in the test facility applies only when the item is required to operate during the test.

e. Test items shall be positioned at least 15 cm (6 inches) from each other or from walls, floors, ceilings, etc. to allow for adequate circulation.

f. If the item to be tested consists of several separate units, these units may be tested separately provided the functional aspects are maintained as defined in the requirements document.

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

4.5.4 Interrupted tests. Unless otherwise specified in the individual methods, the following procedures shall be followed when a test is interrupted. Any deviation from this guidance shall be explained in the test report.

4.5.4.1 In-tolerance interruptions. Interruptions during which the prescribed test tolerances are not exceeded shall be considered as part of the total test duration. (No allowance is necessary if exposure to the proper test levels was maintained.)

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4.5.4.2 Methods 503.2, 506.2, 510.2, 511.2, 514.3, 516.3 and 519.3. (See figure 3.)

a. Undertest. If test tolerances have been exceeded resulting in an undertest condition, the test may be resumed from the point at which tolerances were exceeded following reestablishment of prescribed conditions (except as noted in the individual methods), and extended to insure that the prescribed test cycle is achieved.

b. Overtest. If an overtest condition occurs, the preferable course of action is to stop the test and start over with a new test item. However, if any damage is a direct result of the overtest conditions and will not affect other test item characteristics, or if the item can be repaired, the test may be resumed and extended as in the undertest condition. If an item failure occurs during the remainder of the test, the test results shall be considered invalid.

4.5.4.3 Methods 500.2, 501.2, 502.2, 505.2, 508.3, 509.2, 512.2, 513.3, 520.0 and 521.0. Each of these methods contains guidance for handling out-of-tolerance test interruptions. Any such interruption must be carefully analyzed. If the decision is made to continue testing from the point of interruption, to restart the last successfully completed test cycle, or to restart the entire test with the same test item, and a failure occurs, it is essential to consider the possible effects of the interruption or of the extended length of the test.

4.5.5 Combined tests. Combinations of tests may produce a more realistic representation of the effects of the environment than a series of single tests can. Combined testing is encouraged.

4.5.6 Post-test data. At the completion of each environmental test, the test item shall be inspected in accordance with the equipment specifications, and the results shall be compared with the pretest data obtained in accordance with 4.5.1. Post-test data shall include:

a. Complete identification of all test equipment and accessories.

b. The actual test sequence (program) used.

c. Deviation from the planned test program.

d. The room ambient test conditions recorded periodically during the test period.

e. Test item operational data.

f. A signature and data block for certification of the test data by the test engineer.

g. Other data as specified in the individual methods or equipment requirements document(s).

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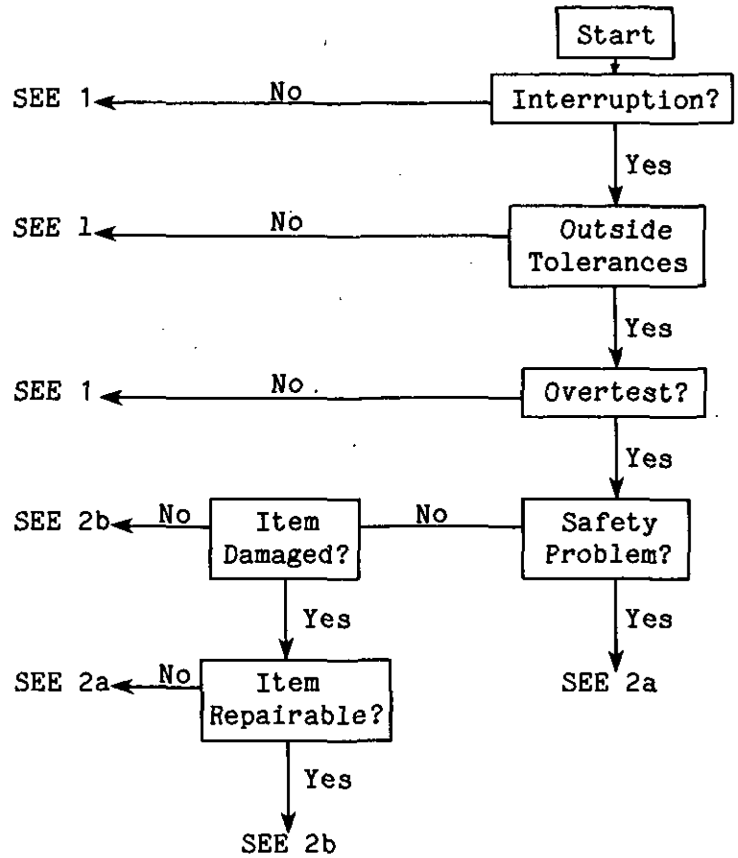

NOTES:

1. Continue test (see individual methods); extend test time if necessary.

2. Alternatives:

   a. Restart at the beginning.

   b. Complete the test with undamaged or repaired test item. (NOTE: Test results will be invalid if an item failure occurs.)

FIGURE 3. Interrupted test cycle logic - Methods 503.2, 506.2, 510.2, 511.2, 514.3, 516.3, and 519.3.

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4.5.7 Failure criteria. Failure of the test item to meet any one of the following conditions shall constitute a test item failure.

a. Deviation of monitored functional parameter levels beyond acceptable limits established in 4.5.1 and specified in the requirements document.

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

b. Nonfulfillment of safety requirements or the development of safety hazards.

c. Nonfulfillment of specific test item requirements.

d. Changes to the test item which could prevent the equipment from meeting its intended service life or maintenance requirements. (For example: Corroded oil drain plug cannot be removed with specified tools.)

e. Deviation from established environmental requirements.

f. Other (see 4.5.8).

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

4.5.9 Environmental test report. An environmental test report shall be completed according to DID No. DI-R-7127.

4.6 Climatic regions. For the purposes of this document, three climatic regions are defined to which equipment may be designed and tested: hot/dry, hot/humid (or "basic"), and cold.

4.6.1 Map of climatic regions. Figures 4a and 4b show land areas where the various climatic regions exist.

4.6.2 Delimitation of climatic design types. The climate types are distinguished primarily by temperature, and secondarily by humidity.

a. Hot climatic regions. This region includes most of the low-latitude deserts of the world. During summer in these areas, temperatures above 43°C (110°F) occur frequently, but except for a few specific places, temperatures will seldom be above 49°C (120°F). In winter, temperatures are likely to be in the same range as for the "basic" climatic region. If materiel is designed only for the hot climate, a specially tailored low temperature design value should be sought. Small portions of this area are sometimes subject to very high absolute humidities, although the highest temperatures and highest dewpoints do not occur at the same time.

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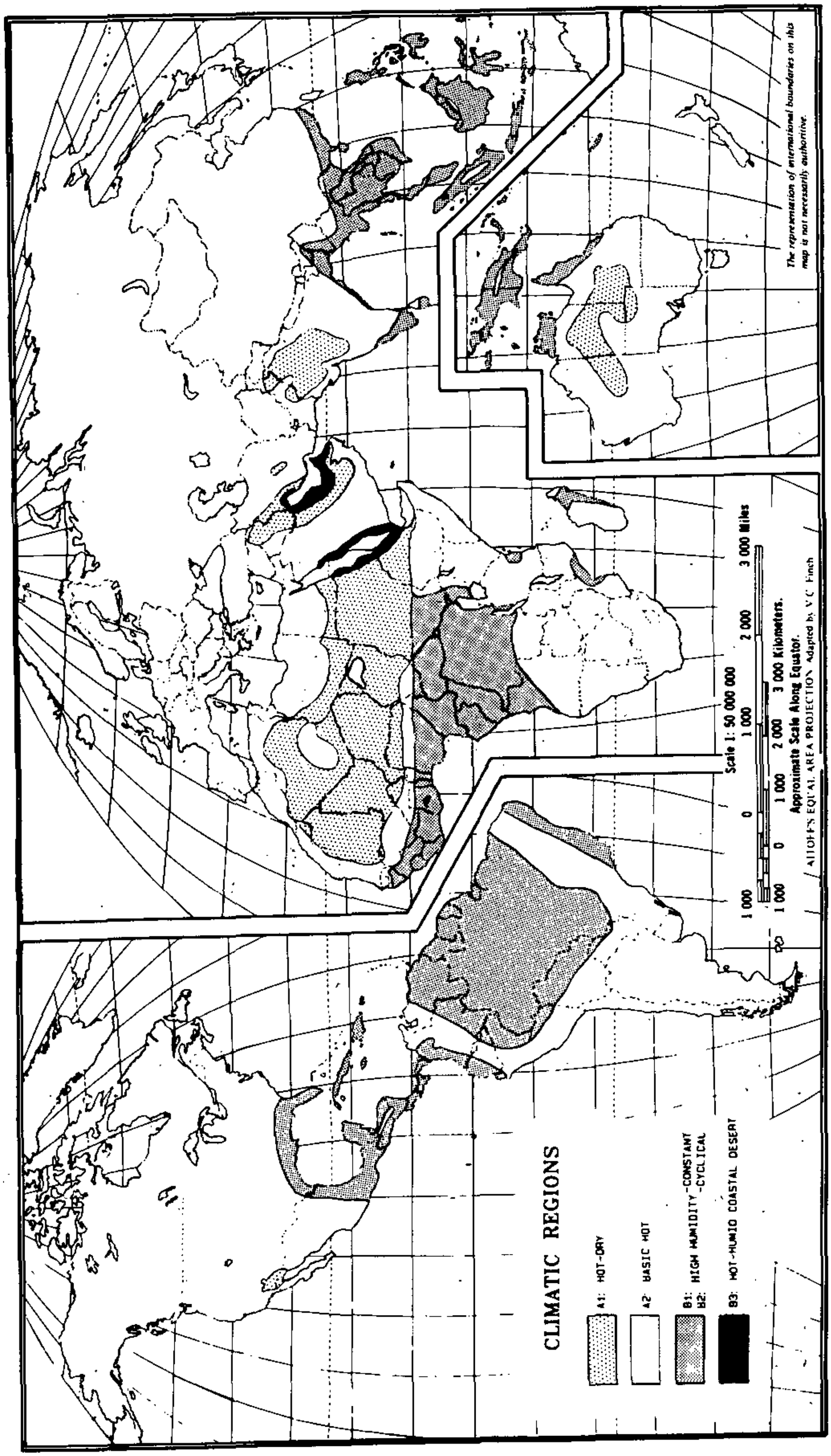

FIGURE 4a. World climatic regions - hot.

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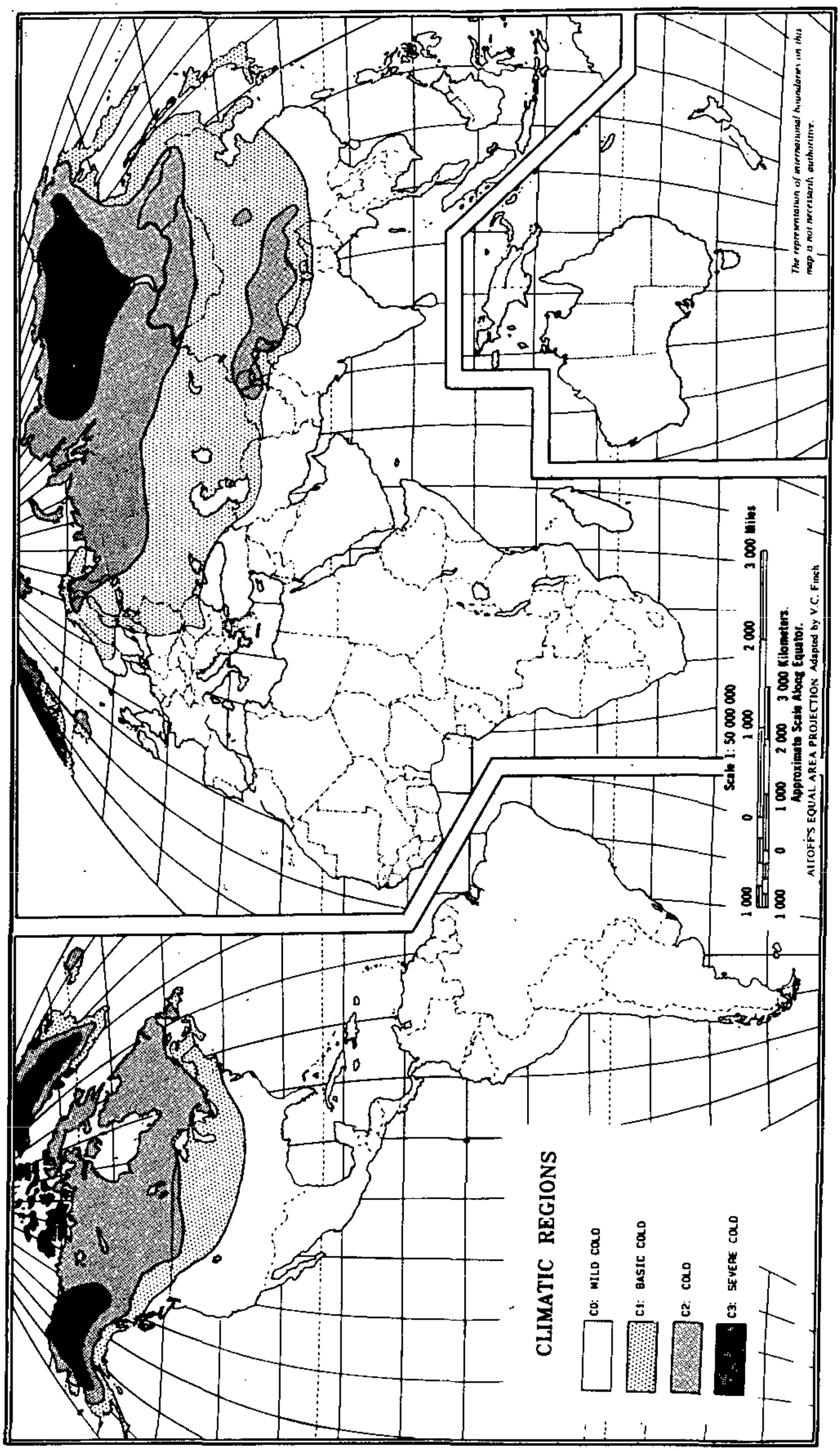

FIGURE 4b. World climatic regions - cold.

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b. Basic climatic regions. These regions include the most densely populated and heavily industrialized parts of the world as well as the humid tropics. The entire range of basic design conditions does not necessarily occur in any one place. Each single condition (high temperature, low temperature, high humdity) occurs in a wide area. When taken together, the design values should provide for satisfactory equipment throughout the area. Tropical areas are included in this climate type because their temperature is quite moderate, and their humidity levels are equalled in the mid-latitudes. The feature of the tropics most important for equipment design is the persistence of high humidity over long periods of time. This condition not only promotes corrosion but is an excellent environment for insect and microbiological damage.

c. Cold and severe-cold climatic regions. These areas include northern North America, Greenland, northern Asia, and Tibet. In the cold area, temperature during the coldest month in a normal year may be colder than the basic cold extreme of -32°C (-25°F). In the severe-cold areas, temperature during the coldest month in a normal year may be colder than the cold extreme of -46°C (-50°F), but colder than -51°C (-60°F) no more than 20 percent of the hours in the coldest month of the coldest part of the area (northern Siberia, where absolute minimum temperatures as low as -68°C (-90°F) have been recorded). Because the extreme low temperatures are not controlled by a daily solar cycle, they persist for a long enough period of time for materiel to reach equilibrium at a temperature near the minimum.

5. TEST METHODS

5.1 Individual methods for environmental testing follow section 6.

6. NOTES

6.1 Intended use. The purpose of this standard is to standardize the design and conduct of tests for assessing the ability of military equipment to withstand environmental stresses it will encounter during its life cycle, and to insure that plans and test results are adequately documented.

6.2 Data requirements. When this standard is used in an acquisition, the data identified below shall be delivered only when the task paragraph(s) applicable to a specific DID is applied in a contract and the applicable DID is specified on the DD Form 1423, "Contract Data Requirements List (CDRL)." When the DD Form 1423 is not used and DAR 7-104.9(n)(2) is cited, the data identified below shall be delivered in accordance with requirements specified in the contract or purchase order. Deliverable data associated with the requirements of this standard are cited in the following paragraphs.

Paragraph No.	Data Requirement Title	Applicable DID
4.2.2.1	Environmental Management Plan	DI-R-7123
4.2.2.2	Life Cycle Environmental Profile Plan	DI-R-7124
4.2.2.3	Environmental Design Criteria and Test Plan	DI-R-7125
4.2.2.4	Operational Environmental Verification Plan	DI-R-7126
4.5.9	Environmental Test Report	DI-R-7127

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(Copies of DIDs required by contractors in connection with specific acquisition functions should be obtained from the Naval Publications and Forms Center or as directed by the contracting officer.)

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

6.4 Changes from previous issue. Asterisks or vertical lines are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

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

Preparing activity:
Air Force - 11

Project No. ENVR-0013

Review activities:

Army - MI, ME, AV, GL, TE, MT, AT, CE, AR
Navy - SH, OS, YD, EC
Air Force - 10, 18, 19, 69

International interest (see 6.3)

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METHOD 500.2

LOW PRESSURE (ALTITUDE)

SECTION I

I-1 PURPOSE. Low-pressure (altitude) chamber tests are performed to determine if materiel can withstand, and operate in, a low-pressure environment.

1-2 ENVIRONMENTAL EFFECTS. Examples of some problems that could occur as a result of exposure to reduced pressure are:

a. Leakage of gases or fluids from gasket-sealed inclosures.

b. Rupture or explosion of sealed containers.

c. Change in physical and chemical properties of low-density materials.

d. Erratic operation or malfunction of equipment resulting from arcing or corona.

e. Overheating of equipment due to reduced heat transfer.

f. Evaporation of lubricants.

g. Erratic starting and combustion of engines.

h. Failure of hermetic seals.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS.

NOTE: This test method should be applied at the end of the tailoring process described in section 4 of this standard.

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a. Application. This method is intended to be used for the following applications:

(1) Air shipment of materiel in cargo aircraft.

(2) Equipment designed for installation or operation at high ground elevations.

(3) Explosive (rapid) decompression due to aircraft damage.

b. Restrictions. This method is not intended to be used to test equipment to be installed in and operated in aircraft, missiles that fly at high altitudes (i.e., above 4,570m (15,000 ft)), external stores, or space vehicles, since such equipment would be subjected to method 520. This altitude test would be a duplication of effort and a less effective test for such equipment.

c. Sequence. (See General Requirements, 4.4.4.) This method is considered to be the least damaging of those included in this document for most types of equipment and therefore may be one of the first to be conducted. Other testing may contribute significantly to the effects of low pressure (see I-2) on the test item and may have to be conducted before this method. For example:

(1) Low-temperature and high-temperature testing may affect seals.

(2) Dynamic tests may affect the structural integrity of the test item.

d. Test variations. Before conducting these tests, determine any required variations of the test procedure(s). The choices for varying the test procedure(s) are extremely limited. The primary variations involve the test altitude, altitude change rate, and test duration, as outlined in I-3.2. Other environmental combinations, such as low temperature and low pressure, are not addressed in this method but may be considered.

I-3.1 Choice of test procedure(s)

a. Operational purpose of the test item. From the requirements document(s), determine the functions to be performed by the equipment in a low-pressure environment and any limiting conditions.

b. Test objectives. The primary objectives of the low-pressure (altitude) test are to determine if:

(1) The test item can be stored and operated at high ground elevation sites.

(2) The test item can be transported by air in its normal shipping/storage configuration.

(3) The test item can survive a rapid decompression and, if not, to determine if it will damage the aircraft or present a hazard to personnel.

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c. Selection of the test procedure(s). Three test procedures are included within this method: storage, operation, and rapid decompression. Based on the test data requirements, determine which of the test procedures or combination of procedures is applicable.

(1) Procedure I - Storage. Procedure I is appropriate if the test item is to be stored at high ground elevations or transportated in its shipping/storage configuration.

(2) Procedure II - Operation. Procedure II is used to determine the performance of the test item under low-pressure conditions and can be preceded by procedure I, procedure III, or both. If there are no low-pressure storage or explosive decompression requirements, this procedure can stand alone.

(3) Procedure III - Rapid decompression. Procedure III is used to determine if a rapid decrease in pressure of the surrounding environment will cause a test item reaction that would endanger nearby personnel or the aircraft in which it is being transported. After the rapid decompression test, a potential safety problem could exist that is not obvious. Caution should be exercised during the post-test operational check. This procedure can be preceded by either the storage or the operational test.

I-3.2 Choice of related test conditions. After the test procedure(s) is chosen, the test altitude(s), altitude change (climb/descent) rate, duration of exposure, test item configuration, and any additional appropriate guidelines must be determined.

a. Test altitude. Base determination of the specific test altitudes on the anticipated deployment or flight profile of the test item. If this information is not available, use the following guidance to determine the test altitude:

(1) World ground areas. The highest elevation currently contemplated for ground military operations (equipment operating and nonoperating) is 4,570m (15,000 ft), 57 kPa (8.3 psia) (reference a).

(2) Transport aircraft cargo compartment pressure conditions. Table 500.2-I provides the minimum cargo compartment pressures for various aircraft used to transport cargo. These pressures can occur as a result of failure of the automatic pressurization system. Redundant systems prevent rapid loss of pressure unless explosive decompression occurs. Testing to the 4,570m (15,000 ft) equivalent altitude will assure that the equipment shipped by air will successfully withstand the low-pressure environment.

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TABLE 500.2-I. Minimum cargo compartment pressures.

Aircraft	Minimum Cargo Compartment Pressure		Equivalent Altitude (reference c)	
	(psia)	(kPa)	(ft)	(m)
C-130	8.29	57.2	15,000	4,570
C-141	8.63	59.5	14,000	4,270
C-5A	8.81	60.7	13,500	4,110
DC-8/707/DC-9-80	8.29	57.2	15,000	4,570
DC-10/747/KC-10	8.29	57.2	15,000	4,570
L-1011/767	8.29	57.2	15,000	4,570
C-160 Transall	8.63	59.5	14,000	4,270
A-300/C	10.71	73.8	8,000	2,400

(3) Maximum flight altitude for explosive decompression testing: 12,200m (40,000 ft) (18.84 kPa). When it is known that other altitudes will be encountered, test the equipment for the known elevation.

b. Altitude change rate. If a specific rate of altitude change (climb/descent rate) is not known or specified in the requirements document, the following guidance is offered: In general, and with the exception of the explosive decompression test, the rate of altitude change should not exceed 10 m/s (2,000 ft/min) unless justified by the anticipated deployment platform. In a full military power takeoff, military transport aircraft normally have an average altitude change rate of 7.6 m/s (1,500 ft/min). To conserve fuel, the present procedure is to have a 3.8 to 4.1 m/s (750 to 800 ft/min) altitude change rate, normal practice for commercial aircraft operations. The value of 10 m/s will also be used for ground deployment tests (for standardization purposes) unless otherwise specified.

c. Rapid decompression rate. There are several conditions for which the rapid rate of decompression may vary. These include:

(1) Massive damage to the aircraft, but the aircraft survives and decompression is virtually instantaneous.

(2) Relatively small holes caused by foreign objects through which decompression could occur at a slower rate than in (1) above.

(3) Relatively gradual loss of pressure due to loosening of aircraft structure.

The decompression in procedure III should be accomplished as quickly as possible but shall not take more than 15 seconds.

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d. Test duration. For procedure I, the test duration should be representative of the anticipated service environment, but a test duration of at least 1 hour is considered adequate for most equipment. Procedures II and III do not require extended periods at the test pressure, once it has been reached and any required functions are performed.

e. Test item configuration. Configure the test item in a manner that is characteristic of its normal configuration, i.e., operational for high ground elevation simulation, in its shipping/storage container for air transport, etc.

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

I-4 SPECIAL CONSIDERATIONS

I-4.1 Failure criteria. Failure criteria for procedures I and II are as described in General Requirements, 4.9. For procedure III, the test item fails only if rapid decompression causes a hazard to the aircraft or to the personnel; the test item need not show satisfactory post-test performance unless otherwise specified.

I-4.2 Summary of test information required. The following information is required in the test plan for adequate conduct of the tests of section II:

a. Test procedure.

b. Test altitude(s).

c. Altitude change rates.

d. Test duration.

e. Test item configuration.

f. Additional guidelines used.

I-5 REFERENCES

a. MIL-STD-210, Climatic Extremes for Military Equipment. 15 December 1973.

b. Synopsis of Background Material for MIL-STD-210B, Climatic Extremes for Military Equipment. Bedford, MA: Air Force Cambridge Research Laboratories, 1974. DTIC number AD-780-508.

c. Handbook of Geophysics and Space Environments. Bedford, MA: US Air Force Cambridge Research Laboratories, Office of Aerospace Research, 1965.

d. US Standard Atmosphere: 1976. NOAA/NASA/USAF, 1976.

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METHOD 500.2

LOW PRESSURE (ALTITUDE)

SECTION II

II-1 APPARATUS

II-1.1 Test facility. The required apparatus consists of a chamber or cabinet and auxiliary instrumentation capable of maintaining and continuously monitoring the specific conditions of low pressure. For procedure III, the facility shall be capable of providing decompression in the prescribed time period.

II-1.2 Controls

a. Unless otherwise specified, the altitude change rate shall not exceed 10 m/s (2,000 ft/min).

b. Continuous recordings of chamber pressure shall be taken if required.

c. Readout charts should be capable of being read with a resolution within 2 percent of full scale.

II-1.3 Test interruption. (See General Requirements, 4.5.4.) To achieve the desired effects, the test item must be subjected to the low-pressure (altitude) environment without interruption.

a. Undertest interruptions. Any occurrence that causes the test section pressure to deviate more than 10 percent of the measured value (in meters or feet) toward ambient atmospheric conditions shall be followed by a repeat of the entire test.

b. Overtest interruptions. Any occurrence that results in a pressure decrease of more than 10 percent of the measured value below that cited by the requirements document should be followed by a complete physical examination and operational check (where possible). Any evidence of deterioration should result in a retest. Reinitiation of the entire test with a new test item is allowed. If no deterioration is detected, the entire test shall be repeated.

II-2 PREPARATION FOR TEST

II-2.1 Preliminary steps. Before initiating any testing, determine from the test plan:

a. Which test procedures are required.

b. The low-pressure operation and storage requirements.

II-2.2 Pretest standard ambient checkout. All items require a pretest checkout at standard ambient conditions to provide baseline data. Conduct the checkout as follows:

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Step 1. Insert the test item in the test chamber.

Step 2. Prepare the test item in its operational configuration in accordance with General Requirements, 4.5.2.

Step 3. Record the standard ambient conditions.

Step 4. Conduct as complete of a visual examination of the test item as possible, and document the results.

Step 5. Conduct an operational checkout in accordance with the test plan.

Step 6. Record the results for compliance with General Requirements, 4.5.1.

II-3 PROCEDURES. The following test procedures, alone or in combination, provide the bases for collecting the necessary information concerning the test item in a low-pressure environment. Specific steps are included in the test procedures to combine the test procedures to get the necessary test data. Unless otherwise specified, the chamber temperature shall be maintained at standard ambient conditions.

II-3.1 Procedure I - Storage

Step 1. Adjust the test item's configuration to that required for storage or transit.

Step 2. With the test item in the chamber, adjust the chamber air pressure, at the rate specified in the test plan, to the required test altitude.

Step 3. Maintain the conditions for a minimum of 1 hour unless otherwise specified in the test plan.

Step 4. Adjust the chamber air pressure to standard ambient atmospheric conditions at a rate not to exceed that specified in the test plan.

Step 5. Conduct a complete visual examination and an operational checkout of the test item in accordance with test plan, and document the results.

Step 6. Compare these data with the pretest data.

Step 7. If an operational test is required, proceed to step 1 of procedure II; if a rapid decompression test is required, proceed to step 1 of procedure III.

II-3.2 Procedure II - Operation

Step 1. Adjust the test item to its operational configuration.

Step 2. Adjust the chamber air pressure to the required equivalent operational altitude at a rate not to exceed that specified in the test plan.

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Step 3. Conduct an operational checkout of the test item in accordance with the test plan, and document the results.

Step 4. Adjust the chamber air pressure to standard ambient atmospheric conditions at the rate specified in the test plan.

Step 5. Conduct a complete visual examination and an operational checkout of the test item in accordance with the approved test plan, and document the results.

Step 6. Compare these data with the pretest data.

Step 7. If a rapid decompression test is required, proceed to step 1 of procedure III.

II-3.3 Procedure III - Rapid decompression

Step 1. Adjust the test item configuration to that required for storage or transit.

Step 2. With the test item in the chamber, reduce the chamber air pressure at the rate specified in the test plan to the maximum equivalent altitude of the anticipated aircraft.

Step 3. Reduce the pressure to an equivalent altitude of 12,200m (40,000 ft) (18.8 kPa), or as otherwise specified in the test plan, as quickly as possible but in not more than 15 seconds. Maintain this stabilized reduced pressure for at least 10 minutes.

Step 4. Adjust the chamber air pressure to standard ambient atmospheric conditions at the rate specified in the test plan.

Step 5. Conduct a complete visual examination of the test item, and document the results. NOTE: Be alert for potential safety problems.

Step 6. Conduct an operational checkout of the test item in accordance with the test plan.

Step 7. Document the results.

Step 8. Compare these data with the pretest data.

Step 9. Proceed to step 1 of procedure II if an operational test is required following this procedure.

II-4 INFORMATION TO BE RECORDED. Test data shall be recorded as specified in General Requirements, 4.5, and shall include the following:

a. Previous test methods to which the specific test item has been subjected.

b. Results of each operational check and visual examination (and photographs, if applicable).

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(1) Pretest.

(2) During test.

(3) Post-test.

c. Time-versus-pressure data.

d. Room ambient conditions.

e. Initial failure analysis.

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METHOD 501.2

HIGH TEMPERATURE

SECTION I

I-1 PURPOSE. High-temperature chamber tests are performed to determine if materiel can be stored and operated under hot climatic conditions without experiencing physical damage or deterioration in performance.

I-2 ENVIRONMENTAL EFFECTS. High temperatures may temporarily or permanently impair the performance of the test item by changing the physical properties or dimensions of the material(s) composing it. Examples of some other problems that could occur as the result of high-temperature exposure are:

a. Parts binding from differential expansion of dissimilar materials.

b. Lubricants becoming less viscous; joints losing lubrication by outward flow of lubricants.

c. Materials changing in dimension, either totally or selectively.

d. Packing, gaskets, seals, bearings and shafts becoming distorted, binding, and failing causing mechanical or integrity failures.

e. Gaskets displaying permanent set.

f. Closure and sealing strips deteriorating.

g. Fixed-resistance resistors changing in values.

h. Electronic circuit stability varying with differences in temperature gradients and differential expansion of dissimilar materials.

i. Transformers and electromechanical components overheating.

j. Altering of operating/release margins of relays and magnetic or thermally activated devices.

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k. Shortened operating lifetime.

l. Solid pellets or grains separating.

m. High internal pressures created within sealed cases of projectiles, bombs, etc.

n. Burning of explosives or propellants accelerated.

o. Cast explosives expanding within their cases.

p. Explosives melting and exuding.

q. Organic materials tending to discolor, crack, or craze.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS

NOTE: This test method should be applied at the end of the tailoring process described in sections 1 and 4 of this standard.

a. Application. This method is used when the test item is likely to be deployed in areas where climatic conditions will induce high temperatures within the test item. These procedures will be used when it is judged that the test item performance can be verified by chamber exposure to controlled air temperatures and that the high temperature effects have not been identified during other tests (e.g., temperature-altitude, solar radiation).

b. Test objectives. The primary objectives of the high-temperature tests are to determine if:

(1) The test item will operate without degradation in, or after storage in, a climate which induces high temperatures within the test item.

(2) The test item can be operated and handled without affecting its integrity.

(3) The test item is safe during and following high-temperature exposure.

c. Restrictions. This method is not applicable for:

(1) Evaluation of equipment in a high-temperature environment where solar radiation contributes to differential heating or actinic (photochemical) effects. For such an environment, use method 505.2.

(2) Identification of time-dependent performance degradation which occurs during long-term storage in or exposure to high temperatures. (Such testing would require extended test exposures.) Selection of test durations and conditions for such extended exposure would have to be based upon a specific test program requirement and consideration given to natural environmental testing.

(3) Equipment to be installed where the influence of altitude or cooling air may be significant.

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d. Sequence. (See General Requirements, 4.4.4.) The high-temperature test is usually scheduled early in the test sequence following initial dynamic transportation tests. This test may contribute significantly to the results of low pressure testing of seals.

e. Test variations. This method provides a choice of two subtests: Procedures I (Storage) and II (Operation).

(1) The test procedure selection is based upon:

(a) The operational purpose of the test item.

(b) The natural exposure circumstances.

(c) The test data required to determine whether the operational purpose of the test item has been met.

(2) The related test conditions that may be used during the test are determined by:

(a) The anticipated temperature and humidity ranges of the geographical deployment area.

(b) Test item response temperature(s) (critical component temperature).1/

(c) The anticipated duration of exposure at the deployment area.

(d) Test item configuration (operational and storage).

(e) Additional guidelines as appropriate.

I-3.1 Choice of test procedure

I-3.1.1 The operational purpose of the test item. From the requirements document, determine the function to be performed by the test item in, or following exposure to, a high-temperature environment.

I-3.2 Natural exposure circumstances. From the requirements document, determine what high-temperature climatic exposure the test item is likely to experience during the storage and operational phases of its life cycle. Also consider whether the item will be:

a. Under cover in an enclosure.

b. Directly exposed to sunlight.

1/ Critical components of the test item directly affect the functioning of equipment. The temperatures that these components experience are of prime concern, regardless of the ambient conditions or skin temperature of the test item. The response temperature(s) is the result of the exposure which is achieved from the temperature cycle, duration, and thermal/physical properties of the equipment.

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c. Exposed to reflected solar radiation.

d. Stacked.

e. Wind ventilated.

f. Above, on, or under the earth's surface.

I-3.1.3 Selection of test procedure(s). Two test procedures are included within this method: storage and operation. Determine the procedure(s) to be used.

I-3.1.3.1 Procedure I - Storage. Procedure I is used to determine how storage at high temperatures affects the test item's safety and performance. This test procedure includes exposure to high temperatures (and low humidity where applicable) that may be encountered in the test item's storage situation. The test conditions and duration can be established from field measurements or can be derived from information provided within this procedure. There are two climatic areas (figures 4a and 4b, section 4) where high storage temperatures are typically encountered: Hot and Basic Hot. In each of these climatic areas, the maximum response temperature of the test item may be higher than the maximum ambient air temperature because the heating from solar radiation is greater on material than it is on the free atmosphere. The storage situation must be evaluated with respect to:

a. Exposure to solar radiation: Is this exposure directly on the test item, shipping container, protective package, shelter, etc.?

b. Climatic area of concern.

c. Analysis of the path of heat transfer from the ambient air and solar radiation to the test item.

I-3.1.3.2 Procedure II - Operation. Procedure II is used to determine the performance of the test item during exposure to high-temperature conditions. In most cases, this procedure shall be preceded by procedure I, unless the test item is not intended to be stored in a high-temperature environment. The operational test differs from the storage test in that the test item is conditioned to temperatures determined to be applicable to or resulting from exposure in its operational configuration. Once brought to this temperature, the test item is operated to determine performance characteristics. The operational phase can be accomplished by:

a. Exposure to cyclic chamber conditions with the test item operating either continuously or during the period of maximum response.

b. Exposure to constant temperature where the test item will be operated following temperature stabilization. The temperature level for this exposure will either be given by the requirements documents, derived from the field data, or derived from the response to the cyclic chamber conditions.

I-3.2 Choice of related test conditions. Having determined the operational purpose, the natural exposure circumstances, and the test procedure(s), it is necessary to select the type of exposure, test temperature(s), test duration, test item configuration, and any additional appropriate guidelines.

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a. Type of exposure. In order to determine the test temperatures, the way in which the test item is exposed to heat must be determined first. The exposure conditions that must be considered include:

(1) *Ambient air conditions. Of interest are the most severe* conditions that materiel, which could be deployed in any climatic area of the world, would experience when under cover in fully ventilated locations such as open cabins, sun-shaded areas, and underside regions of aircraft where the test item is shaded from direct solar heating. Ambient air temperature and humidity conditions are those measured in standard meteorological shelters at a height of 1.2 to 1.8 meters (4 to 6 feet) above the ground. If field data are not available, the conditions for this exposure may be approximated from tables 501.2-I and 501.2-II. Table 501.2-III gives a summary of high-temperature diurnal cycle ranges for different areas of the world.

(2) Induced conditions. These conditions are from the same regions as the ambient air conditions but with an allowance made for the effect of solar heating. These are typical conditions to which materiel is exposed while under cover where there is little or no ventilation and where the effects of solar heating on the cover causes a rise in the air temperature adjacent to the materiel. Examples of where these conditions occur are:

(a) Inside unventilated enclosures.

(b) Within enclosed vehicle bodies.

(c) Within aircraft sections having surfaces exposed to solar heating.

(d) Inside of tents.

(e) Under closed tarpaulins.

These conditions are not the temperatures attained by equipment, but rather the air temperature observed in various locations where materiel is operated or stored. The cycling conditions for this exposure are given in tables 501.2-I and 501.2-II and are to be used only if appropriate field measured data do not exist.

(3) Extreme induced conditions. These conditions are induced but involve temperatures as high as 70° to 85°C (160° to 185°F), making greater allowance for the effects of solar radiation. Applicable conditions for such testing include equipment that is employed in the open (for which method 505.2 should be used) and in enclosed compartments having glazed or transparent panels (aircraft cockpits, vehicle compartments, etc.). Another consideration is the location of equipment near heat-producing devices which influence or intensify the air temperature surrounding the test item. These extreme induced conditions would be applied by extending the levels of the temperatures given *in tables 501.2-I and 501.2-II.*

b. Test temperature(s). Determine the test temperature(s). If field measurements of actual exposure and response are available, the chamber conditions shall be derived from these data. Without availability of field measurements, the chamber conditions will be derived from the following information and evaluations.

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Table 501.2-I. High temperature cycles, climatic category - Hot[1/]

Time of Day	Ambient Air Conditions			Induced Conditions		
	Temperature °C	(°F)	Humidity, % RH	Temperature °C	(°F)	Humidity, % RH
0100	35	(95)	6	35	(95)	6
0200	34	(94)	7	34	(94)	7
0300	34	(93)	7	34	(94)	7
0400	33	(92)	8	33	(92)	7
0500	33	(91)	8	33	(92)	7
0600	32	(90)	8	33	(91)	7
0700	33	(91)	8	36	(97)	5
0800	35	(95)	6	40	(104)	4
0900	38	(101)	6	44	(111)	4
1000	41	(106)	5	51	(124)	3
1100	43	(110)	4	56	(133)	2
1200	44	(112)	4	63	(145)	2
1300	47	(116)	3	69	(156)	1
1400	48	(118)	3	70	(158)	1
1500	48	(119)	3	71	(160)	1
1600	49	(120)	3	70	(158)	1
1700	48	(119)	3	67	(153)	1
1800	48	(118)	3	63	(145)	2
1900	46	(114)	3	55	(131)	2
2000	42	(108)	4	48	(118)	3
2100	41	(105)	5	41	(105)	5
2200	39	(102)	6	39	(103)	6
2300	38	(100)	6	37	(99)	6
2400	36	(98)	6	35	(95)	6

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Table 501.2-II. High temperature cycles, climatic category - basic hot[1/]

Time of Day	Ambient Air Conditions			Induced Conditions		
	Temperature °C	(°F)	Humidity, % RH	Temperature °C	(°F)	Humidity, % RH
0100	33	(91)	36	33	(91)	36
0200	32	(90)	38	32	(90)	38
0300	32	(90)	41	32	(90)	41
0400	31	(88)	44	31	(88)	44
0500	30	(86)	44	30	(86)	44
0600	30	(86)	44	31	(88)	43
0700	31	(88)	41	34	(93)	32
0800	34	(93)	34	38	(101)	30
0900	37	(99)	29	42	(110)	23
1000	39	(102)	24	45	(113)	17
1100	41	(106)	21	51	(124)	14
1200	42	(107)	18	57	(134)	8
1300	43	(109)	16	61	(142)	6
1400	43	(110)	15	63	(145)	6
1500	43	(110)	14	63	(145)	5
1600	43	(110)	14	62	(144)	6
1700	43	(109)	14	60	(140)	6
1800	42	(107)	15	57	(134)	6
1900	40	(104)	17	50	(122)	10
2000	38	(100)	20	44	(111)	14
2100	36	(97)	22	38	(101)	19
2200	35	(95)	25	35	(95)	25
2300	34	(93)	28	34	(93)	28
2400	33	(91)	33	33	(91)	33

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Table 501.2-III. Summary of high temperature diurnal cycle ranges[1/]

Category	Location	Ambient Air °C (°F)	Induced 2/ °C (°F)
Hot (A1)	Northern Africa, Middle East, Pakistan and India, Southwestern United States and Northern Mexico	32 - 49 (90-120)	33 - 71 (91-160)
Basic Hot (A2)	Many parts of the world, extending outward from hot category of the United States, Mexico, Africa, Asia, and Australia, Southern Africa, South America, Southern Spain and Southwest Asia.	30 - 43 (86-110)	30 - 63 (86-145)

1/ The exact diurnal cycles for temperature and humidity are given in tables 501.2-I and 501.2-II.

2/ The term "induced" refers to temperatures resulting in large part from manmade or equipment-made environmental factors.

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(1) Storage test: The test temperatures for storage test exposures should include cyclic conditions that are derived from the natural diurnal cycles. The cycles provided in tables 501.2-I and 501.2-II and information in I-3.2a(3) are the extreme meteorological and induced diurnal cycles for major world areas. The temperature extremes given are based on a frequency of 1% of the hours during the most severe month in the most severe part of the area encompassed by the climatic region of interest. The map in General Requirements, figure 4, shows the boundaries of the areas of concern. The chamber air temperature and humidity conditions can be derived or calculated from the analysis of the storage situation (I-3.1.3.1) and the cycles provided in tables 501.2-I and 501.2-II and in paragraph I-3.2a(3). The values given in the tables represent the conditions of air within the storage place or adjacent to the test item. Derivation of the actual test temperatures must consider the thermal path to the test item, type of heat transfer, mass of the test item in relation to the mass of the surrounding air, and other empirical and thermal properties of the test item.

(2) Operational test: The chamber air temperature for the operational test can be derived from an analysis similar to that performed for the storage test. Consideration of all of the probable exposure situations must be based on the operational purpose of the test item. Again, the major contributing factor to be considered is the effect of solar heating on the exposed materiel and the expected response of the test item to the conditions. The heating mechanism or thermal path affecting the test item as a whole or its critical component(s) must be determined. If the thermal path is a form of convective heat transfer free of the effects of solar radiation, then the ambient conditions of tables 501.2-I and 501.2-II and of paragraph I-3.2a(3) could be used to derive the chamber air temperature and humidity test conditions/cycles. Operational testing should occur with the test item experiencing the maximum response to the established exposure. This exposure can be accomplished by operating the test item during the temperature cycling period. Such operation would also provide information on the operational ability of the test item experiencing a limited internal thermal gradient. Equipment for which the operational testing cannot be accommodated with cycling conditions shall be exposed to constant temperature. The temperature level used for this exposure would be the extreme value measured or obtained from field measurements or obtained from the response of the test item when exposed to the temperature cycles derived from tables 501.2-I and 501.2-II and from paragraph I-3.2a(3). When the test item or its critical components are configured so that their temperature cannot be monitored, the estimate of the value must be based upon thermal path, mass, and other properties of the test item. Figure 501.2-1 may be used as a guide.

c. Duration of exposure. Determine the test duration. The duration of high-temperature exposure may be as significant as the temperature itself. Because procedures I and II expose the test items to cyclic temperatures, the number of cycles is critical. (Cycles are 24-hour periods unless otherwise specified.)

(1) Storage. The number of cycles required is that which will satisfy the design requirements. Since little is known about how to time-compress this test, the number of cycles for the storage test is set at a minimum of seven to coincide with the 1% frequency of occurrence of the hours of extreme temperatures during the most severe month in an average year at the

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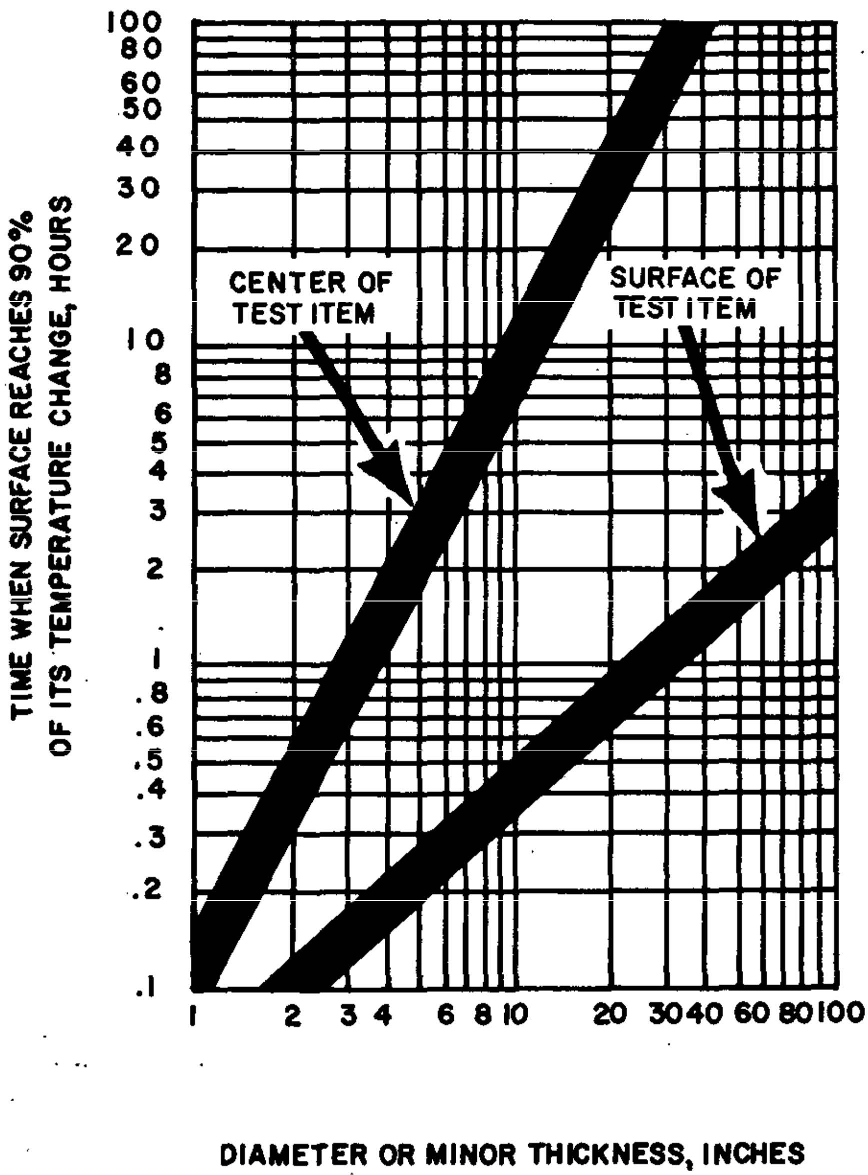

FIGURE 501.2-1 Temperature stabilization curves.

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most severe location. (The maximum temperature occurs for approximately 1 hour in each cycle.) When considering extended storage, critical test items, or test items determined to be very sensitive to high temperature, the number of cycles should be increased to assure that the design requirements are met.

(2) Operation. The minimum number of cycles for the operational exposure test is three. This number should be sufficient for the test item to reach its maximum response temperature. A maximum of seven cycles is suggested when repeated temperature response is difficult to obtain.

d. Test item configuration. Determine the test item configuration. The anticipated configuration(s) of the test item during storage and operation should be used during the test. As a minimum, the following configurations should be considered:

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

(2) Protected or unprotected (under canopy, enclosed, etc.).

(3) In its normal operating configuration (realistic or with restraints, such as with openings that are normally covered).

(4) Modified with kits for special applications.

e. Humidity. Low relative humidity (RH) may occasionally have a significant effect on some material during high-temperature testing. In such instances, consideration must be given to controlling RH as indicated in tables 501.2-I and 501.2-II.

f. Critical item component. Components of a test item that are known or suspected to be sensitive to the effects of high temperatures and whose failure will affect the overall performance of the test item are referred to as "critical item components." These components should be identified and thoroughly evaluated before this test to eliminate testing exposures that would not realistically be encountered by the test item during its life cycle.

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

I-4 SPECIAL CONSIDERATIONS

I-4.1 Failure analysis. The failure of a test item to meet the requirements of the equipment specifications must be analyzed carefully, and related information must be considered, such as:

a. Results of nondestructive examinations (if any) of materiel following the storage test may be conducted at the extreme temperatures.

b. Degradation or changes in operating characteristics allowed at the high extreme temperatures.

c. Necessity for special kits or special operating procedures for high temperature exposure.

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d. Evidence of improper lubrication and assurance that the lubricants specified for the enviromental condition were used.

I-4.2 Storage modes. The studies conducted on stored materiel indicate that military equipment is stored in a variety of modes. These modes range from those that provide the greatest protection, such as controlled temperature-humidity warehouses, to those that are the most severe in terms of high-temperature stress, such as in open dump storage.

I-4.3 Summary of test information required. The following information is required in the test plan for the adequate conduct of the tests of section II:

a. Test procedure.

b. Critical components, if applicable.

c. Location of temperature sensors.

d. Test temperature(s) or temperature cycle and how the temperatures were derived.

e. Test duration.

f. Test item configuration.

g. Relative humidity control requirements (if necessary).

h. Additional guidelines.

I-5. REFERENCES

a. AR 70-38, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions. 1 August 1979.

b. MIL-STD-210, Climatic Extremes for Military Equipment. 15 December 1973.

c. Synopsis of Background Material for MIL-STD-210B, Climatic Extremes for Military Equipment. Bedford, MA: Air Force Cambridge Research Laboratories, 24 January 1974. DTIC number AD-780-508.

d. UK Ordnance Board Proceeding 4189, 13 September 1977 (Draft STANAG 2895).

e. NATO STANAG 2831, Climatic Environmental Conditions Affecting the Design of Materiel for Use by NATO Forces Operating in a Ground Role.

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METHOD 501.2

HIGH TEMPERATURE

SECTION II

II-1 APPARATUS

II-1.1 Test Facility

a. The required apparatus consists of a chamber or cabinet together with auxiliary instrumentation capable of maintaining and continuously monitoring the required conditions of high temperature (and humidity, where required) throughout an envelope of air surrounding the test item(s). (See General Requirements, 4.4.1.)

b. Air velocity in the vicinity of the test item shall not exceed 1.7 m/s (325 ft/min) unless justified by the test item platform environment to prevent unrealistic heat transfer in the test item.

c. Continuous recordings of chamber and test item temperature measurements shall be taken if required.

II-1.2 Controls

a. Temperature. Unless otherwise specified in the test plan, if any action other than test item operation (such as opening the chamber door) results in a significant change of the test item temperature (more than 2°C (3.6°F)) or chamber air temperature, the test item will be restabilized at the required temperature before the test continues. If the operational check is not completed within 15 minutes, reestablish test item temperature/RH conditions before continuing.

b. Unless otherwise specified, the rate of temperature change shall not exceed 10°C (18°F) per minute.

II-1.3 Test interruption. (See General Requirements, 4.5.4.)

a. Undertest interruption

(1) Cycling. If a cyclic high-temperature test is being conducted when an unscheduled interruption occurs that causes the test conditions to fall out of allowable tolerances toward standard ambient temperatures, the test must be reinitiated at the end of the last successfully completed cycle.

(2) Steady-state. If a steady-state (noncyclic) test is being conducted and an unscheduled interruption occurs that causes the test conditions to fall out of allowable tolerances toward standard ambient conditions, the test item shall be restabilized at the required test temperature and the test continued from the point where test conditions were left. Duration of initial and final test periods shall be recorded.

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b. Overtest interruption. Any interruption in a cyclic or steady-state test that results in more extreme exposure of the test item than required by the equipment specifications should be followed by a complete physical inspection and an operational check (where possible) before continuation of testing. This is especially true where a safety problem could exist, such as with munitions. If a problem is discovered, the preferable course of action is to terminate the test and reinitiate testing with a new test item. If this is not done and a test item failure occurs during the remainder of the test, the test results could be considered invalid because of the overtest conditions. If no problem has been encountered, reestablish pre-interruption conditions and continue from the point where the test tolerances were exceeded.

II-2 PREPARATION FOR TEST

II-2.1 Preliminary steps. Before starting the test, determine from the test plan:

a. Which test procedures are required.

b. The high-temperature operation and storage requirements and accompanying temperature cycles and durations.

c. If relative humidity is to be controlled.

d. The location of temperature sensors.

e. The test item's test configuration.

II-2.2 Pretest standard ambient checkout. All items require a pretest standard ambient checkout to provide baseline data. Conduct the checkout as follows:

Step 1. Install temperature sensors in, on, or around the test item as required by the test plan.

Step 2. Insert the test item into the chamber and stabilize the test item at controlled ambient conditions (General Requirements, 4.4b).

Step 3. Conduct a complete visual examination of the test item with special attention to stress areas, such as corners of molded cases.

Step 4. Document the results.

Step 5. Prepare the test item in accordance with General Requirements, 4.5.2, and required test item configuration.

Step 6. Conduct an operational checkout in accordance with the approved test plan.

Step 7. Record the results for compliance with General Requirements, 4.5.1.1.

Step 8. If the test item operates satisfactorily, proceed to II-3. If not, resolve the problems and restart at Step 1 above.

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II-3. PROCEDURES. The following test procedures alone, or in combination, provide the basis for collecting the necessary information concerning the test item in a high-temperature environment. Proceed to the first test procedure as determined by the test plan.

II-3.1 Procedure I - Storage

Step 1. Install the required temperature sensors on, in, and around the test item and chamber.

Step 2. Place the test item in its storage configuration.

Step 3. Adjust the chamber environment to the initial test conditions as specified in the test plan.

Step 4. Expose the test item to the temperature (and humidity, if applicable) conditions of the storage cycle for at least seven cycles (a total of 168 hours) or as specified in the test plan. If applicable, monitor the temperature of the critical item components and document.

Step 5. At the completion of the last cycle, adjust the chamber air temperature to controlled ambient conditions and maintain until temperature stabilization of the test item has been achieved.

Step 6. Conduct a complete visual and operational checkout of the test item and record the results.

II-3.2 Procedure II - Operation

Step 1. Place the test item in the chamber in its operational configuration.

Step 2. From the test plan, determine the operational temperature extreme(s), whether constant or cyclic, and whether the temperature(s) was:

a. Specified by the requirements documents: Proceed to Step 7 for constant temperature exposure or Step 12 for cycling exposure.

b. Derived from field measurements: Proceed to Step 7 for constant temperature exposure or Step 12 for cycling exposure.

c. Cyclic and derived from paragraph I-3.2: Proceed to Step 12.

d. Constant and not provided or determined elsewhere: Perform Steps 3 through 6.

Step 3. With the test item placed in the chamber in its operational configuration, install the temperature sensors necessary to measure the temperature throughout the test item, insuring that the critical components or areas of concern are included.

Step 4. Adjust the chamber air conditions to the initial temperature (and humidity, if applicable) levels of the prescribed operational cycle.

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Step 5. Expose the test item to the temperature (and humidity, if applicable) levels specified for the operational cycle for at least three cycles, or as necessary to obtain repeated test item response (±2°C). A maximum of seven cycles is suggested if repeated response is difficult to obtain.

Step 6. From the exposure data, determine the maximum critical-component temperature or response temperature of the test item. This will be the operational temperature for Step 7.

Step 7. Constant temperature exposure. With the test item in the chamber in the operational configuration, adjust the chamber air temperature to the operational temperature and, if required, adjust the humidity to the appropriate level of the cycle. Maintain the chamber in a steady-state condition until temperature stabilization of the test item has been achieved (General Requirements, 4.4.3).

Step 8. Conduct as complete a visual examination of the test item as possible considering chamber access limitations.

Step 9. Document the results.

Step 10. Operate the test item until temperature stabilization of the test item has been achieved. Conduct an operational checkout of the test item in accordance with the approved test plan and document the results.

Step 11. Proceed to Step 15.

Step 12. Cycling temperature exposure. With the test item in the chamber in its operational configuration, adjust the chamber air temperature (and humidity, if applicable) to the initial conditions of the operational cycle appropriate for the test item deployment.

Step 13. Expose the test item to at least three cycles or the number of cycles necessary to assure repeated test item response. Conduct as complete a visual examination of the test item as possible considering chamber access limitations. Document the results.

Step 14. Operate the test item during the maximum response period of the exposure cycle.1/ Repeat until a complete operational checkout of the test item has been accomplished in accordance with the approved test plan and the results have been documented.

1/ The maximum response period may not coincide with the maximum temperature cycle conditions because of thermal lag of the test item.

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Step 15. With the test item not operating, adjust the chamber air temperature to controlled ambient conditions and maintain until temperature stabilization of the test item has been achieved.

Step 16. Conduct a complete visual examination and an operational checkout in accordance with the approved test plan and document the results.

Step 17. Compare these data with the pretest data.

II-4 INFORMATION TO BE RECORDED

a. Previous tests to which the test item has been subjected.

b. Results of each performance check and visual examination (and photographs, if applicable) and comparison with the failure criteria:

(1) Pretest.

(2) During test.

(3) Post-test.

c. Record of chamber temperatures (and humidity if applicable) versus time conditions.

d. Record of the test item temperature-versus-time data for the duration of the test.

e. Initial failure analysis.

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METHOD 502.2

LOW TEMPERATURE

SECTION I

I-1 PURPOSE. Low-temperature chamber tests are performed to determine if materiel can be stored, manipulated, and operated under pertinent low-temperature conditions without experiencing physical damage or deterioration in performance.

I-2 ENVIRONMENTAL EFFECTS. Low temperatures have adverse effects on almost all basic materials. As a result, exposure of test items to low temperatures may either temporarily or permanently impair the operation of the test item by changing the physical properties of the material(s) composing it. Therefore, low-temperature tests must be considered whenever the test item will be exposed to temperatures below standard ambient. Examples of some problems that could occur as the result of exposure to cold are:

a. Hardening and embrittlement of materials.

b. Binding of parts from differential contraction of dissimilar materials and the different rates of expansion of different parts in response to temperature transients.

c. Loss of lubrication and lubricant flow due to increased viscosity.

d. Changes in electronic components (resistors, capacitors, etc.).

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e. Changes in performance of transformers and electromechanical components.

f. Stiffening of shock mounts.

g. Cracking of explosive solid pellets or grains, such as ammonium nitrate.

h. Cracking and crazing, embrittlement, change in impact strength, and reduced strength.

i. Static fatigue of restrained glass.

j. Condensation and freezing of water.

k. Decrease in dexterity, hearing, and vision of personnel wearing protective clothing.

l. Change of burning rates.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS

NOTE: This test method should be applied at the end of the tailoring process described in section 4 of this standard.

a. Application. This method is used when the test item is likely to be deployed in a low-temperature environment during its life cycle and the effects of low temperature have not been determined during other tests (such as the temperature-altitude test).

b. Restrictions. This method is not intended for testing equipment to be installed in and operated in aircraft, since such equipment would usually be tested according to method 520.

c. Sequence. (See General Requirements, 4.4.4.) Because this test (except for the physical manipulation procedure) is less likely to permanently damage the test item, it is normally scheduled early in the test sequence. This test may significantly alter the performance of seals during the low-pressure testing of 500.2.

d. Test variations. This method is composed of three low-temperature subtests: Procedures I (Storage), II (Operation), and III (Manipulation). Before the tests are conducted, a choice of one or more test procedures must be made. In addition, the variables for each test must be determined.

(1) The choice of test procedure(s) depends on the likelihood of the test item being:

(a) Operated1/ at low temperatures.

1/ Operation is the excitation of the test item with a minimum of contact by personnel. It does not include handling (manipulation).

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(b) Stored at low temperatures.

(c) Manipulated at low temperatures.

(2) The test conditions that are used during the test are determined by:

(a) The expected temperature at the deployment location.

(b) The expected duration at the deployment location.

(c) The test item configuration.

(d) Additional guidelines as appropriate.

I-3.1 Choice of test procedure(s)

a. Operational purpose of the test item. From the requirements documents, determine the functions to be performed by the equipment in a low-temperature environment and any limiting conditions, such as storage.

b. Test objectives. The primary objectives of the low-temperature test are to determine if:

(1) The test item can meet the performance specifications after storage or during operation in a cold environment.

(2) The test item can be operated safely during or following low-temperature exposure.

(3) The handling (manipulation) required to make the test item operational can be conducted without affecting its functional performance.

Based on this information and the purpose of the test item, determine what test data are necessary to ascertain to what extent the test item will satisfy its low-temperature requirements.

c. Selection of the test procedure(s). Three test procedures are included within method 502.2: storage, operation, and manipulation. Based on the test data requirements, determine which test procedure, combination, or sequence of procedures is applicable. In most cases, all three procedures should be applied.

(1) Procedure I - Storage. Procedure I is appropriate if the test item is likely to be stored at low temperatures during its service life. Procedure I is used when it is necessary to determine how low-temperature storage affects the test item's safety or performance.

(2) Procedure II - Operation. Procedure II is used to determine the performance of the test item at low temperatures and can be preceded by procedure I, procedure III, or both. If the test item is to be stored at low

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temperatures before use, procedure I is conducted before procedure II. If a manipulation test is required, procedure III can precede the operational test. If the test item is not intended to be stored at low temperature or manipulated before use, procedure II is conducted directly.

(3) Procedure III - manipulation. Procedure III is used to determine the ease with which the test item can be set up and disassembled by personnel wearing heavy, cold-weather clothing. Storage testing, operational testing, or both can precede the manipulation test if required.

I-3.2 Choice of related test conditions. After choosing the test procedure(s), choose the test temperatures, test duration, test item configuration, and any additional appropriate conditions.

a. Test temperature. The specific test temperatures are preferably selected from the requirements documents. If this information is not available, determination of test temperature(s) should be based on the world areas in which the test item will be used, plus any additional considerations. The information below provides guidance for choosing the test temperatures for:

- Selected regions.
- Worldwide use without extended storage.[2/]
- Worldwide use with extended storage periods.

(1) Selected regions. Table 502.2-I and the map in General Requirements, figure 4, can be used to determine the test temperature when the test item is to be used at specific regions only. The air temperature extremes shown in table 502.2-I are based on a frequency of occurrence of the hours during the most severe month at the most severe location within the geographical area encompassed by the climatic region, except for severe cold, which is based on a 20 percent probability of occurrence. The values shown represent the range of the diurnal cycle. For this method, the lowest value in each range is usually considered.

(2) Worldwide use. When the test item is to be stored or operated throughout the world, temperature selection must include not only consideration of the absolute cold, but also of the frequency of a given cold condition. Unless frequency is considered, it is possible to create an overtest condition. In terms of frequency, the probability-of-occurrence values shown below refer to the percent of total hours, in the most extreme month and area in the world,

2/ Extended storage is defined as storage for 2 years or longer.

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TABLE 502.2-I. Summary of low temperature diurnal cycle temperature ranges. 3/

Climatic Region	Location	Temperature	
		Operational	Induced
Mild Cold (C0)	Coastal areas of Western Europe under prevailing maritime influence, southeast Australia, lowlands of New Zealand	-6°C to -19°C (21°F to -2°F)	-10°C to -21°C (14°F to -6°F)
Basic Cold (C1)	Most of Europe Northern contiguous US Southern Canada High-latitude coasts (e.g., southern coast of Alaska) High elevations in lower latitudes	-21°C to -31°C (-6°F to -24°F)	-25°C to -33°C (-13°F to -27°F)
Cold (C2)	Northern Canada Alaska (excluding the interior) Greenland (excluding the "cold pole") Northern Scandinavia Northern Asia (some areas) High Elevations (Northern and Southern Hemispheres) Alps Himalayas Andes	-37°C to -46°C (-35°F to -51°F)	-37°C to -46°C (-35°F to -51°F)
Severe Cold (C3)	Interior of Alaska Yukon (Canada) Interior of the Northern Islands Greenland Ice Cap Northern Asia	-51°C (-60°F)	-51°C (-60°F)

3/ From AR 70-38, 1 August 1979.

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during which the given temperature is equalled or surpassed. For example, the 20 percent probability of occurrence of a temperature of -51°C means that -51°C or lower temperatures may be expected to occur 20 percent of the hours during the most extreme month in the most extreme cold area of the world (excluding Antarctica).

Low Temperature		Probability of Occurrence
-51°C 4/	(-60°F)	20%
-54°C	(-65°F)	10%
-57°C	(-71°F)	5%
-61°C	(-78°F)	1%

The 20 percent probability of occurrence is used for most applications with normal development cost considerations; however, other values may be chosen to satisfy specific applications or test requirements.

(3) Worldwide use with extended storage periods. If materiel is to be stored for extended periods (years) without shelter or protection in areas that experience very low temperatures, such as the "cold pole" of northeast Siberia or central Greenland, there is an increased chance that the test item may experience much lower temperatures (approaching -65°C (-85°F) or less). Such prolonged exposure to extreme low temperatures can affect the safety of items such as munitions, life support equipment, etc.

b. Duration of exposure to low temperatures. The period of time that the low-temperature exposure exists may be a factor.

(1) Nonhazardous or non-safety-related (non-life-support type) equipment. Most materiel in this category (in a nonoperating mode), with the possible exception of organic plastics (I-2h and I-3.2b(2)), will not experience deterioration following temperature stabilization of the test item at low temperatures. Following temperature stabilization of the test item, a storage period of 4 hours will be used for this materiel if no other value is available.

(2) Explosives, munitions, organic plastics, etc. These items may continue to deteriorate following temperature stabilization; consequently, it is necessary to test them at low temperatures for long periods of time. A minimum storage period of 72 hours is recommended, since extreme temperatures have existed for at least that length of time.

4/ Corresponds to Severe Cold condition.

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(3) Restrained glass. Glass, ceramics, and glass-type products (such as those used in optical systems, laser systems, and electronic systems) that require mounting or restraining in specific positions may experience static fatigue. A more extended period of low temperature may be required to induce this phenomenon. A 24-hour exposure usually gives an 87 percent probability of uncovering this type of design defect.

c. Test item configuration. The configuration of the test item is an important factor in how temperature affects it. Therefore, the anticipated configuration of the test item during storage or use should be used during the test. As a minimum, the following configurations should be considered:

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

(2) Protected or unprotected.

(3) Deployed (realistically or with restraints, such as with openings that are normally covered).

(4) Modified with kits for special applications.

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

I-4 SPECIAL CONSIDERATIONS

I-4.1 Failure analysis. The failure of a test item to meet the requirements of the equipment specification must be analyzed carefully, and related information must be considered, such as:

a. Nondestructive test/examination following exposure to low temperature may be conducted at the low test temperature.

b. Degradation allowed in operating characteristics when at low temperatures.

c. Necessity for special kits or special cold-weather procedures.

d. Evidence of improper lubrication and assurance that lubricants specified for the environmental condition were used.

e. For starting failures on internal-combustion engines, assurance of the presence of proper fuels and deicers, if appropriate.

f. Condition and adequacy of the power source.

I-4.2 Summary of test information required. The following information is required in the test plan for adequate conduct of the tests of section II.

a. Test procedure(s).

b. Test duration.

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c. Test item configuration.

d. Location of temperature sensors (if required).

e. Test temperatures and time-versus-temperature data.

f. Additional guidelines.

I-5 REFERENCES

a. AR 70-38, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions. 1 August 1979.

b. MIL-STD-210, Climatic Extremes for Military Equipment. 15 December 1973.

c. Synopsis of Background Material for MIL-STD-210B, Climatic Extremes for Military Equipment. Bedford, MA: Air Force Cambridge Research Laboratories, January 1974. DTIC number AD-780-508.

d. NATO STANAG 2831, Climatic Environmental Conditions Affecting the Design of Material for Use by NATO Forces Operating in a Ground Role.

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METHOD 502.2

LOW TEMPERATURE

SECTION II

II-1 APPARATUS

II-1.1 Test facility

a. The required apparatus consists of a chamber or cabinet and auxiliary instrumentation capable of maintaining and continuously monitoring the required conditions of low temperature throughout an envelope of air surrounding the test item(s) (see General Requirements, 4.4.1a).

b. Air velocity in the vicinity of the test item shall not exceed 1.7 m/s (325 ft/min) unless justified by the test item platform environment, to prevent unrealistic cooling (heat transfer) in the test item.

II-1.2 Controls

a. Temperature. Unless otherwise specified in the test plan, if any action other than test item operation (such as opening the chamber door) results in a significant change of the test item temperature (more than 2°C (3.6°F)) or chamber air temperature, the test item will be restabilized at the required temperature before continuation. If the operational check is not completed within 15 minutes, reestablish the test item temperature conditions before continuing.

b. Rate of temperature change. Unless otherwise specified, the rate of temperature change shall not exceed 10°C (18°F) per minute.

c. Temperature measurement. Temperature sensor instrumentation is required on or in the test item to establish temperature stabilization data.

d. Temperature recording. Continuous recordings of the chamber and test item temperature shall be made if required.

II-1.3 Test interruption (See General Requirements, 4.5.4.)

a. Undertest interruptions. An interruption which allows test temperatures to fluctuate outside allowable tolerances toward ambient conditions should be followed by a complete physical inspection and operational check (where possible). If no problems are encountered, restabilize the test item at the test temperature and continue from the point of the interruption. Any problems should constitute test item failure, since no extreme conditions were encountered.

b. Overtest interruptions. Any interruption that results in more extreme exposure of the test item than required by the equipment specification should be followed by a complete physical examination and operational check (where

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possible) before any continuation of testing. This is especially true where a safety problem could exist, such as with munitions. If a problem is discovered, the preferable course of action is to terminate the test and reinitiate testing with a new test item. If this is not done and test item failure occurs during the remainder of the test, the test results could be considered invalid because of the overtest condition. If no problem has been encountered, reestablish preinterruption conditions and continue from the point where the test tolerances were exceeded.

II-2 PREPARATION FOR TEST

II-2.1 Preliminary steps. Before initiating any testing, determine from the test plan:

a. Which test procedures are required.

b. The low-temperature operation and storage requirements.

II-2.2 Pretest standard ambient checkout. All items require a pretest standard ambient checkout to provide baseline data. Conduct the checkout as follows (change of step sequence may be required for large test items):

Step 1. Install temperature sensors in or on the test item as required to determine the test item temperature(s).

Step 2. Insert the test item into the chamber and stabilize the test item at standard ambient conditions (General Requirements, 4.4a).

Step 3. Conduct a complete visual examination of the test item, with special attention to stress areas such as corners of molded cases.

Step 4. Document the results.

Step 5. Prepare the test item in accordance with General Requirements, 4.5.2, and required test item configuration.

Step 6. Conduct an operational checkout in accordance with the approved test plan.

Step 7. Record results for compliance with General Requirements, 4.5.1.

Step 8. If the test item operates satisfactorily, proceed to II-3. If not, resolve the problems and restart at step 1.

II-3 PROCEDURES. The following test procedures, alone or in combination, provide the bases for collecting the necessary information concerning the test item in a cold environment. Operational checkouts should be conducted after storage and after manipulation to verify successful completion of both procedures. Proceed to the first test procedure as determined from the test plan.

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II-3.1 Procedure I - Storage

Step 1. Adjust the test item to its storage configuration, and install it in the test chamber.

Step 2. Adjust the chamber air temperature to that specified in the test plan for storage.

Step 3. Following temperature stabilization of the test item (General Requirements, 4.4.3), maintain the storage temperature for a period as specified in the test plan.

Step 4. Conduct a visual examination of the test item and compare the results with the pretest data. Record any pertinent physical changes or the fact that there were no obvious changes.

Step 5. If low-temperature operation is required, proceed to II-3.2; otherwise, proceed to step 6 below.

Step 6. Adjust the chamber air temperature to standard ambient and maintain until temperature stabilization of the test item has been achieved.

Step 7. Conduct a complete visual examination of the test item, and document the results.

Step 8. Conduct an operational checkout of the test item, and document the results.

Step 9. Compare these data with the pretest data.

II-3.2 Procedure II - Operation

Step 1. With the test item in the test chamber, adjust the chamber air temperature to the low operating temperature of the test item as specified in the test plan. Maintain until temperature stabilization of the test item has been achieved.

Step 2. Conduct as complete a visual examination of the test item as chamber access limitations will allow.

Step 3. Document the results.

Step 4. Conduct an operational checkout of the test item as in II-2.2, step 6.

Step 5. Document the results.

Step 6. If manipulation of the test item is required at low temperature, proceed to step 4 of II-3.3. If not, proceed to step 7 of this procedure.

Step 7. Adjust the chamber air temperature to standard ambient and maintain until temperature stabilization of the test item has been achieved.

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Step 8. Conduct a complete visual examination of the test item.

Step 9. Document the results.

Step 10. Conduct an operational checkout as in II-2.2, step 6.

Step 11. Document the results.

Step 12. Compare these data with the pretest data.

II-3.3 Procedure III - Manipulation

Step 1. With the test item in the test chamber, adjust the chamber air temperature to the low operating temperature of the test item, as determined from the test plan. Maintain for 2 hours following temperature stabilization of the test item (to assure stabilization).

Step 2. While maintaining the low operating temperature, place the test item in its normal operating configuration by using the options of step 4.

Step 3. Reestablish the temperature to that used in step 1, above.

Step 4. Based on the type of test chamber available, select one of the two following options:

a. Option 1 - To be used when a "walk-in" type chamber is available: With personnel clothed and equipped as they would be in a low-temperature tactical situation, disassemble the test item as would be done in the field, and repack it in its normal shipping/storage container(s), transit case, or other mode and configuration.

b. Option 2 - To be used when small chambers (non-walk-in) are used: Perform the option 1 procedure, except that the disassembly and packing will be performed by personnel reaching through chamber access holes or the open door while they are wearing heavy gloves such as would be required in the natural environment. NOTE - Opening of the chamber door may cause frost to form on the test item in addition to a gradual warming of the test item. Manipulation necessary to perform the required setup or teardown should be limited to 15-minute intervals, between which the temperature of step 1 above should be reestablished.

Step 5. If operation of the test item is required at low temperatures, repeat step 2, above, and then proceed to step 1 of II-3.2. If not, proceed to step 6 of this procedure.

Step 6. Conduct a complete visual examination of the test item.

Step 7. Document the results for comparison with the pretest data.

Step 8. Adjust the chamber air temperature to standard ambient and maintain until temperature stabilization of the test item has been achieved.

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Step 9. Conduct a complete visual examination of the test item.

Step 10. Document the results.

Step 11. Conduct an operational checkout of the test item as in II-2.2, step 6.

Step 12. Document the results.

Step 13. Compare these data with the pretest data.

II-4 INFORMATION TO BE RECORDED

a. Previous test methods to which the test item has been subjected.

b. Results of each performance check, visual examination (and photographs, if applicable), and comparison with the failure criteria.

(1) Pretest.

(2) During test.

(3) Post-test.

c. Length of time required for each performance check.

d. Status of the test item for each visual examination.

e. Defects noted during visual examinations.

f. Clothing and special equipment used to set up or disassemble the test item.

g. Test temperatures.

h. Duration of each exposure.

i. Appropriate anthropometric measurements of personnel performing manipulation tests.

j. Temperature-time-versus data (test item and chamber).

k. Initial failure analysis.

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METHOD 503.2

TEMPERATURE SHOCK

SECTION I

I-1 PURPOSE. Temperature shock tests are conducted to determine if materiel can withstand sudden changes in the temperature of the surrounding atmosphere without experiencing physical damage or deterioration in performance.

I-2 ENVIRONMENTAL EFFECTS. As a result of exposure to sudden temperature changes, operation of the test item may be affected either temporarily or permanently. Examples of problems that could occur as a result of exposure to sudden changes in temperature are:

a. Shattering of glass, vials, and optical equipment.

b. Binding or slackening of moving parts.

c. Separation of constituents.

d. Changes in electronic components.

e. Electronic or mechanical failures due to rapid water or frost formation.

f. Cracking of solid pellets or grains in explosives.

g. Differential contraction or expansion of dissimilar materials.

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h. Deformation or fracture of components.

i. Cracking of surface coatings.

j. Leaking of sealed compartments.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS

NOTE: This test method should be applied at the end of the tailoring process described in section 4 of this standard.

a. Application. This method is applicable to equipment which may experience extreme rapid temperature changes in its anticipated area or mode of deployment. These include:

(1) Ascent from a desert airfield (high temperature) to high altitude (low temperature) in unheated aircraft compartments or stored externally. This includes equipment such as aircraft external stores (electrical equipment pods, guided bombs, etc.), stores installed in bomb bays, and optical equipment.

(2) Air delivery/airdrop from high altitude (low-temperature) to a desert environment (high temperature).

(3) Transfer of (ground) equipment to and from heated areas within a low-temperature environment (includes air delivery to a cold environment).

This method may also be used as a screening test to reveal potential flaws in equipment exposed to less extreme conditions.

b. Restrictions. This method is not intended for equipment that will not experience sudden extreme temperature changes because of its packaging, installed location, etc. This is not to be used to assess performance characteristics after lengthy exposure to extreme temperatures, as are methods 501.2 and 502.2. Additionally, this method does not address the temperature shock experienced by equipment which is exposed to warm air and solar-radiation heating and is then immersed in cold water, or the thermal shock caused by rapid transient warmup by engine compressor bleed air.

c. Sequence. (See General Requirements, 4.4.4.) This test method should follow the high- and low-temperature tests where test item response characteristics and performance determinations have been obtained. Such information should be used for better defining the test conditions to be used for this procedure.

d. Test variations. This method has one procedure for which there are several variations in application (temperature range). Before conducting the test, a determination must be made as to which test conditions are appropriate. The test conditions that are used during the test are determined by:

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(1) The expected exposure temperatures.

(2) The test item's logistic configuration.

(3) The test item's deployment configuration.

(4) The test item's extreme storage temperatures.

(5) Additional guidelines as appropriate.

I-3.1 Choice of test variations

a. Operational purpose of the test item. From the requirements documents, determine the function to be performed by the equipment and the deployment or deployment location which could result in exposure to sudden changes in ambient temperature.

b. Test objectives. The primary objectives of the temperature shock test are to determine if:

(1) The test item can satisfy its performance requirements after exposure to sudden changes in temperature of the surrounding atmosphere.

(2) The test item can be safely operated following exposure to the sudden changes in temperature of the surrounding atmosphere.

c. Selection of the test variations. Several exposure situations are addressed within this method: aircraft flight exposure, air delivery - desert, and ground transfer or air delivery - arctic. Based on the anticipated deployment, determine which test variation is applicable. The most extreme exposure range should determine the test conditions, but test levels may be extended to detect design flaws.

(1) Aircraft flight exposure. This is appropriate if the test item is to be exposed to desert or tropical ground heat and, a few minutes later, exposed to the extreme low temperatures associated with high altitude.

(2) Air delivery - desert. This is appropriate for equipment which is delivered over desert terrain from unheated, high-altitude aircraft.

(3) Ground transfer or air delivery - arctic. This is intended to test equipment for the effects of movement to and from heated storage, maintenance, or other enclosures or a heated cargo compartment in cold regions.

(4) Engineering design. This is used to detect marginal design or workmanship practices.

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I-3.2 Choice of related test conditions. After choosing the test exposure variation, select the test temperatures, test durations, test item configuration, and any additional appropriate variables. Values other than those suggested may be used if realistic.

a. Test temperatures. The test temperatures are preferably selected from field data or from the requirements documents. If this information is not available, the test temperatures can be determined from the anticipated deployment application or world areas in which the test item will be deployed, or from the most extreme nonoperating temperature requirements.

(1) Deployment application (aircraft flight exposure). The thermal stresses that equipment will experience during exposure to this operational environment are dependent upon the ambient conditions, flight conditions, and performance of the onboard environmental control systems.

(a) The temperature and humidity at various altitudes can be found in MIL-STD-210.

(b) Table 503.2-I shows temperatures typical at ground level in hot climates. The temperatures shown are based on frequency of occurrence and correspond to a 1-percent frequency of occurrence at or close to the geographical boundary between the category of interest and the next-more-severe category. The probability of occurrence increases as the distance from this line into the category area increases. Table 503.2-II and figure 4 (General Requirements) can be used to determine test temperatures for the anticipated deployment locations.

(2) Air delivery/airdrop. The test conditions for this exposure are based upon the conditions that will probably exist in the cargo compartment of the aircraft and on the ground at the point of impact. The lower temperature extreme should assume an unheated, unpressurized aircraft cargo compartment with the aircraft at an altitude of 8 kilometers (26,200 ft). This is the limiting altitude for cargo aircraft because of oxygen-pressure requirements when the aircraft cargo compartment is unpressurized immediately before airdrop operations. The temperature at this altitude over a desert can be found in MIL-STD-210. This high temperature surface extremes should be determined according to I-3.2a, from tables 503.2-I and 503.2-II, or from method 501.2.

(3) Ground transfer/air delivery - arctic. The conditions developed for heated inclosures located in cold regions are 21°C (70°F) and 25 percent relative humidity. These conditions were selected to roughly correspond to normal heating practices in the Arctic and on aircraft. Selection of the outside ambient conditions should be based upon the climatic categories or areas listed in table 503.2-III.

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TABLE 503.2-I. Diurnal cycle of temperature for high-temperature climatic categories.

Time	Hot-dry				Basic hot			
	Ambient Temperature		Induced Temperature		Ambient Temperature		Induced Temperature	
	°C	°F	°C	°F	°C	°F	°C	°F
0100	35	95	35	95	33	91	33	91
0200	34	94	35	94	32	90	32	91
0300	34	93	34	94	32	90	32	90
0400	33	92	33	92	31	88	31	88
0500	33	91	33	92	30	86	30	86
0600	32	90	33	91	30	86	31	88
0700	33	91	36	97	31	88	34	93
0800	35	95	40	104	34	93	38	101
0900	38	101	44	111	37	99	42	107
1000	41	106	51	124	39	102	45	113
1100	43	110	56	133	41	106	51	124
1200	44	112	63	145	42	107	57	134
1300	47	116	69	156	43	109	61	142
1400	48	118	70	158	43	110	63	145
1500	48	119	71	160	43	110	63	145
1600	49	120	70	158	43	110	62	144
1700	48	119	67	153	43	109	60	140
1800	48	118	63	145	42	107	57	134
1900	46	114	55	131	40	104	50	122
2000	42	108	48	118	38	100	44	111
2100	41	105	41	105	35	97	38	101
2200	39	102	39	103	34	95	35	95
2300	38	100	37	99	34	93	34	93
2400	37	98	35	95	33	91	33	91

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TABLE 503.2-II. High-temperature geographical climatic categories.

Category1/	Location2/	Climatic Conditions	
		Operational °C (°F)	Induced °C (°F)
Hot Dry (A1)	Northern Africa, Middle East, Pakistan, India, southwestern United States and northern Mexico.	32 - 49 (90 - 120) 8 to 3% RH	33 - 71 (91 - 160) 7 to 1% RH
Basic Hot (A2) RH	Extending outward from the hot-dry category of the United States, Mexico, Africa, Asia, and including Australia, southern Africa, South America, southern Spain and southwest Asia.	30 - 43 (85 - 110) 14 to 14% RH	30 - 63 (86 - 145) 44 to 5%

1/ See table 503.2-I for the diurnal temperature/humidity cycles of these climatic categories.

2/ See General Requirements, figure 4, for locations.

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TABLE 503.2-III. Low-temperature geographical climatic categories.

Category	Location[3/]	Climatic Conditions	
		Operational	Induced
Mild Cold (C0)	Coastal areas of Western Europe under prevailing maritime influence, southeast Australia, lowlands of New Zealand.	-6° to -19°C (21° to -2°F)	-10° to -21°C (14° to -6°F)
Basic Cold (C1)	Most of Europe, northern contiguous US southern Canada, High-latitude coasts, e.g., southern coast of Alaska High elevations in lower latitudes	-21° to -31°C (-6° to -24°F)	-25° to -33°C (-13° to -27°F)
Cold (C2)	Northern Canada, Alaska (excluding the interior), Greenland (excluding the "cold pole"), northern Scandinavia, northern Asia (some areas), Tibet, High Elevations (Northern and Southern Hemispheres): Alps Himalayas Andes	-37° to -46°C (-35° to -51°F)	-37° to -46°C (-35° to -51°F)
Severe Cold (C3)	interior of Alaska Yukon (Canada), interior of the Northern Islands, Greenland ice cap, northern Asia	-51°C (-60°F)	-51°C (-60°F)

3/ See General Requirements, figure 4, for locations.

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(4) Engineering design. The test conditions should reflect the extreme anticipated storage conditions.

b. Test item temperature. The information in I-3.2a is intended to describe the air temperatures to which equipment will be exposed during various types of operations. Determination of the actual equipment temperatures will be based on time of expected exposure and type of exposure. Actual onboard aircraft equipment temperatures can be calculated during a thermodynamic analysis as in method 520, estimated based upon expected flight durations, or assumed to be in equilibrium with the surrounding air conditions. Actual response temperatures achieved when equipment is exposed to the climatic conditions of the various ground climatic categories could be obtained from the test results of high- and low-temperature exposure (methods 501.2, 502.2, and 505.2) for either the operational or storage configuration. The latter assumption must take into account the induced effects of solar radiation during storage and transit in various climates.

c. Extreme high temperature exposure. An item is likely to experience the highest heating during storage in the sun in the Hot Dry and Basic Hot climates. Therefore, transitions from hot to cold will be conducted with the test item stabilized at its high-storage temperature. Transitions from cold to hot will be conducted with the high-temperature facility air temperature at the maximum storage temperature of the appropriate cycle. Immediately following this transfer, the high-temperature facility will be cycled through the appropriate diurnal cycle (table 503.2-I) from the beginning of the hour at which the maximum air temperature is experienced until the test item response temperature is reached. Other tests, such as electronic screening, may require even more extreme temperatures.

d. Duration of exposure. The objective of this test is to determine the effect of rapid temperature changes on the test item. Therefore, the test item must be exposed to the temperature extremes for a duration equal to either the actual operation (i.e., actual flight time) or to that required to achieve temperature stabilization.

e. Test item configuration. The configuration of the test item strongly affects test results. Therefore, the anticipated configuration of the item during storage, shipment, or use should be used during the test. As a minimum, the following configurations should be considered:

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

(2) Protected or unprotected.

(3) Deployed (realistically or with restraints).

(4) Modified with kits for special applications.

(5) Packaged for airdrop.

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f. Relative humidity. The relative humidity (RH) during portions of this test could be a factor in the resistance of the test item to temperature shock. Equipment with a high moisture content could be affected by freezing of the moisture. In most cases, the RH may be uncontrolled, but specific RH values may be required when RH must be taken into consideration.

I-4 SPECIAL CONSIDERATIONS

I-4.1 Failure analysis. The failure criteria of General Requirements, 4.5.7, apply.

I-4.2 Test conditions. The test conditions as presented in this procedure are intended to be in general agreement with other extremes described in this document. The primary purpose in establishing these levels is to provide realistic conditions for the traverse between the two temperature extremes. Thus, the temperatures at which the item is stabilized before transfer must be the most realistic, or possibly the most extreme, that would be encountered during the specific operation.

I-4.3 Summary of test information required. The following information is required in the test plan for adequate conduct of the tests of section II:

a. Test item configuration.

b. Test temperature extremes.

c. Duration of exposure at each temperature.

d. Test item response temperature (from Method 501.2).

e. The high-temperature cycle, the test item response temperature, and the initial temperature for the temperature cycling.

f. Additional guidelines.

I-5 REFERENCES

a. AR 70-38, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions, dated 1 August 1979.

b. MIL-STD-210, Climatic Extremes for Military Equipment, dated 15 December 1973.

c. Synopsis of Background Material for MIL-STD-210B, Climatic Extremes for Military Equipment. Bedford, MA: Air Force Cambridge Research Laboratories, 24 January 1974. DTIC number AD-780-508.

d. NATO STANAG 2831, Climatic Environmental Conditions Affecting the Design of Material for Use by NATO Forces Operating in a Ground Role.

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METHOD 503.2

TEMPERATURE SHOCK

SECTION II

II-1 APPARATUS

II-1.1 Test facilities

a. The required apparatus consists of two chambers or cabinets in which the test conditions can be established and maintained. Unless otherwise specified, the chambers must be equipped so that, after transfer of the test item, the test conditions within the chamber can be stabilized within 5 minutes. Material-handling equipment may be necessary for transfer of the test item between chambers.

b. The chambers shall be equipped with auxiliary instrumentation capable of maintaining and continuously monitoring the test conditions throughout an envelope of air surrounding the test item(s). (See General Requirements, 4.4.1a.)

II-1.2 Controls

a. Temperature. Unless otherwise specified in the test plan, if any action other than test item operation (such as opening of the chamber door, except at transfer time) results in a significant change (more than 2°C (3.6°F)) of the test item temperature or chamber air temperature, the test item will be stabilized at the required temperature before continuation.

b. Air velocity. Air velocity in the vicinity of the test item shall not exceed 1.7 m/s (325 ft/min) to provide standard testing conditions, unless justified by the test item platform environment.

c. Transfer time. Transfer the test item between the two environments (high and low temperatures) as rapidly as possible but in no more than 5 minutes (unless the test item is large and requires handling equipment).

II-1.3 Test interruption (See General Requirements, 4.5.4.)

a. Undertest interruption. If, before the temperature change, an unscheduled test interruption occurs that causes the test conditions to exceed allowable tolerances toward standard ambient temperatures, the test must be reinitiated at the point of interruption and the test item reestablished at the test condition. If the interruption occurs during the transfer, the test item must be reestablished at the previous temperature and then transferred.

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b. Overtest interruption. Any interruption that results in more extreme exposure of the test item than required by the equipment specification should be followed by a complete physical examination and operational check of the test item (where possible) before any continuation of testing. This is especially true where a safety problem could exist, such as with munitions. If a problem is discovered, the preferable course of action is to stop the test and start over with a new test item. If this is not done and test item failure occurs during the remainder of the test, the test results could be invalid due to the overtest condition. If no problem is discovered, reestablish preinterruption conditions and continue from the point where the test tolerances were exceeded.

II-2 PREPARATION FOR TEST

II-2.1 Preliminary steps. Before initiating any testing, from the test plan:

a. Determine the test temperature levels.

b. Determine the test item configuration.

c. Determine the operational requirements.

d. Estimate the time required at each temperature. (Install temperature sensors if necessary.)

II-2.2 Pretest standard ambient checkout. All test items require a pretest checkout at standard ambient conditions so that baseline data can be established. Munitions and other items, where applicable, shall also be examined by nondestructive examination methods. Conduct the checkout as follows:

Step 1. Stabilize the test item at standard ambient conditions (General Requirements, 4.4a).

Step 2. Conduct a complete visual examination of the test item with special attention to stress areas such as corners of molded areas and interfaces between different materials.

Step 3. Document the results.

Step 4. Prepare the test item in accordance with General Requirements, 4.5.2, and required test item configuration.

Step 5. Conduct an operational checkout in accordance with the approved test plan.

Step 6. Record results for compliance with General Requirements, 4.5.1.

Step 7. If the test item operates satisfactorily, proceed to step 1 of procedure I. If not, resolve the problems and restart at step 1, above.

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II-3 PROCEDURE I. The following procedure provides the basis for collecting the necessary information concerning the test item in a severe temperature-shock environment:

Step 1. With the test item in the chamber, adjust the chamber air temperature to the low-temperature extreme specified in the test plan. Maintain this temperature for 1 hour or until the test item has been stabilized, whichever is longer.

Step 2. Transfer the test item to the high-temperature environment (as specified in the test plan) in no more than 5 minutes. Chamber control shall be such that after insertion of the test item, the chamber temperature shall be within the specified test tolerance after a period of not more than 5% of the exposure time. Cycle the chamber through the appropriate diurnal cycle until the test item response temperature (from the test plan) has been reached. Maintain this temperature until the test item has stabilized. (See General Requirements, 4.4.3.)

Step 3. Transfer the test item to the low-temperature environment as above, and stabilize it at that temperature.

NOTE: If the test procedure is interrupted because of work schedules, etc., the test item can be left at the test temperature or returned to standard ambient conditions for the time required. Before continuing the test, the test item must be restabilized at the temperature of the last successfully completed period before the interruption (see II-1.3).

Step 4. Repeat steps 2 and 3.

Step 5. Repeat step 4.

Step 6. Return the test item to controlled ambient conditions (General Requirements, 4.4b) and stabilize.

Step 7. Operate and inspect the test item and obtain results in accordance with General Requirements, 4.5.6. Compare these data with the pretest data.

II-4 INFORMATION TO BE RECORDED

a. Previous test methods to which the test item has been subjected.

b. Results of each performance check and visual examination, and comparison with the failure criteria.

(1) Pretest.

(2) During test.

(3) Post-test.

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c. Length of time required for each performance check.

d. High and low test temperatures.

e. Transfer times.

f. Duration of each exposure.

g. Test interruptions.

h. Initial failure analysis.

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SOLAR RADIATION (SUNSHINE)

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SECTION I

I-1 PURPOSE. This test is conducted to determine the effects of solar radiation on equipment that may be exposed to sunshine during operation or unsheltered storage on the earth's surface or in the lower atmosphere.

I-2 ENVIRONMENTAL EFFECTS

I-2.1 Heating effects. The heating effects of solar radiation differ from those of high air temperature alone in that the amount of heat absorbed or reflected depends on the roughness and color of the surface on which the radiation is incident. In addition to the differential expansion between dissimilar materials, changes in the intensity of solar radiation may cause components to expand or contract at different rates, which can lead to severe stresses and loss of structural integrity. In addition to those specified in method 501.2, some other examples of heating effects include:

a. Jamming or loosening of moving parts.

b. Weakening of solder joints and glued parts.

c. Change in strength and elasticity.

d. Loss of calibration or malfunction of linkage devices.

e. Loss of seal integrity.

f. Changes in electrical or electronic components.

g. Premature actuation of electrical contacts.

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h. Fading of colors of color-coded components.

i. Changes in characteristics of elastomers and polymers.

j. Blistering and peeling of paints and other finishes.

k. Softening of potting compounds.

I-2.2 Actinic effects. In addition to the heating effects of I-2.1, which are caused by the infrared portion of the solar spectrum, certain degradation from solar energy may be attributable to other portions of the spectrum, particularly the ultraviolet. Since the rate at which these reactions will occur generally increases as the temperature rises, the full spectrum must be used to adequately simulate the actinic effects of solar radiation. Some examples of deterioration caused by actinic effects are:

a. Fading of fabric color.

b. Checking and fading of paints.

c. Deterioration of natural and synthetic elastomers and polymers through photochemical reactions initiated by shorter wavelength radiation.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS

NOTE: This test method should be applied at the end of the tailoring process described in section 4 of this standard.

a. Application. This method is used when the test item is likely to be exposed to solar radiation in the open in hot climates during its life cycle, and the effects mentioned in I-2.1 and I-2.2 are of concern. In most cases, this method should replace method 501.2 (high temperature).

b. Restrictions. This method is not to be used to simulate the heating effects that result from enclosed or covered storage conditions. The solar spectrum and energy levels are those that are received at sea level. The ultraviolet portion is simulated only in a general way, but is considered adequately representative of levels in most geographic areas.

c. Sequence. (See General Requirements, 4.4.4.) The solar radiation test may be applied at any stage in the test program.

d. Test variations. This method is composed of two solar radiation tests: procedures I (cyclic) and II (steady state).

(1) The choice of test procedure is based on the following:

(a) The anticipated exposure circumstances.

(b) The expected problem areas within the test item.

(c) The duration of exposure to solar radiation.

(2) The related test conditions that are used during the test are determined by:

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(a) The anticipated areas of deployment.

(b) The test item configuration.

(c) Additional guidelines as appropriate.

I-3.1 Choice of test procedure

a. Operational purpose of the test item. From the requirements documents, determine the function(s) to be performed by the test item during or after exposure to direct solar radiation.

b. Test objectives. The primary objectives of the test are to determine if:

(1) The test item can satisfy its operational requirements during and after exposure to solar radiation.

(2) The physical degradation which occurs during exposure produces adverse effects on the test item. Based on this information and the purpose of the test item, determine what test data are necessary to evaluate the required performance of the test item during and after exposure to solar radiation.

c. Selection of the test procedure. Two test procedures are included with this method. Based on the test data requirements, determine which of the test procedures is applicable.

(1) Procedure I - Cycling for heat effects. This test procedure is used if the test item is expected to withstand the heat from exposure in the open in hot climates and still be able to perform without degradation both during and after exposure. The solar radiation test (as opposed to the high temperature test, method 501.2) should be used when the test item could be affected (see I-2) by differential heating or when the heating caused by solar radiation is unknown. After the induced temperature and temperature effects have been determined to be comparable to the temperature and temperature effects that could be produced by method 501.2 (high temperature), the latter could (for economic reasons) be substituted for this solar radiation test.

(2) Procedure II - Steady state for prolonged actinic effects. This procedure is used when the principal concern is the possibility that long periods of exposure to sunshine will result in detrimental actinic effects. Because actinic effects do not usually occur unless the exposure is prolonged, it is inefficient to use the cycling test of procedure I, which could conceivably take months to conduct. The approach, therefore, is to use an accelerated test which is designed to reduce the time to produce integrated effects of long periods of exposure. The key to using this procedure successfully is maintaining enough cooling air to prevent the test item from exceeding temperatures that would be attained under natural conditions (such as the cycling test simulates), so that there will not be an exaggerated test

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which unfairly penalizes the test item. However, there should not be enough cooling air to produce unrealistic cooling. Since the actinic effects are highly dependent upon the solar radiation spectrum (as well as intensity and duration), the spectrum must be as close as possible to that of natural sunlight.

The 4-hour "lights off" period of each 24-hour cycle allows for test item conditions (physical and chemical) to return toward normal and provides some degree of thermal stress exercising.

I-3.2 Choice of related test conditions. After choosing the test procedure, choose the diurnal cycle, test duration, test item configuration, and any additional appropriate conditions.

a. Diurnal cycle. For procedure I, two high-temperature diurnal cycles are provided in table 505.2-I, with the same solar radiation conditions for both. The first cycle (Hot Dry) has a peak temperature of 49°C (120°F) and 1120 W/m^2 (355 $Btu/ft^2/h$) and represents the hottest conditions, exceeded not more than 1 percent of the hours in the most extreme month at the most severe locations under consideration. This cycle is used when there is a requirement for the test item to perform satisfactorily worldwide. The second cycle (Basic Hot Dry) is less severe and peaks at an air temperature of 44°C (111°F) and a solar radiation intensity of 1120 W/m^2. This cycle is used when there is a requirement for the test item to perform without degradation in many geographical areas of the world that extend outward from the Hot Dry regions of the United States, Mexico, Africa, Asia, Australia, South Africa, South America, southern Spain, and southwest Asia. (See method 501.2 for area descriptions.) This cycle is also used when special precautions are taken to provide protection against the sun in hot, dry areas (such as with munitions).

b. Test duration

(1) Procedure I. (See figure 505.2-1.) The test item shall be exposed to continuous 24-hour cycles of controlled simulated solar radiation and dry-bulb temperature as indicated in table 505.2-I or as specified in the requirements documents. The number of cycles performed shall be the minimum necessary to produce the peak response temperature caused by the stacking effect of the test item (within 2°C (3.6°F) of the peak response temperature achieved during the previous 24-hour cycle) or three continuous cycles, whichever is longer. For most applications, the maximum test duration should be seven cycles.

(2) Procedure II. (See figure 505.2-2.) Procedure II will give an acceleration factor of approximately 2.5 as far as the total energy received by the test item is concerned. Eight hours of exposure to 1120 W/m^2 (355 $Btu/ft^2/h$), as in the steady-state test, is equal to 24 hours of the cycling test (20 hours of light and 4 hours of no light per cycle). A duration of ten 24-hour cycles is suggested for equipment which is occasionally used outdoors, such as portable test items, etc. For equipment continuously exposed to outdoor conditions, a test duration of 56 cycles or longer is suggested. Increasing the irradiance above the specified level is not recommended, because of the danger of overheating, and there is presently no indication that attempting to accelerate the test in this way gives results that correlate with equipment response under natural solar radiation conditions.

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TABLE 505.2-I. Temperature solar radiation diurnal cycles.1/

Time	Hot-Dry			Basic Hot			Solar Radiation (See Figure 505.2-1)	
	°C	°F	RH (%)	°C	°F	RH (%)	W/m²	Btu/ft²/hr
0000	37	98	6	33	91	33	0	0
0300	34	93	7	32	90	41	0	0
0600	32	90	8	30	86	44	55	18
0900	38	101	6	37	99	29	730	231
1200	44	112	4	42	107	18	1120	355
1500	48	119	3	44	110	14	915	291
1600	49	120	3	44	110	14	730	231
1800	48	118	3	42	107	15	270	85
2100	41	105	5	36	97	22	0	0
2400	37	98	6	33	41	33	0	0
Max	49	120	8	44	110	44	1120	355
Min	32	90	3	30	86	14	0	0

1/ Selection of temperature conditions depends on the requirements document(s) and the condition to which the particular item will be subjected during normal usage.

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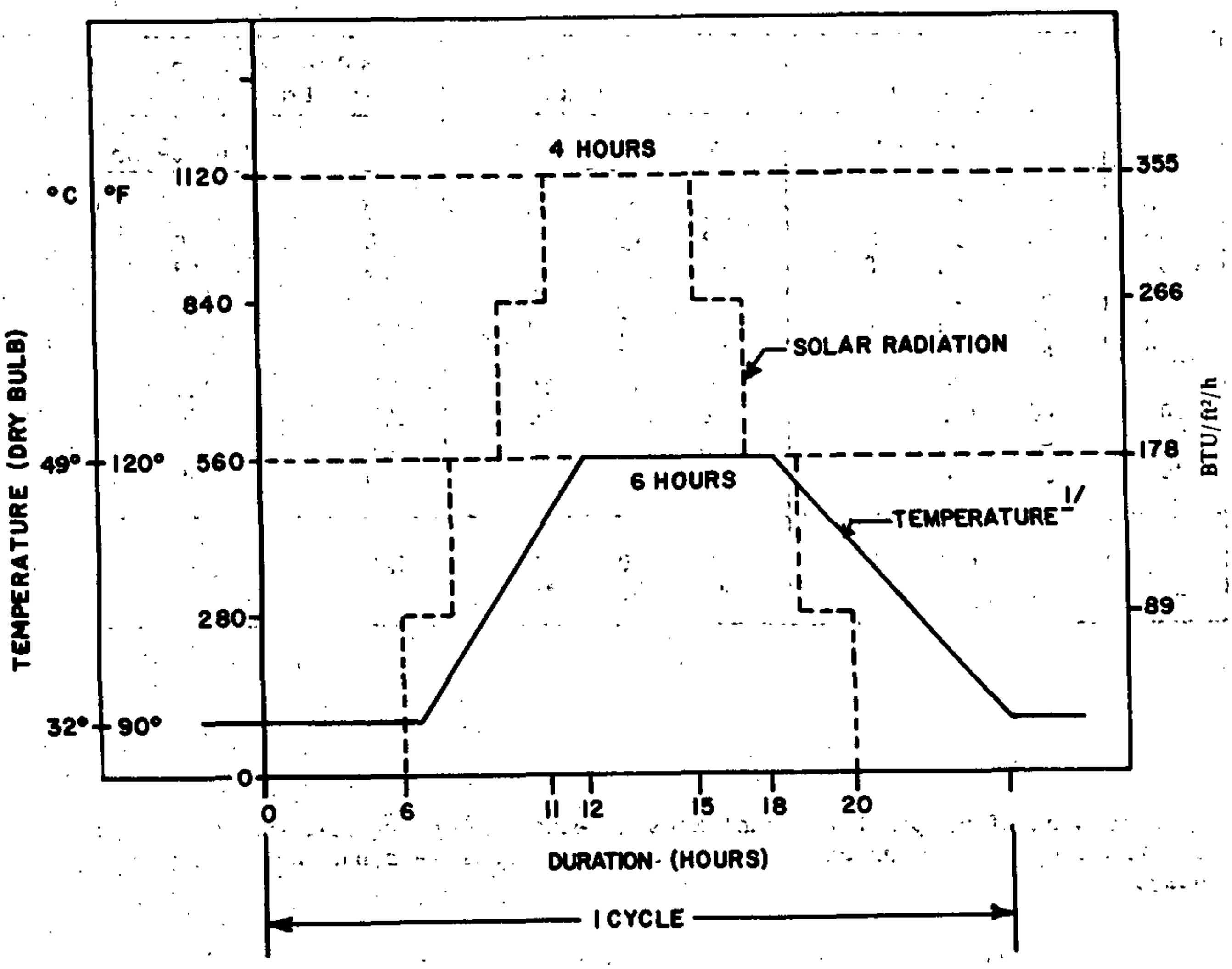

FIGURE 505.2-1. SIMULATED SOLAR RADIATION CYCLE (PROCEDURE I)

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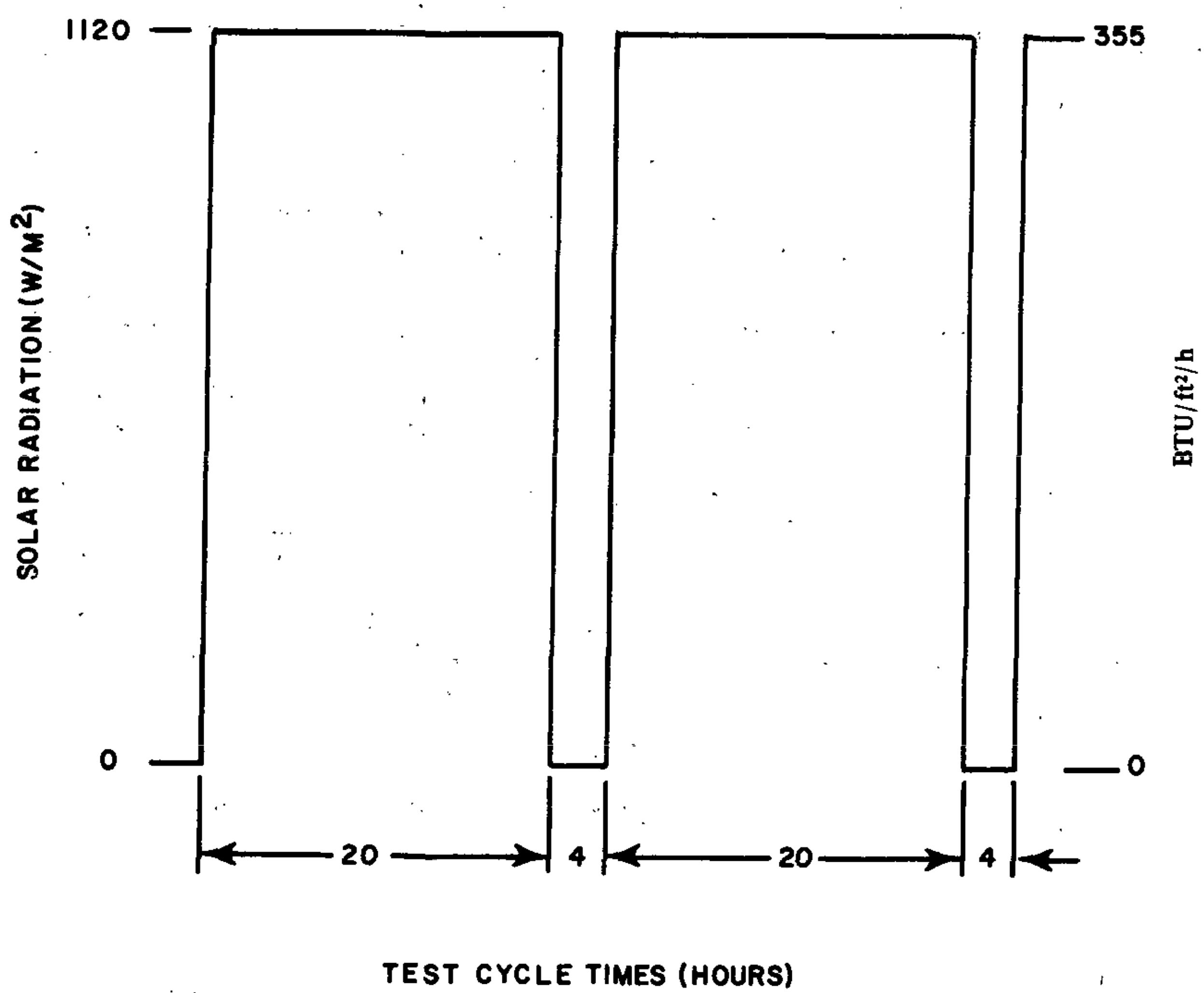

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c. Configuration. The test item configuration should be the same as its configuration during exposure to solar radiation. The orientation of the test item relative to the direction of radiation will have a significant impact on the heating effects, as will its mounting (on supports or on a substrate of specified properties, e.g., a layer of concrete of specified thickness or a sand bed of certain reflectivity).

d. Additional guidelines. Review the requirements document(s). Apply any additional guidelines appropriate.

I-4 SPECIAL CONSIDERATIONS

I-4.1 Failure analysis (See General Requirements, 4.5.7.)

a. Procedure I. Both at peak temperature and after return to standard ambient conditions, the performance characteristics of the test item will not be altered to the extent that the test item does not meet its requirements. Actinic effects that do not affect performance, durability, or required characteristics will be recorded as observations only.

b. Procedure II. The performance and characteristics (such as color or other surface conditions) of the test item will not be altered to the extent that the test item does not meet requirements. Actinic effects that do not affect performance, durability, or required characteristics will be recorded as observations only. The fading of colors could result in higher heating levels within the test item.

I-4.2 Summary of test information required. The following information is required in the test plan for adequate conduct of the tests of section II.

a. Test item configuration and orientation.

b. Test procedure.

c. Location of temperature sensors.

d. Number of cycles.

e. Appropriate diurnal cycle (for procedure I).

f. Spectral radiation of the source.

g. Test item preparation (see II-1.2b).

h. Test item operational requirements (see II-3.1, step 2).

i. Additional guidelines.

I-5 REFERENCES

a. AR 70-38, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions, 1 August 1979.

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b. MIL-STD-210, Climatic Extremes for Military Equipment, 15 December 1973.

c. Synopsis of Background Material for MIL-STD-210B, Climatic Extremes for Military Equipment. Bedford, MA: Air Force Cambridge Research Laboratories, January 1974. DTIC number AD-780-508.

d. Draft STANAG 2895, Climatic Environmental Conditions Affecting the Design of Materiel for Use of NATO Forces, 13 September 1977.

e. NATO STANAG 2831, Climatic Environmental Conditions Affecting the Design of Material for Use by NATO Forces Operating in a Ground Role.

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METHOD 505.2

SOLAR RADIATION (SUNSHINE)

SECTION II

II-1 APPARATUS

II-1.1 Test facility

a. The required facility consists of a chamber or cabinet, auxiliary instrumentation, and a solar lamp bank. This apparatus must be capable of maintaining and monitoring the required conditions of temperature, airflow, and irradiation.

b. For procedure I, the possible cooling effects of airflow over the test specimens must be considered. An airflow of as little as 1 m/s can cause a reduction in temperature rise of over 20 percent. It is essential, therefore, to control and measure the rate of airflow, which should be as low as possible consistent with achieving satisfactory control of temperature. Adjustments of the temperature within the enclosure and control of chamber gradients by suitable heating and cooling of the walls of the enclosure eliminate the need for high air velocities. The air velocity shall be maintained between 0.25 and 1.5 m/s (50 to 300 ft/min).

c. The volume of the test chamber shall be a minimum of 10 times that of the envelope volume of the test item.

d. The solar radiation source area shall be such that the length and width of the test item shall be no more than one-half the same dimensions of the lamp bank and may be composed of either radiant heat-producing lamps (for procedure I) or lamps that simulate the solar spectrum (for procedure II or both I and II).

e. The irradiance shall have a maximum intensity of 1120 W/m^2 (±10%), and the radiation falling on the test item shall be uniform to within ±10% of the desired value, with the spectral distribution given in table 505.2-II. Where thermal effects only are to be assessed, deviation from this spectral distribution is permitted, but the irradiance must be adjusted to give an equivalent heating effect. In order to calculate this adjustment, it is necessary to know:

(1) The spectral reflectance or transmittance of the irradiated surfaces, and

(2) The spectral energy distribution of the particular lamps being used (and also the effect of any associated reflectors or glasses). The radiation shall be directed onto the test item and shall irradiate the entire surface of the test item facing the solar radiation source. The value of 1120

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W/m² shall include any radiation reflected from the test chamber walls and received by the test item, but it should not include long-wave infrared radiation emitted by the chamber walls. The radiation-measuring device shall be calibrated in the wavelength range of the test source radiations.

TABLE 505.2-II. Spectral energy distribution and permitted tolerances.

CHARACTERISTIC	Spectral Region			
	ULTRAVIOLET		VISIBLE	INFRARED
Bandwidth	0.28 to 0.32 μm	0.32 to 0.40 μm	0.40 to, 0.78 μm	0.78 to 3.00 μm
Irradiance	5 W/m²	63 W/m²	517 to 604 W/m²	492 W/m²
Tolerance	±35%	±25%	±10%	±20%

*NOTE: The amount of radiation wavelength shorter than 0.30 μm reaching Earth's surface is insignificant.

f. The radiation source shall be located at least 76 cm (30 inches) away from any other surface of the test item.

g. Light source

(1) Tests conducted for degradation and deterioration of materials due to actinic effects, as well as heat buildup within the test items, must satisfy the full spectrum of table 505.2-II and may use one of the following acceptable radiation sources:

(a) Xenon arc or mercury xenon arc (used singly) with suitable reflector.

(b) Combination of high pressure sodium vapor and improved mercury vapor with suitable reflectors.

(c) High-intensity multivapor, mercury vapor (with suitable reflectors), and incandescent spot lamps.

(d) Carbon arc lamps with suitable reflectors.

NOTE: Other combinations of the lamps listed above and in II-1.1g(2) below may be used if it is proven that the combination produces the spectrum of table 505.2-II.

(2) Tests in which it is not sought to reproduce the sun's spectrum may use the appropriate lamps from:

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(a) Mercury vapor lamps (internal reflector type only).

(b) Combination of incandescent spot lamps and tubular-type mercury vapor lamps with external reflectors.

(c) Combination of incandescent spot lamps and mercury vapor lamps with internal reflectors.

(d) Metal halide.

(e) Mercury xenon arc lamps with suitable reflectors.

(f) Multivapor (clear or coated bulb) with suitable reflectors.

(g) Tungsten filament lamps.

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

II-1.2 Controls

a. Temperature. Chamber air temperature shall be maintained in accordance with General Requirements, 4.4.1a, and measured (with adequate shielding from radiated heat) at a point or points in a horizontal plane 0 to 50 mm below the prescribed irradiation plane, at half the distance between the test item and the wall of the chamber or at 1m from the test item, whichever is smaller. This is to insure reasonable control of the envelope of air surrounding the test item.

b. Surface contamination. Dust and other surface contamination may significantly change the absorption characteristics of irradiated surfaces. Unless otherwise required, specimens should be clean when they are tested. However, if effects of surface contamination are to be assessed, the relevant specification should include the necessary information on preparation of surfaces.

c. Instrumentation

ITEM	TOLERANCE
Pyranometer or pyrheliometer	Total irradiation (direct and scattered) to ± 47 W/m^2 (± 14 Btu/ft^2/h)
Spectroradiometer or filtered pyranometer	$\pm 5\%$ of reading.

NOTE: Values may be assumed to represent plus or minus two standard deviations; thus, the stated tolerances should not be exceeded in more than 1 measurement out of 20. Solar radiation intensity shall be measured with a pyranometer or pyrheliometer. Spectral distribution of irradiance as a function of wavelength shall be measured with a spectral radiometer or filtered pyranometer.

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d. Calibration of chamber. Because of the variety of permissible lamps and chamber designs, it is particularly important that the chamber be calibrated to assure that the proper levels of radiant infrared energy are impacting the test area when heat alone is of concern and that the proper intensity and spectral distribution of solar radiation are impacting the test area when actinic effects are of concern. Over the area covered by the test item, the radiation intensity must be within ±10%. As the lamps age, their spectral output changes. To insure that solar radiation chambers meet established specifications, a check on spectral distribution, intensity, and uniformity shall be performed at intervals not exceeding 500 hours of operation to insure that the facilities continue to meet established specifications. This value is based on the manufacturer's guarantee for minimum bulb life.

II-1.3 Test interruptions (See General Requirements, 4.5.4.)

a. Undertest interruptions

(1) Procedures I and II. The test rationale is based on the total cumulative effect of the solar environment. Any undertest interruption should be followed by restabilization at the specified conditions and continuation of the test from the point of the interruption.

(2) Procedure I. If an interruption occurs after 18 hours 20 minutes of the last cycle of procedure I, the test shall be considered complete. (At least 92 percent of the test would have been completed, and the probability of a failure is low during the remaining reduced levels of temperature and solar radiation.)

b. Overtest interruption. Any overtest conditions must be followed by a thorough examination and checkout of the test item to verify the effect of the overtest. Since any failure following continuation of testing will be difficult to defend as unrelated to the overtest, a new test item should be used.

II-2 PREPARATION FOR TEST

II-2.1 Preliminary steps. Before initiating any testing, determine from the test plan:

a. Which test procedures are required.

b. The diurnal cycle to be used.

c. Other variables, such as number of cycles, etc.

II-2.2 Pretest standard ambient checkout. All items require a pretest standard ambient checkout to provide baseline data. Conduct the checkout as follows:

Step 1. Install the test item in the chamber and stabilize it at standard ambient conditions (General Requirements, 4.4a) and in a manner that will simulate service usage, unless the storage configuration is specified. Position the test item in accordance with the following:

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a. As near the center of the test chamber as practical and so that the surface of the item is not closer than 0.3m (1 ft) to any wall or 0.76m (30 in.) to the radiation source when the source is adjusted to the closest position it will assume during the test.

b. Oriented, within realistic limits, to expose its most vulnerable parts to the solar radiation, unless a prescribed orientation sequence is to be followed.

c. Separated from other items that are being tested simultaneously, to insure that there is no mutual shading or blocking of airflow.

Step 2. Conduct a visual examination of the test item with special attention to stress areas, such as corners of molded cases.

Step 3. Document the results.

Step 4. Prepare the test item in accordance with General Requirements, 4.7.2, and required test item configuration (see I-3.2c), with the temperature sensors necessary to determine test item response.

Step 5. Conduct an operational checkout in accordance with the approved test plan.

Step 6. Record results for compliance with General Requirements, 4.5.6.

Step 7. If the test item operates satisfactorily, place it in its test configuration (if other than operational). If not, resolve the problem and restart at step 1. Position the test item in accordance with the following and proceed to the first test as specified in the test plan.

a. As near the center of the test chamber as practical. (See II-1.1c and d.)

b. Oriented, within realistic limits, to expose its most vulnerable parts to the solar radiation, unless a prescribed orientation sequence is to be followed.

c. Separated from other items that are being tested to insure that there is no mutual shading or blocking of airflow.

II-3 <u>PROCEDURES</u>. The following test procedures, alone or in combination, provide the bases for evaluating the performance of the test item in a solar radiation environment.

II-3.1 <u>Procedure I - Cycling for heat effects</u>

Step 1. Raise the chamber air temperature to the 0000-hour temperature of table 505.2-I.

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Step 2. Expose the test item to continuous 24-hour cycles of controlled simulated solar radiation and dry-bulb temperature as indicated in table 505.2-II or as specified in the equipment specification. The number of cycles performed shall be whichever of the following is longer:

a. The minimum necessary to insure that the peak response temperature of the most critical area of the test item achieved during a cycle is within ±2°C (±3.6°F) of the peak response temperature achieved during the previous 24-hour cycle, or

b. Three continuous cycles.

Increase and decrease the solar radiation intensity in a minimum of four steps up and four steps down to approximate the curve of figure 505.2-3 (table 505.2-I). The test item may or may not be operated throughout the test, at the option of the equipment specification. When an evaluation of the heating effects is important, operation at least at peak temperature should be specified. For certain one-shot items (e.g., rockets), thermocouples affixed to critical portions of the test item should be used to determine the time and value of peak temperature. The time of operation shall coincide with peak temperature.

Step 3. Continue cycling until the peak response temperature (measured at representative locations) achieved during a cycle is within ±2°C (±3.6°F) of the peak response temperature achieved during the previous 24-hour cycle, or during 7 cycles, whichever comes first.

Step 4. Conduct an operational checkout of the test item as in II-2.2, step 5.

Step 5. Adjust the chamber air temperature to standard ambient conditions and maintain until temperature stabilization of the test item has been achieved.

Step 6. Conduct a complete visual examination of the test item.

Step 7. Document the results.

Step 8. Conduct an operational checkout of the test item as in II-2.2, step 5.

Step 9. Document the results.

Step 10. Compare these data with the pretest data.

II-3.2 <u>Procedure II - Steady state for prolonged actinic effects</u>

Step 1. Adjust the solar radiation source to a radiant energy rate of 120 ± 47 W/m^2 (355 ± 14 Btu/ft^2/h), or as specified in the equipment specification, and a temperature of 49°C (120°F).

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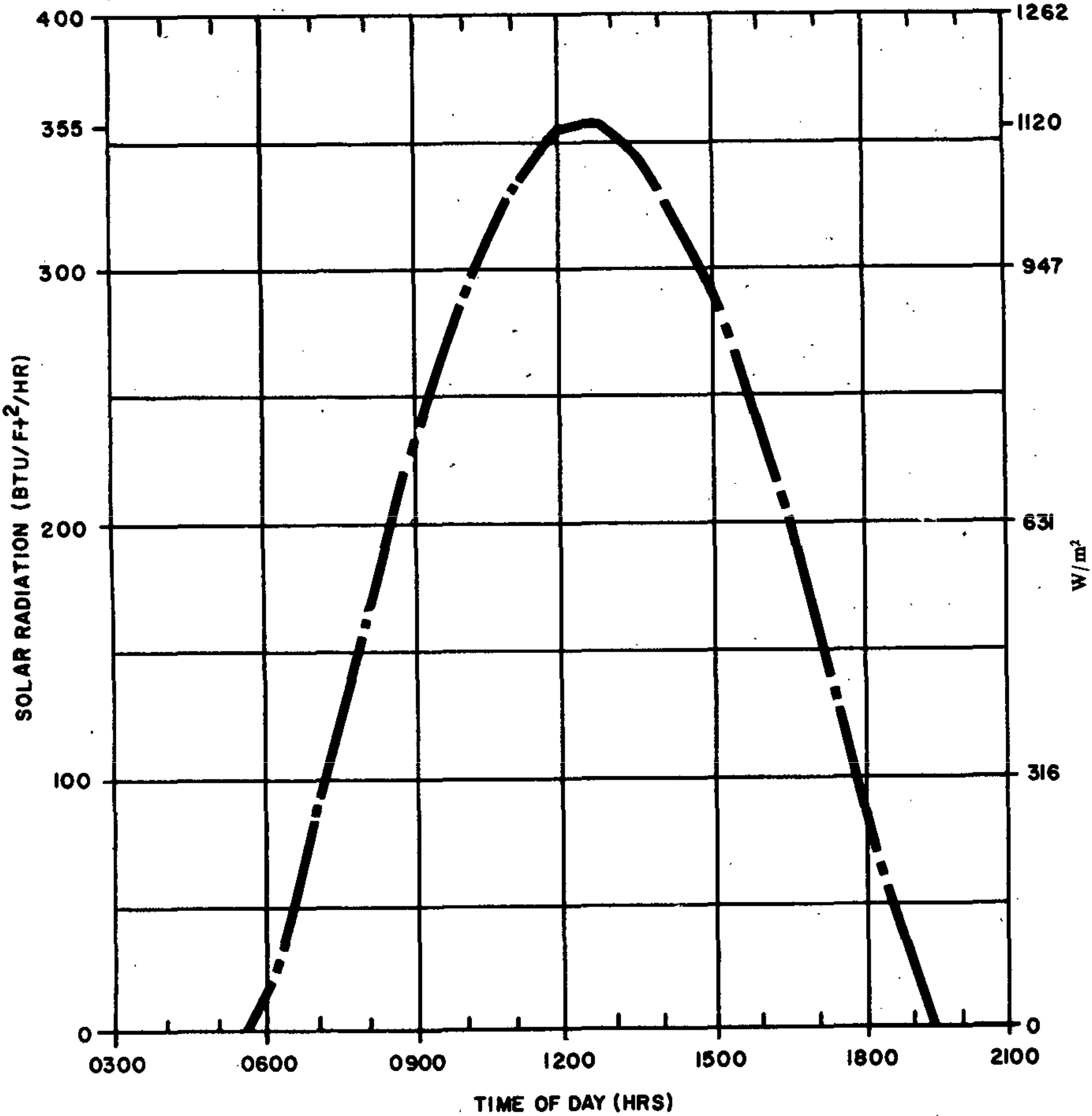

FIGURE 505.2-3. Daily solar radiation cycle.

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Step 2. Maintain these conditions for 20 hours.1/

Step 3. Measure and record the test item temperatures.

Step 4. Turn off the solar radiation source for 4 hours.

Step 5. Repeat steps 1 thru 4 for the number of cycles specified in the test plan.

Step 6. Conduct a performance check and visual examination as in II-2.2, steps 2 and 5 and document the results.

II-4 INFORMATION TO BE RECORDED

a. Previous test methods to which the test item has been subjected.

b. Test procedure.

c. Results of each performance check.

d. Results of each visual examination (and photographs, if applicable).

e. Location of temperature sensors on the test item.

f. Test item temperatures and exposure periods.

g. Solar lamp bank identification.

h. Additional data as required.

1/ If required, operational checks should be conducted during the last 4 hours of each 20-hour exposure when test temperatures are maximized.

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c. Sequence. (See General Requirements, 4.4.4.) This method is applicable at any stage in the test program, but its effectiveness as a test method is maximized if it is performed after the dynamic tests.

The leakage test (method 512.2) is normally considered to be more severe than the rain test for determining the penetrability of the test item. Equipment that passes the leakage test may not require exposure to the rain test if its configuration is unchanged and the effects of penetration are the main concern.

d. Test variation. This method is comprised of three rain-related test procedures. Before the test is conducted, a determination must be made of which test procedures and test conditions are appropriate. Determination of related test conditions that are used during the test are based on:

(1) The test item configuration.

(2) The operational purpose of the test item.

I-3.1 Choice of test procedure(s)

a. Test objectives. The primary objectives of the rain test are to determine if:

(1) Rain can penetrate the enclosure of the test item while it is in its operational or storage configuration.

(2) The test item can meet its performance specifications during and after exposure to rain.

(3) Rain causes physical deterioration of the test item.

(4) The rain and collected rainwater removal systems are effective.

b. Selection of the test procedure. Three test procedures are included within method 506.2: blowing rain, drip, and watertightness. Select the procedure that presents the most severe exposure anticipated for the test item.

(1) Procedure I - Blowing rain. Procedure I is applicable for equipment which will be deployed out-of-doors and which will be unprotected from blowing rain. The accompanying wind velocity can vary from almost calm to extremely high. Test items which cannot be adequately tested with this procedure because of their large size should be considered for testing under procedure III.

(2) Procedure II - Drip. Procedure II is appropriate when equipment is normally protected from rain but may be exposed to falling water from condensation or leakage from upper surfaces.

(3) Procedure III - Watertightness. Procedure III should be considered when large (shelter-size) equipment is to be tested and a blowing-rain facility is not available or practical. This procedure is not intended to simulate natural rainfall but will provide a high degree of confidence in the watertightness of a piece of equipment.

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I-3.2 Choice of related test conditions. Variables under each test procedure include the test item configuration, rainfall rate, wind velocity, test item exposure surfaces, water pressure, and any additional appropriate guidelines in accordance with the requirements document.

a. Test item configuration. The test item should be tested in all the configurations in which it can be placed during its life cycle. As a minimum, the following configurations should be considered:

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

(2) Protected or not protected.

(3) In its operational configuration.

(4) Modified with kits for special applications.

b. Rainfall rate. The rainfall rate used in procedure I may be tailored to the anticipated deployment locale and duration. An instantaneous rainfall rate equivalent to 0.80 mm/min (1.89 in./h) occurs commonly in areas of heavy rainfall, but a minimum rate of 10 cm/hr (4 in./h) is recommended, since it is not an uncommon occurrence and would provide a reasonable degree of confidence in the test item. Asia, for example, is known to have high rainfall intensities. The highest recorded intensity for 1 minute occurred in Maryland and was 31.2 mm/min (1.23 in./min). For testing purposes, the following table of rainfall rates (from MIL-STD-210B) for worldwide expected durations of exposure (EDE) from 2 to 25 years is more realistic.

TABLE 506.2-I. Expected rainfall rates for different exposure durations.

EDE (yr)	Rate	
	(in./h)	(cm/h)
2	4.0	10
5	4.7	12
10	5.2	13
25	5.8	15

c. Droplet size. Nominal drop-size spectra exist for instantaneous rainfall rates, but, according to MIL-STD-210B, for the long-term rainfall rates they are meaningless, since rates are made up of many different instantaneous rates possessing different spectra. For these tests, droplet sizes should not be smaller than approximately 0.5 mm in diameter, 1/ which is considered to be mist or drizzle rather than rain (reference e.), or larger than 4.5 mm.

1/ Observations show that there are no drops of less than roughly 0.5 mm diameter during intense rains (reference c).

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d. Wind velocity. High rainfall intensities accompanied by winds of 18 m/s (40 mph) are not uncommon during storms. Unless otherwise specified, this velocity is recommended for procedure I tests. Winds of 33 m/s (75 mph) are the threshold for hurricane-force winds.

e. Test item exposure surface. Wind-driven rain will usually have more of an effect on vertical surfaces than on horizontal surfaces, and vice versa for vertical or near-vertical rain. All surfaces onto which the rain could fall or be driven must be exposed to the test conditions.

f. Water pressure. Procedure III relies on pressurized water. The pressure may be varied according to the requirements documents, but a minimum value of 377 kPa (40 psig) nozzle pressure is given as a guideline based on past experience. This value will produce water droplets traveling at approximately 64 km/h (40 mph) when a nozzle as specified in paragraph II-1.1e is used.

g. Additional guidelines. Review the requirements documents for any additional guidelines.

I-4 SPECIAL CONSIDERATIONS

I-4.1 Failure analysis

I-4.1.1 Operational requirements. The failure of the test item to satisfy the requirements of the equipment specification must be analyzed carefully, and related information must be considered, such as:

a. Degradation allowed in the performance characteristics because of rainfall exposure.

b. Necessity for special kits for special operating procedures.

c. Safety of operation.

I-4.1.2 Water penetration. Based on the individual test item and the requirements for its nonexposure to water, determine if one of the following is applicable:

a. Unconditional failure. Any evidence of water penetration into the test item enclosure following the rain test shall be considered a failure.

b. Acceptable water penetration. Water penetration of not more than 4 cm^3 per 28,000 cm^3 (1 ft^3) of test item enclosure 2/ shall be acceptable, provided the following conditions are met:

2/ This quantity of water (4 cm^3) is approximately the quantity required to raise the relative humidity of 1 cubic foot of air at standard ambient conditions (50% RH at 21°C (70°F) to saturation at 49°C (120°F)). The 49°C value is realistic for equipment exposed to higher temperature and solar radiation effects.

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(1) There is no immediate effect of the water on the operation of the test item.

(2) The test item in its operational configuration (transit/storage case open or removed) shall successfully complete the induced temperature/humidity procedure of method 507.2 for the geographical area in which it is designed to be deployed.

I-4.2 Temperature. Experience has shown that a temperature differential between the test item and the rainwater can affect the outcome (leakage) of a rain test. It is recommended that whenever possible, the test item temperature be at least 10°C (18°F) higher than the rain temperature at the beginning of each 30-minute exposure period to produce a negative pressure differential inside the test item.

I-4.3 Summary of test information required. The following information is required in the test plan for adequate conduct of the tests of section II:

a. Test procedure(s).

b. Test item configuration.

c. Rainfall rate.

d. Test item preheat temperature.

e. Exposure surfaces/durations.

f. Wind velocity.

g. Water pressure.

h. Water temperature.

i. Additional guidelines.

I-5 REFERENCES

a. AR 70-38, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions, 1 August 1979.

b. MIL-STD-210, Climatic Extremes for Military Equipment, 15 December 1973.

c. Synopsis of Background Material for MIL-STD-210B, Climatic Extremes for Military Equipment. Bedford, MA: Air Force Cambridge Research Laboratories, 1974. DTIC number AD-780-508.

d. Army Materiel Command Pamphlet AMCP-706-116, Engineering Design Handbook, Environmental Factors.

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e. Huschke, R.E. (ed.). Glossary of Meteorology. Boston: American Meteorological Society, 1970.

f. MIL-S-55286, Shelter, Electrical Equipment S-280( )/G.

g. MIL-S-55541, Shelter, Electrical Equipment S-250( )/G.

h. RTCA/DO-160, Environmental Conditions and Test Procedures for Airborne Equipment, January 1980.

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METHOD 506.2

RAIN

SECTION II

II-1 APPARATUS

II-1.1 Test Facility

a. For procedure I, the rain facility shall have the capability of producing falling rain accompanied by wind blowing at the rate specified herein. The facility temperature shall be uncontrolled, except as regulated by water introduced as rain. The rain shall be produced by a water distribution device of such design that the water is emitted in the form of droplets having a diameter range predominantly between 0.5 and 4.5 millimeters (see I-3.2c). The rain shall be dispersed completely over the test item when accompanied by the prescribed wind.

b. The wind source shall be positioned with respect to the test item so that it will cause the rain to beat directly, with variations up to 45° from the horizontal, and uniformly against one side of the test item. The wind source shall be capable of producing horizontal wind velocities equal to and exceeding 18 m/s (40 mi/h). The wind velocity shall be measured at the position of the test item before placement of the test item in the facility. No rust or corrosive contaminants shall be imposed on the test item by the test facility.

c. A water-soluble dye such as fluorescein may be added to the rainwater to aid in locating and analyzing water leaks.

d. For procedure II, the test setup should provide a volume of water greater than 280 (+30, -0) $L/m^2/h$ (7 $gal/ft^2/h$) dripping from a dispenser with drip holes on a 25.4 mm pattern, as shown in figure 506.2-1.

e. For procedure III, the nozzles used should produce a square spray pattern or other overlapping pattern (for maximum surface coverage) and droplet size predominantly in the 2 to 4.5 mm range at approximately 375 kPa (40 psig). At least one nozzle should be used for each 6 ft^2 of surface area and should be positioned 19 ± 1 in. from the test surface.3/

II-1.2 Controls

a. For procedures I and II, the rainfall rate shall be verified immediately before each test.

b. For procedure I, the air velocity shall be verified immediately before each test.

c. For procedure III, the nozzle spray pattern and pressure shall be verified before each test.

3/ From MIL-S-55286 and MIL-S-55541.

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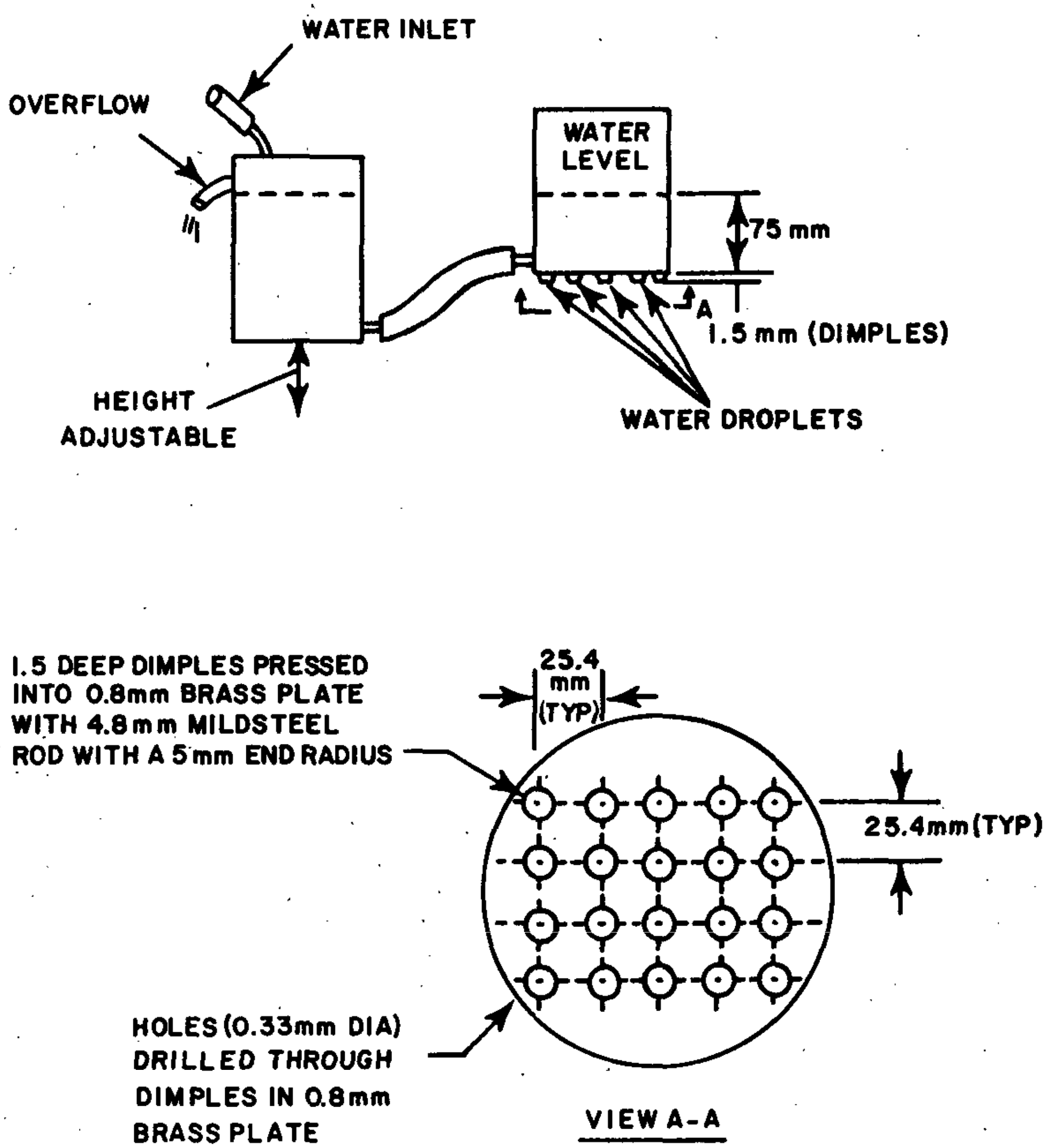

FIGURE 506.2-1

DETAILS OF DISPENSER FOR DRIPPROOFNESS TEST

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d. Unless otherwise specified, water used for rain tests can be from local water supply sources.

II-1.3 Test interruption (See General Requirements, 4.5.4.)

a. Undertest interruption. Interruption of a rain test is unlikely to generate any adverse effects, and normally the test shall be continued from the point of interruption.

b. Overtest interruption. Any interruption that results in more extreme exposure of the test item than required by the equipment specification should be followed by a complete operational and physical check. If no problems are encountered, the test item shall be restored to its pretest condition and the test restarted at the point of interruption.

II-2 PREPARATION FOR TEST

II-2.1 Preliminary steps. Before initiating any testing, determine from the test plan:

a. Which test procedures are required.

b. The rainfall rate and wind velocity for procedure I.

c. The other variables applicable to the desired procedure.

II-2.2 Pretest standard ambient checkout. All test items require a pretest standard ambient checkout to provide baseline data. Conduct the checkout as follows:

Step 1. Stabilize the test item at standard ambient conditions per General Requirements, 4.4a, in the test chamber, if applicable.

Step 2. Conduct a complete visual examination of the test item.

NOTE: No sealing, taping, caulking, etc., shall be used except as required in the test item drawings.

Step 3. Document the results.

Step 4. Prepare the test item in accordance with General Requirements, 4.5.2, and required test item configuration.

Step 5. Conduct an operational checkout in accordance with the approved test plan.

Step 6. Record the results for compliance with General Requirements, 4.5.6.

Step 7. If the test item operates satisfactorily, proceed to II-3. If not, resolve the problems and restart at step 1.

II-3. PROCEDURES. The following test procedures provide the basis for collecting the necessary information concerning the test item's watertightness. Proceed to the first procedure as specified in the test plan.

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II-3.1 Procedure I - Blowing rain

Step 1. With the test item in the facility and in its normal operating position, adjust the rainfall rate as specified in the test plan. (The sealed test item shall be heated to a higher temperature than the rain water (see I-4.2) and restored to its normal operating configuration immediately before testing.)

Step 2. Initiate the wind at the velocity specified in the test plan and maintain for at least 30 minutes.

Step 3. If an operational check is required, the test item shall be operated for the last 10 minutes of the 30-minute rain.

Step 4. Rotate the test item to expose to the rain source any other side of the test item that could be exposed to blown rain in its deployment cycle.

Step 5. Repeat steps 1 through 4 until all possible variations have been accomplished.

Step 6. Examine the test item in the test chamber, if possible; otherwise, remove the test item from the test facility and conduct a visual inspection. If a noticeable amount of free water has penetrated the test item, judgment must be used before operation of the test item. It may be necessary to empty water from the test item to prevent a safety hazard. Measure the volume of water.

Step 7. Measure and document any free water found inside the protected areas of the test item.

Step 8. If required, operate the test item for compliance with the requirements document.

Step 9. Document the results.

II-3.2 Procedure II - Drip

Step 1. Install the test item in the test facility in accordance with General Requirements, 4.5.2, in its operational configuration with all connectors and fittings engaged. (The sealed test item shall be heated to a higher temperature than the rain water (see I-4.2) and restored to its normal operating configuration immediately before testing.)

Step 2. With the test item operating, subject it to water falling from a height of approximately 1 meter (3 feet) at a uniform rate (as produced by a 75-mm-high water level in the dispenser) for 15 minutes (see figure 506.2-1). The test setup shall be arranged so that all of the upper surface gets droplets on it at some time during the test. Test items with glass-covered dials shall be tilted at a 45° angle, dial up.

Step 3. At the conclusion of the 15-minute exposure, remove the test item from the test facility and remove sufficient panels or covers to allow the interior to be seen.

Step 4. Visually inspect the test item for evidence of water penetration.

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Step 5. Measure and document any free water inside the test item.

Step 6. Conduct an operational check of the test item as specified in the test plan, and document the results.

II-3.3 Procedure III - Watertightness

Step 1. Install the test item in the test facility with all doors, louvers, etc., closed.

Step 2. Position the nozzles as required by the test plan or as indicated in II-1.1e.

Step 3. Spray all exposed surfaces of the test item with water for not less than 40 minutes per face.

Step 4. After each 40-minute spray period, inspect the interior of the test item for evidence of free water. Estimate its volume and the probable point of entry and document.

Step 5. Visually inspect the test item for evidence of water penetration.

Step 6. Conduct an operational check of the test item as specified in the test plan, and document the results.

II-4 INFORMATION TO BE RECORDED

a. Previous test methods to which the test item has been subjected.

b. Results of each performance check and visual examination (and photographs, if applicable).

(1) Pretest.

(2) During test.

(3) Post-test.

c. Length of time required for each performance check.

d. Status of the test item for each visual examination.

e. Exposure durations.

f. Rainfall rate.

g. Wind velocity.

h. Water and test item temperatures.

i. Water pressure (if applicable).

j. Surfaces of the test item subjected to rainfall.

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METHOD 507.2

HUMIDITY

Page

SECTION I

I-1 PURPOSE. The humidity tests are performed to determine the resistance of materiel to the effects of a warm, humid atmosphere.

I-2 ENVIRONMENTAL EFFECTS. Moisture can cause physical and chemical deterioration of materiel. Temperature changes and humidity may cause condensation inside of equipment. Typical problems that can result from exposure to a warm, humid environment are:

a. Swelling of materials due to moisture absorption.

b. Loss of physical strength.

c. Changes in mechanical properties.

d. Degradation of electrical and thermal properties in insulating materials.

e. Electrical shorts due to condensation.

f. Binding of moving parts due to corrosion or fouling of lubricants.

g. Oxidation and/or galvanic corrosion of metals.

h. Loss of plasticity.

i. Accelerated chemical reactions.

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j. Chemical or electrochemical breakdown of organic surface coatings.

k. Deterioration of electrical components.

l. Degradation of image transmission through glass or plastic optical elements.

m. Absorption of moisture by explosives and propellants.

n. Accelerated biological activity.

o. Deterioration of hygroscopic materials.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS

NOTE: This test method should be applied at the end of the tailoring process described in section 4 of this standard.

a. Application. This method is used when the test item is likely to be deployed in a warm, humid environment. Such conditions can occur year-round in tropical areas and seasonally in midlatitude areas.

b. Restrictions. None.

c. Sequence. (See General Requirements, 4.4.4.) The test procedures of this method are potentially damaging. The place of this method in the sequence of a test item's life cycle is illustrated in General Requirements, figure 2. The humidity test should follow the initial logistic dynamic exposure of the test item (after arrival at its initial point of disembarkation). It is generally inappropriate to conduct this test on the same test sample used for salt fog or fungus tests.

d. Test variations. The most important ways the test can vary are in duration, temperature-humidity cycles, and ventilation.

I-3.1 Choice of test procedure(s). This method consists of three procedures.

a. Procedure I - Natural. Procedure I simulates natural environmental cycles and is conducted on test items which are open to the environment or frequently ventilated.

b. Procedure II - Induced. Procedure II simulates unventilated conditions that may occur during storage or transit and is appropriate for sealed items or items enclosed in sealed items. For the purpose of this test, a sealed item is one that could have a relatively high internal level of humidity and lacks continuous or frequent ventilation. It does not include hermetically sealed items. The internal humidity may be caused by these or other mechanisms:

(1) Entrapped, highly humid air.

(2) Presence of free water.

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(3) Penetration of moisture through test item seals.

(4) Release of water or water vapor from hygroscopic material within the test item.

c. Procedure III - Aggravated. Procedure III exposes the test item to more extreme temperature and humidity levels than those found in nature but for shorter durations. It is used to reduce the time and cost of testing. This procedure is used to identify potential problem areas, and the test levels are, for all practical purposes, fixed.

I-3.2 Choice of related test conditions. Related test conditions depend on the climate, duration, and test item configuration during shipping, storage, and deployment. The variables common to all three procedures are the temperature-humidity cycles, duration, and configuration. These are discussed below. Requirements documents may impose or imply additional test conditions. The worst-case conditions should form the basis for selecting the test and test conditions to use.

a. Test temperature-humidity. The specific test temperature-humidity values are selected preferably from the requirements documents. If this information is not available, determination of the test temperature-humidity values for procedures I and II can be based on the world geographical areas in which the test item will be used, plus any additional considerations. Table 507.2-I includes the temperature and relative humidity conditions for three geographical categories where high relative humidity conditions may be of concern, and two related categories of induced conditions. Figures 507.2-1 and 507.2-2 are approximations of the cycles and are to be used if chamber control of table 507.2-I cycles is difficult to achieve. The curves are constructed with consideration of chamber limitations. A description of each category follows.

(1) Hot-humid. Severe (high) dewpoint conditions occur 10 to 15 times a year along a very narrow coastal strip, probably less than 5 miles wide, bordering bodies of water with high surface temperatures, specifically the Persian Gulf and the Red Sea. Most of the year these same areas experience hot-dry conditions. Due to the relatively small area in which these conditions occur, most types of equipment need not be designed to withstand this environment.

(2) Constant high humidity. Constant high humidity is found most often in tropical areas, although it occurs briefly or seasonally in the midlatitudes. The constant-high-humidity cycle occurs in heavily forested areas where nearly constant temperature and humidity may prevail during rainy seasons with little (if any) solar radiation exposure. Tropical exposure in a tactical configuration or mode is likely to occur under a jungle canopy. Exposed materiel is likely to be constantly wet or damp for many days at a time. World areas where these conditions occur are the Congo and Amazon Basins, the jungles of Central America, Southeast Asia (including the East Indies), the north and east coasts of Australia, the east coast of Madagascar, and the Caribbean islands. The conditions can exist for 25 to 30 days each month in the most humid areas of the tropics. The most significant variation of this cycle is its frequency of occurrence. In equatorial areas, it occurs

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TABLE 507.2-I. High-humidity diurnal categories.[1]

Time	Natural								Induced					
	Hot-Humid (Cycle 1)			High Humidity					Hot-Humid (Cycle 4)			Cyclic High Humidity (Cycle 5)		
				Constant (Cycle 2)		Cyclic (Cycle 3)								
	Temp °F	Temp °C	RH %	Temp °F °C	RH %	Temp °F	Temp °C	RH %	Temp °F	Temp °C	RH %	Temp °F	Temp °C	RH %
0000	88	31	88	Nearly constant at 24°C (75°F) throughout the 24 hours	100[2]	80	27	100	95	35	63	91	33	68
0100	88	31	88		100	80	27	100	95	35	67	91	22	69
0200	88	31	88		100	79	26	100	94	34	72	90	32	70
0300	88	31	88		100	79	26	100	94	34	75	90	32	71
0400	88	31	88		100	79	26	100	93	34	77	88	31	72
0500	88	31	88		100	78	26	100	92	33	79	86	30	74
0600	90	32	85		100	78	26	100	91	33	80	88	31	75
0700	93	34	80		98	81	27	94	97	36	70	93	34	64
0800	96	36	76		97	84	29	88	104	40	54	101	38	54
0900	98	37	73		95	87	31	82	111	44	42	107	42	43
1000	100	38	69		95	89	32	79	124	51	31	113	45	36
1100	102	39	65		95	92	33	77	135	57	24	124	51	29
1200	104	40	62		95	94	34	75	144	62	17	134	57	22
1300	105	41	59		95	94	34	74	151	66	16	142	61	21
1400	105	41	59		95	95	35	74	156	69	15	145	63	20
1500	105	41	59		95	95	35	74	160	71	14	145	63	19
1600	105	41	59		95	93	34	76	156	69	16	144	62	20
1700	102	39	65		95	92	33	79	151	66	18	140	60	21
1800	99	37	69		95	90	32	82	145	63	21	134	57	22
1900	97	36	73		97	88	31	81	136	58	29	122	50	32
2000	94	34	79		98	85	29	91	122	50	41	111	44	43
2100	91	33	85		100	83	28	95	105	41	53	101	38	54
2200	90	32	85		100	82	28	96	103	39	58	95	35	59
2300	89	32	88		100	81	27	100	99	37	62	93	34	63

1/ Temperature and humidity values are for ambient air.

2/ For chamber control purpose, 100% RH implies as close to 100% as possible but not less than 95%.

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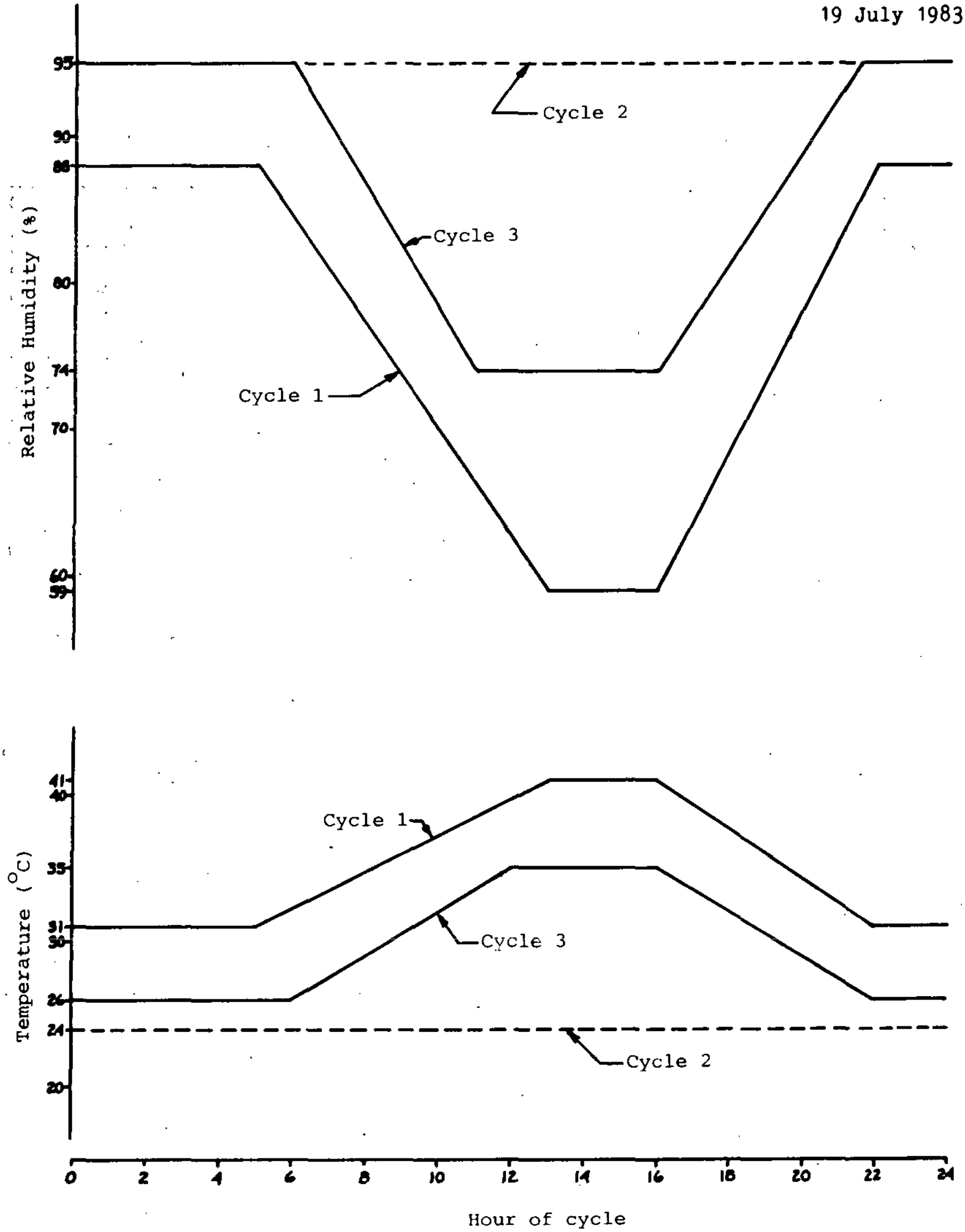

FIGURE 507.2-1. Natural temperature-humidity cycles.

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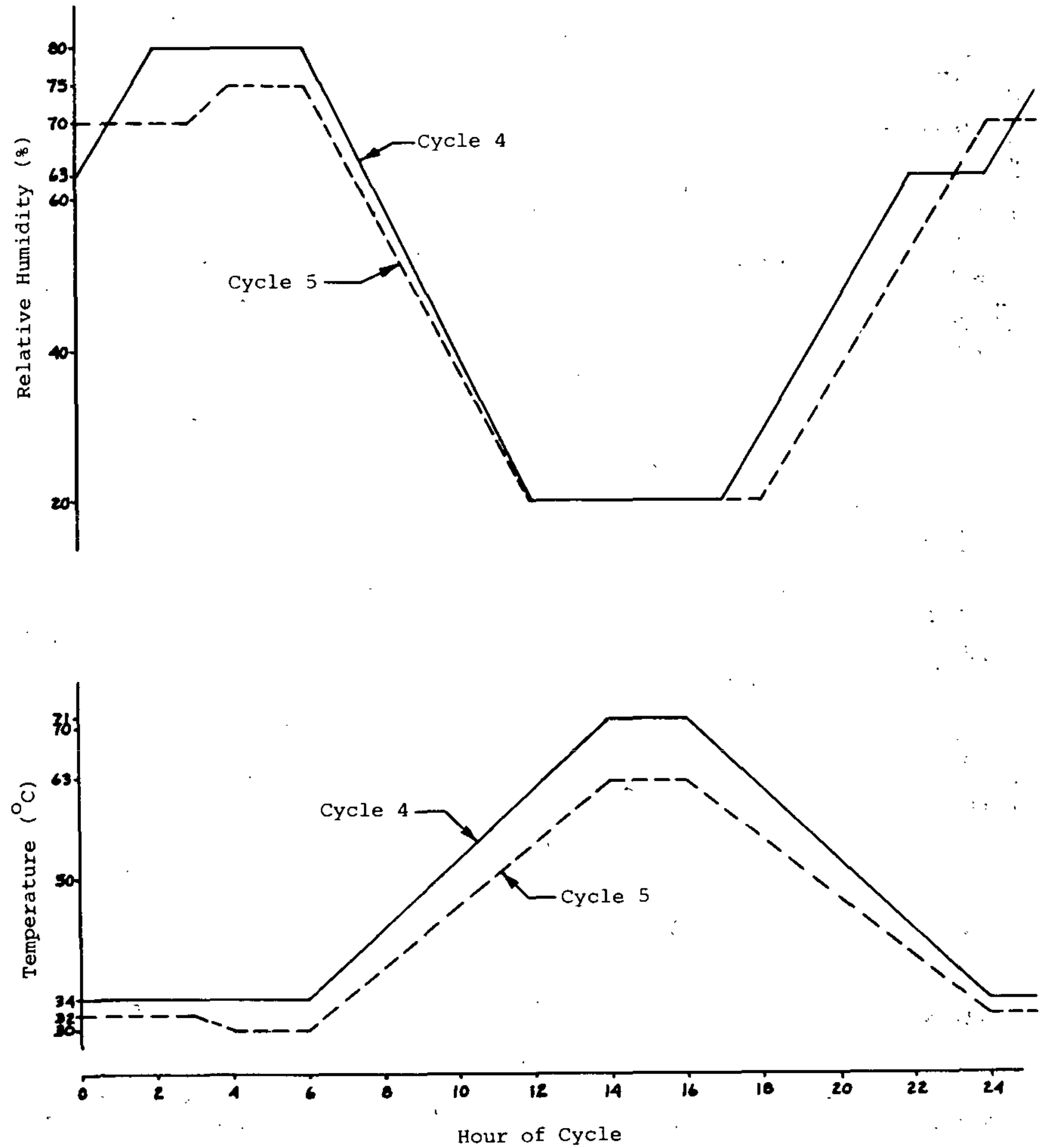

FIGURE 507.2-2. Induced temperature-humidity cycles.

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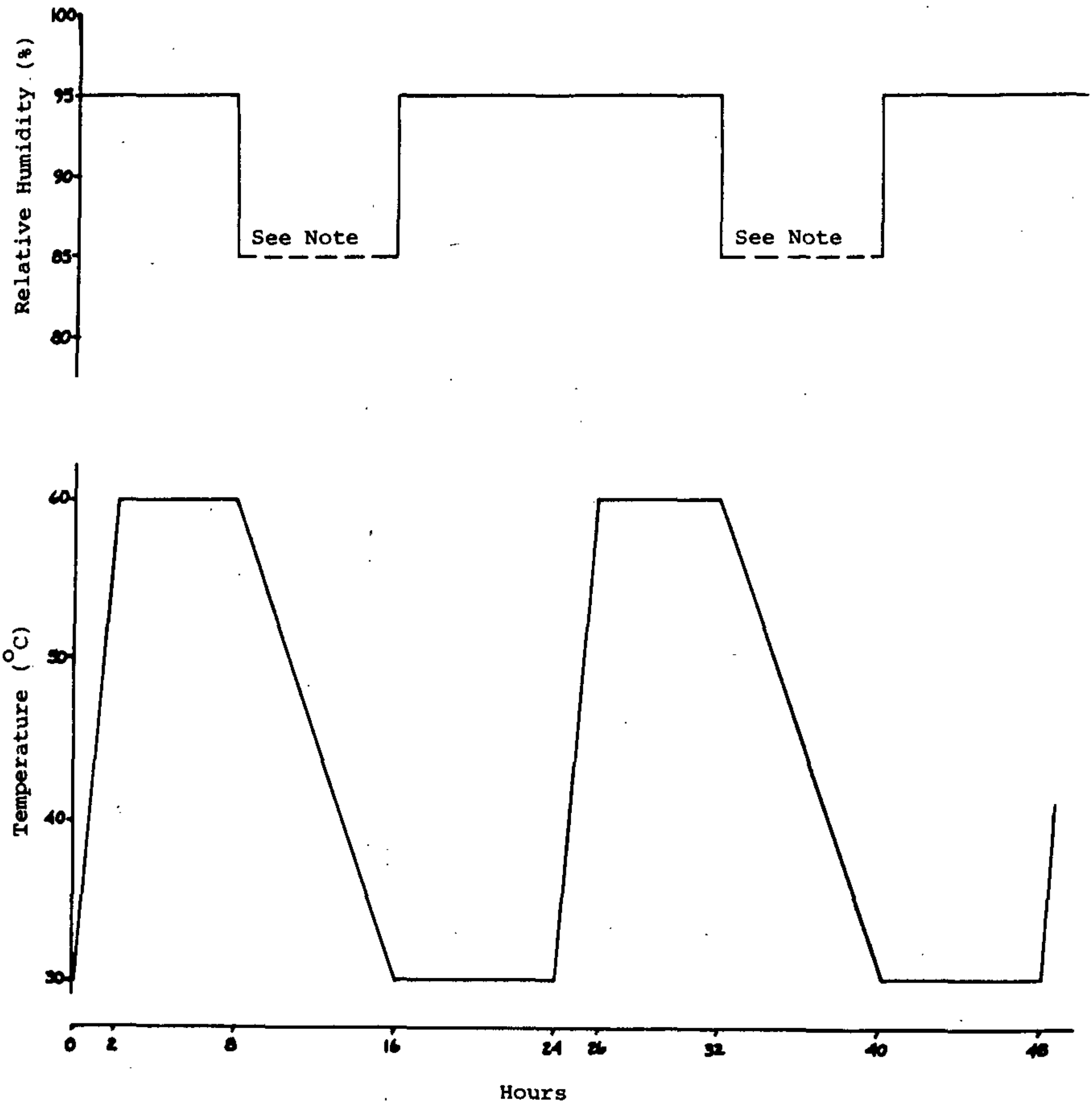

Note: Relative humidity maintained above 85% during temperature drops.

FIGURE 507.2-3. Aggravated temperature-humidity cycles.

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monthly, year round. The frequency decreases as the distance from the equator increases. The midlatitudes can experience these conditions several days a month for 2 to 3 months a year.

(3) Cyclic high humidity. Cyclic-high-humidity conditions are found in the open in tropical areas where solar radiation is a factor. In these areas, exposed items are subject to alternate wetting and drying, but the frequency and duration of occurrence are essentially the same as in the constant-high-humidity areas.

In addition to these three categories of natural high-humidity conditions, there are two cycles for induced conditions:

(4) Induced hot-humid. This condition exists when equipment in the hot-humid category receives heat from solar radiation with little or no cooling air.

(5) Induced variable high humidity. This condition exists when equipment in the variable-high-humidity category receives heat from solar radiation with little or no cooling air.

b. Test duration. The number of temperature-humidity cycles (total test time) is critical in achieving the purpose of the test. It is preferable to use the number of cycles given in the requirements documents for the materiel. If this information is not available, use the following guidance (see table 507.2-II):

NOTE: Any degradation that could contribute to failure of the test item during more extensive exposure periods or during exposure to other deployment environments, such as shock and vibration, shall be documented. Further, testing shall be extended for a sufficient period of time to evaluate the long-term effect of its realistic deployment duration (deterioration rate becomes asymptotic).

(1) Tests employing procedure I - Natural

(a) Hazardous test items. Hazardous test items are those in which any unknown physical deterioration sustained during testing could ultimately result in damage to materiel or injury or death to personnel when the test item is used. Hazardous test items will generally require longer test durations than nonhazardous test items to establish confidence in the test results. Twice the normal test duration is recommended (see table 507.2-II, cycles 1 through 3). Each test can be terminated prematurely after the quick-look level has been reached if the materiel has failed the visual or functional checkout.

(b) Nonhazardous test items. Nonhazardous test items should be exposed from 10 to 60 cycles of conditioning, depending upon the geographical area to which the materiel will be exposed (see table 507.2-II, cycles 1 through 3). Each test can be terminated prematurely after the quick-look level has been reached if it is determined that the test item has already failed the test and further testing is futile.

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TABLE 507.2-II. Test cycles (days).

	NATURAL			INDUCED	
Hazardous Items	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5
Normal Test Duration1/	20	120	90	30	30
Quick Look1/	7	15	12	7	7
Non-Hazardous Items					
Normal Test Duration1/	10	60	45	15	15
Quick Look1/	5	15	12	7	7

1/ Operational checks are required at least once every 5 days, but more frequent checks are recommended for early detection of potential problems.

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(2) Tests employing procedure II - Induced

(a) Hazardous test items. Hazardous test items will generally require longer tests than nonhazardous items to establish confidence in test results. Since induced conditions are much more severe than natural conditions, potential problems associated with high temperature/high relative humidity will be revealed sooner, and the results can be analyzed with a high degree of confidence. Consequently, hazardous test items should be exposed to extended periods (double the normal periods) of conditioning, depending upon the geographical category to which the materiel will be exposed (see table 507.2-II, cycles 4 and 5). Each test can be terminated after the quick-look level has been reached if the materiel has failed the visual or functional checkout or if deterioration is obvious.

(b) Nonhazardous test items. Induced conditions are much more severe than natural conditions and potential problems associated with high temperatures/high humidity will thus be revealed sooner, and the results can be analyzed, in most cases, with a high degree of confidence. Nonhazardous test items should be exposed to test durations as specified in table 507.2-II, cycles 4 and 5, depending upon the geographical category to which the materiel will be exposed. Each test can be terminated after the quick-look level has been reached if it has been determined that the test item has already failed the test and additional testing is futile, or if deterioration is obvious.

(3) Test employing procedure III - Aggravated. Based on past experience, a minimum of 10 cycles is recommended to reveal potential test item problems. For the test items incorporating seals to protect moisture-sensitive materials, e.g., pyrotechnics, longer test durations may be required.

(4) Quick-look. After a relatively short period of testing has elapsed, the test item may be given a visual inspection and operational checkout, and a decision may be made to continue or stop the test. The time after which a quick look can be made is different for each test cycle and is specified in table 507.2-II. Termination at this time (or at any time before completion of the specified test durations) should be considered if a failure or "no-test" is accepted. A complete test cycle is still required but is not recommended on the same test item.

c. Test item configuration. During performance of the temperature-humidity procedures of this method, the test item will be configured as specified below or as specifically outlined in the requirements documents. Test item configuration must be selected to reproduce, as closely as technically possible, the configuration that the test item would assume when deployed. The following configurations should be considered, but the worst-case situations are usually used.

(1) In its assigned shipping/storage container.

(2) Out of its shipping/storage container but not set up in its deployment mode.

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(3) In its operational mode (realistically or with restraints, such as with openings that are normally covered).

d. Additional guidelines. Review the requirements documents. Apply any additional guidelines necessary.

I-4 SPECIAL CONSIDERATIONS

I-4.1 Failure analysis. The failure of a test item to meet the requirements of the equipment specifications must be analyzed carefully, and related information must be considered, such as:

a. Degradation allowed in operating characteristics when the test item is exposed to the test levels of temperature and humidity.

b. Necessity for the use of special operating procedures or special kits during exposure to the test levels of temperature and humidity.

c. Deterioration of any kind in any area of the test item must be completely described and evaluated as a potential failure or failure mode.

NOTE: The failure mechanism of this test combines the effects of both high temperature and high relative humidity.

I-4.2 Summary of test information required. The following information is required in the test plan for adequate conduct of the tests of section II.

a. Test item configuration and orientation.

b. Test procedure and category.

c. Test cycle parameters.

d. Test item temperatures and relative humidities.

e. Test duration.

f. Any sealed areas to be opened during testing.

g. Additional guidelines.

I-5 REFERENCES

a. AR 70-38, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions, 1 August 1979.

b. MIL-STD-210, Climatic Extremes for Military Equipment, 15 December 1973.

c. Synopsis of Background Material for MIL-STD-210B, Climatic Extremes for Military Equipment. Bedford, MA: Air Force Cambridge Research Laboratories, 24 January 1974. DTIC number AD-780-508.

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d. Draft STANAG 2895, Climatic Environmental Conditions Affecting the Design of Materiel for Use of NATO Forces, 13 September 1977.

e. NATO STANAG 2831, Climatic Environmental Conditions Affecting the Design of Material for Use by NATO Forces Operating in a Ground Role.

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METHOD 507.2

HUMIDITY

SECTION II

II-1 APPARATUS

II-1.1 Test facility

a. The required apparatus consists of a chamber or cabinet, and auxiliary instrumentation capable of maintaining and continuously monitoring the required conditions of temperature, and relative humidity throughout an envelope of air surrounding the test item(s). (See General Requirements, 4.4.1.)

b. Unless otherwise specified, the test volume of the chamber or cabinet and the accessories contained therein shall be constructed and arranged in such a manner as to prevent condensate from dripping on the test item(s). The test volume shall be vented to the atmosphere to prevent the buildup of total pressure and prevent contamination from entering. Relative humidity shall be determined by employing either solid-state sensors whose calibration is not affected by water condensation or by an equivalent method, such as fast-reacting wet-bulb/dry-bulb sensors or dewpoint indicators. Sensors that are sensitive to condensation, such as the lithium chloride type, are not recommended for tests with high relative humidity levels. A data collection system separate from the chamber controllers shall be employed to measure test volume conditions. A recording device shall be mandatory for the data collection system. If charts are used, the charts shall be readable to within $\pm 0.6^{\circ}C$. If the wet-wick control method is approved for use, the wet bulb and tank shall be cleaned and a new wick installed before each test and at least every 30 days. Water used in wet-wick systems shall be of the same quality as that used to produce the humidity. Water bottle, wick, sensor, and other components making up relative humidity measuring systems shall be visually examined at least once every 24 hours during the test. The velocity of air flowing across the wet-bulb sensor shall be not less than 4.5 meters per second (900 feet per minute), and the wet wick shall be on the suction side of the fan to eliminate the effect of fan heat. The flow of air anywhere within the envelope of air surrounding the test item shall be maintained between 0.5 and 2 meters per second (98 to 394 ft/min).

c. Relative humidity within the envelope of air surrounding the test item shall be created by steam or water injection. Water used in either method shall be distilled, demineralized, or deionized and have a resistance of not less than 500,000 ohms. Its quality shall be determined at periodic intervals (not to exceed 15 days) to assure its acceptance. If water injection is used to humidify the envelope of air, the water shall be temperature conditioned before its injection to prevent upset of the test conditions and shall not be injected directly into the test section. Condensation developed within the chamber test volume during the test, shall be drained from the test volume and discarded.

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d. No material other than water shall be brought into physical contact with the test item(s) that will cause the test item(s) to deteriorate or that will affect the test results. No rust or corrosive contaminants or any material other than water shall be introduced into the chamber test volume.

e. Dehumidification, humidification, heating, and cooling of the air envelope surrounding the test item shall be achieved by methods that do not change the chemical composition of the air, water, or water vapor within that volume of air.

II-1.2 Controls

a. Test parameters. Unless otherwise specified in the requirements documents, temperature and relative humidity measurements made during the test shall be continuous if measurements are in analog form, or at intervals of 15 minutes or less if measurements are in digital form.

b. All instrumentation used with the selected test chamber shall be capable of meeting the accuracies, tolerances, etc., of General Requirements, 4.4.1 and 4.4.2.

II-1.3 Test interruption (See General Requirements, 4.5.4.)

a. Undertest interruptions. An undertest interruption may be best handled by keeping the chamber closed in an effort to maintain tolerances. As long as the tolerances are maintained, testing may be resumed by reestablishing the prescribed conditions and continuing from the point of the interruption. If an unscheduled interruption occurs that causes the test conditions to exceed the allowable tolerances toward standard ambient temperatures, the test must be reinitiated at the end of the last successfully completed cycle. Any test item failure that occurs shall be treated as a failure.

b. Overtest interruptions. An interruption that results in exposure of the test item to conditions more extreme than required by the requirements documents should be followed by a complete physical examination and operational check of the test item (where possible) before any continuation of testing. This is especially true where a safety problem could exist, such as with munitions. If a problem is discovered, the preferable course of action is to terminate the test and reinitiate testing with a new test item. If this is not done and test item failure occurs during the remainder of the test, the test results may be considered invalid. If no problem has been encountered, reestablish preinterruption conditions and continue from the point where the test tolerances were exceeded.

II-2 PREPARATION FOR TEST

II-2.1 Preliminary steps. Before initiating any testing:

a. Determine from the test plan which test procedures are required.

b. Determine from the test plan the temperature-humidity operation and storage requirements and corresponding temperature-humidity cycle(s) from table 507.2-I.

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c. The test chamber should be operated and its proper operation verified before the actual test is begun.

II-2.2 Pretest standard ambient checkout. All items require a pretest checkout at controlled ambient conditions (General Requirements, 4.4b) to provide baseline data. For procedure I, this checkout should be conducted before step 1. Conduct the pretest checkout as follows:

Step 1. Insert the test item into the test chamber.

Step 2. Prepare the test item in its required operational configuration in accordance with General Requirements, 4.5.2.

Step 3. Adjust the chamber to controlled ambient conditions (General Requirements, 4.4b) and maintain for 24 hours.

Step 4. Conduct a complete visual examination of the test item.

Step 5. Document the results.

Step 6. Conduct an operational checkout in accordance with the approved test plan.

Step 7. Record results for compliance with General Requirements, 4.5.1.

II-3 PROCEDURES. The following test procedures provide the necessary information concerning the test item in a warm-humid environment. Proceed to the first test procedure as specified in the test plan.

II-3.1 Procedure I - Natural

Step 1. With the test item in the chamber in its operational configuration, adjust the chamber conditions to those given in table 507.2-I for the time 0000 of the specified cycle.

Step 2. Perform a 24-hour cycle with the time-temperature-humidity values specified in the appropriate cycle or the approximated curves of figure 507.2-1.

Step 3. Perform an operational checkout of the test item at any convenient time in the 24-hour cycle during which test conditions are constant and at maximum temperature and RH levels. Operational checks should be conducted at least once every five cycles.

Step 4. Repeat steps 2 and 3 for the number of cycles indicated in table 507.2-II unless otherwise directed by the requirements documents.

Step 5. Adjust the chamber to controlled ambient conditions and maintain for at least 24 hours.

Step 6. Conduct a complete visual examination of the test item.

Step 7. Document the results.

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Step 8. Conduct an operational checkout of the test item in accordance with the approved test plan.

Step 9. Document the results.

Step 10. Compare these data with the pretest data.

II-3.2 Procedure II - Induced

Step 1. Insert the test item into the chamber.

Step 2. If specified, open any sealed areas (other than hermetically sealed) of the test item.

Step 3. Adjust the chamber temperature and relative humidity to those shown in the appropriate induced category of table 507.2-I for time 0000.

Step 4. Cycle the chamber air temperature and RH with time as shown in the appropriate cycle of table 507.2-I (or in the approximated curves of figure 507.2-2) through the 24-hour cycle.

Step 5. Repeat step 4 for the number of times indicated in table 507.2-II for the appropriate cycle unless other guidance is provided by the test plan.

Step 6. Adjust the chamber to controlled ambient conditions and maintain for 24 hours following stabilization of the test item.

Step 7. Conduct a complete visual checkout of the test item.

Step 8. Document the results.

Step 9. Put the test item in its normal operating configuration.

Step 10. Conduct a complete operational checkout of the test item.

Step 11. Document the results.

Step 12. Compare these data with the pretest data.

II-3.3 Procedure III - Aggravated (See figure 507.2-3.)

Step 1. Prepare the test item in accordance with General Requirements, 4.5.2, and perform the pretest standard ambient checkout.

Step 2. Gradually raise the internal chamber temperature to 60°C (140°F) and the relative humidity to 95% ± 5% over a period of 2 hours.

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

Step 4. Maintain 85% or greater relative humidity and reduce the internal chamber temperature in 8 hours to 30°C (86°F) and 95% ± 5% relative humidity.

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Step 5. Maintain the 30°C (86°F) and 95% ± 5% relative humidity for an additional 8 hours.

Step 6. Repeat steps 2, 3, and 4 for a total of 10 cycles (not less than 240 hours).

Step 7. Near the end of the fifth and tenth cycles, while still at 30°C (86°F) and 95% relative humidity, operate the test item and obtain and record results in accordance with General Requirements.

II-4 INFORMATION TO BE RECORDED

a. Previous test methods to which the test item has been subjected.

b. Results of each performance check (pre-, during, and post-test) and visual examination (and photographs, if applicable).

c. Length of time required for each performance check.

d. Procedure and test levels used.

e. Exposure durations.

f. Time versus temperature and humidity.

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METHOD 508.3

FUNGUS

SECTION I

I-1 PURPOSE. The purpose of the fungus chamber test is to assess the extent to which the test item will support fungal growth or how the fungal growth may affect performance or use of the test item.

I-2 ENVIRONMENTAL EFFECTS. Fungal growth impairs the functioning or use of equipment by changing its physical properties.

I-2.1 Detrimental effects. The detrimental effects of fungal growth are summarized as follows:

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

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

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

(b) Animal- and vegetable-based adhesives.

(c) Grease, oils, and many hydrocarbons.

(d) Leather.

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(2) Synthetic materials:

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

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

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

(d) Paints and varnishes which contain susceptible constituents.

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

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

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

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

I-2.2 Physical interference. Physical interference can occur as follows:

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

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

I-2.3 Health and aesthetic factors. Fungal growth on equipment can cause physiological problems (e.g., allergies) or be so esthetically unpleasant that the users will be reluctant to use the equipment.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS

NOTE: This test method should be applied at the end of the tailoring process described in section 4 of this standard.

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a. Application. Since microbial deterioration is a function of temperature and humidity and is an inseparable condition of hot-humid tropics and the midlatitudes, it must be considered in the design of all standard, general-purpose materiel (reference a). This method is used when an item is to be tested to determine if fungal growth will occur and, if so, how it will affect the use of the test item.

b. Restrictions. This test is designed to economically obtain data on the susceptibility of materiel. It should not be used for testing of basic materials since various other test procedures, including soil burial, pure culture, mixed culture, and plate testing, are available.

c. Sequence. (See General Requirements, 4.4.4.) This method should not be conducted after a salt fog test (method 509.2) or a sand and dust test (method 510.2). A heavy concentration of salt may affect the germinating fungal growth, and sand and dust can provide nutrients, thus leading to a false indication of the biosusceptibility of the test item.

d. Test variations. In addition to an optional operational test at the end of the fungus test, test variables include duration of test and test item configuration.

I-3.1 Test objectives. The primary objectives of the fungus test are to determine:

a. If fungi will grow on the test item (see II-3.1.2a for the types of fungi).

b. How rapidly fungi will grow on the test item.

c. How any fungal growth affects the test item.

d. To what extent the fungi will affect the mission of the test item.

e. If the test item can be stored effectively in a field environment.

f. If the test item is safe for use following fungal growth.

g. If there are simple reversal processes, e.g., wiping off fungal growth.

I-3.2 Choice of related test conditions. Once a determination has been made as to whether or not an operational requirement exists, the next decision must concern test duration and test item configuration.

a. Test duration. Twenty-eight days is the minimum test period to allow for fungal germination, breakdown of carbon molecules, and degradation of material. Since indirect effects and physical interference are not likely to occur in the relatively short time frame of the fungus test, extension of the exposure period to 84 days should be considered if a greater degree of certainty (less risk) is required in determining the existence or effect of fungal growth.

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

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

(2) Under realistic storage or use conditions.

(3) With restraints (such as with openings that are normally covered).

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

I-3.3 Choice of test fungi: Five species of test fungi are listed in II-3.1.2a. These organisms were selected because of their ability to degrade materials, their worldwide distribution, and their stability. They must be used in all method 508.3 tests.

a. Because the test item is not sterile before testing, other microorganisms will be present on the surfaces. When the test item is inoculated with the five test fungi, both these and the other organisms will compete for available nutrients. It is not surprising to see organisms other than the test fungi growing on the test item at the end of the test.

b. Additional species of fungi may be added to those required in this test method. However, if additional fungi are used, their selection shall be based on prior knowledge of specific material deterioration. For example, *Aureobasidium pullulans* can be employed because of its known specificity for degrading paints.

I-4 SPECIAL CONSIDERATIONS

I-4.1 Failure analysis

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

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

(1) The extent of growth on the component(s) supporting growth. Table 508.3-I can be used as a guide for this evaluation.

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

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

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

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c. Disturbance of any fungal growth must be kept to a minimum during the operational checkout.

d. Human factors effects must be evaluated.

I-4.2 Miscellaneous

a. This method is designed to provide optimal climatic conditions and all of the basic inorganic minerals needed for growth of the fungal species used in the test. The group of fungal species was chosen for its ability to attack a wide variety of materials commonly used in the construction of military equipment. Optional species may be added to the inoculum if required (see I-3.3).

b. This test must be performed by trained personnel at laboratories specially equipped for microbiological work.

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

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

e. The specified temperature range, 24° to 31°C (75° to 88°F), is most conducive to the growth of the test fungi.

f. Control items specified in II-3 are designed to:

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

(2) Establish the suitability of the chamber environment to support fungal growth.

I-4.3 Summary of test information required. The following information is required in the test plan for the adequate conduct of the tests of section II:

a. Test item configuration.

b. Test duration.

c. Optional pre- and post-test operational requirements.

d. Additional guidelines.

I-5 REFERENCES

a. AR 70-38, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions, Chapter 2, Climatic Criteria.

b. MIL-STD-210, Climatic Extremes for Military Equipment.

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TABLE 508.3-I. Microbial test evaluation scheme.

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

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METHOD 508.3

FUNGUS

SECTION II

II-1 APPARATUS

II-1.1 Test facility

a. The required apparatus consists of chambers or cabinets, together with auxiliary instrumentation capable of maintaining and monitoring the specific conditions of temperature and humidity, that comply with 4.4.1 and 4.4.2, General Requirements.

b. The chamber and accessories shall be constructed and arranged in such a manner as to prevent condensation from dripping on the test item.

c. The chamber shall be vented to the atmosphere to prevent the buildup of pressure.

II-1.2 Controls

a. Relative humidity shall be determined by employing either solid-state sensors whose calibration is not affected by water condensation or by an approved equivalent method such as fast-reacting wet-bulb/dry-bulb sensors. Lithium chloride sensors are not recommended because of their sensitivity to water.

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

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

(3) The wet- and dry-bulb sensors shall not be installed in the discharge side of any local fan or blower used to create the requirement of II-1.2a(2).

b. Provisions shall be made for controlling the flow of air throughout the internal test chamber space so that the air velocity shall be between 0.5 and 2 meters per second (98 to 394 ft/min).

c. Free circulation of air around the test item shall be maintained, and the contact area of fixtures supporting the test item shall be kept to a minimum. (See General Requirements, 4.5.2.)

d. Unless otherwise specified, the test chamber temperature and relative humidity shall be recorded continuously.

e. Readout charts shall be readable to within $\pm 0.6^{o}C$ ($\pm 1^{o}F$).

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f. The desired humidity shall be generated by using steam or water having not less than 500,000 ohms resistance.

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

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

g. Unless otherwise specified:

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

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

II-1.3 Test interruption. Every case of an interrupted test shall be examined individually in accordance with General Requirements, 4.5.4. Any deviation from this policy shall be explained in the test report. The fungus test, unlike other environmental tests, involves living organisms. If the test is interrupted, the fact that live organisms are involved must be considered.

a. If the interruption occurs during the first seven days of the test, the test should be restarted from the beginning with a new test item or a cleaned test item.

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

(1) Lowered temperature. A lowering of the test chamber temperature generally will retard fungal growth. If there is no evidence of mycological deterioration and the relative humidity has been maintained, reestablish the test conditions and continue the test from the point where the temperature fell below the prescribed tolerances.

(2) Elevated temperature. Elevated temperatures may have a drastic effect on fungal growth. A complete reinitiation of the test is required if:

(a) The temperature exceeds 40°C (104°F), or

(b) The temperature exceeds 31°C (88°F) for 4 hours or more, or

(c) There is evidence of deterioration of the fungal colonies on the control strips, or

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(d) The relative humidity drops below 50% during the period of elevated temperatures.

Otherwise, reestablish test conditions and continue the test from the point of interruption.

(3) Lowered humidity. A complete reinitiation of the test is required if:

(a) The relative humidity drops below 50%, or

(b) The relative humidity drops below 70% for 4 hours or more, or

(c) There is evidence of deterioriation of the fungal colonies on the control strips.

Otherwise, reestablish test conditions and continue the test from the point of interruption.

c. Cleaning. Although it is preferable to use a new test item, the same test item may be used. Any cleaning required must be conducted at least 72 hours before reinitiation and must be in accordance with II-3.2.1. New cotton control strips shall be placed in the test chamber, and both the test item and the controls will be reinoculated with the test fungi.

II-2 PREPARATION FOR TEST

II-2.1 Preliminary steps. Before initiating any testing, determine from the test plan:

a. The test duration(s).

b. The test item configuration(s).

c. Any other test variations.

II-2.2 Pretest checkout. All test items require a pretest checkout to provide baseline data. Conduct the checkout as follows:

Step 1. Prepare the test item in accordance with General Requirements, 4.5.2, and the required test item configuration as determined from the test plan.

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

Step 3. Document the results of step 2.

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

Step 5. Record results for compliance with General Requirements, 4.5.1.1.

II-3 PROCEDURES

II-3.1 Test preparation

II-3.1.1 Preparation of mineral salts solution

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

Potassium dihydrogen orthophosphate (KH_2PO_4)	0.7g
Potassium monohydrogen orthophosphate (K_2HPO_4)	0.7g
Magnesium sulphate heptahydrate ($MgSO_4 \cdot 7H_2O$)	0.7g
Ammonium nitrate (NH_4NO_3)	1.0g
Sodium chloride (NaCl)	0.005g
Ferrous sulfate heptahydrate ($FeSO_4 \cdot 7H_2O$)	0.002g
Zinc sulfate heptahydrate ($ZnSO_4 \cdot 7H_2O$)	0.002g
Manganous sulfate monohydrate ($MnSO_4 \cdot H_2O$)	0.001g
Distilled water	1000 ml

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

II-3.1.2 Preparation of mixed spore suspension

NOTE - PRECAUTIONS: Although the exact strains of fungi specified for this test are not normally considered to present a serious hazard to humans, certain people may develop allergies or other reactions. Therefore, standing operating procedures (SOPs) for safety should be employed. Also, the tests should be conducted by personnel trained in microbiological techniques.

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a. Using aseptic techniques, prepare the spore suspension containing at least the following test fungi:

Table 508.3-II. Test fungi.

Fungi	Fungus Sources Identification No.	
	USDA[1/]	ATCC[2/]
Aspergillus niger	QM 386	ATCC 9642
Aspergillus flavus	QM 380	ATCC 9643
Aspergillus versicolor	QM 432	ATCC 11730
Penicillium funiculosum	QM 474	ATCC 11797
Chaetomium globosum	QM 459	ATCC 6205

1/ US Department of Agriculture (SEA/FR)
Northern Regional Research Center
ARS Culture Collection
1815 North University Street
Peoria, Illinois 60604

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

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

b. Maintain pure cultures of these fungi separately on an appropriate medium such as potato dextrose agar, but culture *Chaetomium globosum* on strips of filter paper overlaid on the surface of mineral salts agar.

c. Prepare mineral salts agar by dissolving 15.0g of agar in a liter of the mineral salts solution described in II-3.1.1.

NOTE: Do not keep the stock cultures for more than 4 months at 6° ± 4°C (43° ± 7°F); after that time, prepare subcultures and use them for the new stocks.

d. Verify the purity of fungus cultures before the test.

e. Incubate subcultures used for preparing new stock cultures or the spore suspension at 30° ± 1.4°C (86° ± 2.5°F) for 14 to 21 days.

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

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

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

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

j. Filter the dispersed fungal spore suspension into a flask through a 6 mm layer of glass wool contained in a glass funnel.

NOTE: This process should remove large mycelial fragments and clumps of agar.

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

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

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

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

o. Perform a viability check for each organism in accordance with II-3.1.3a.

p. Blend equal volumes of the resultant spore suspension to obtain the final mixed spore suspension.

NOTE: The spore suspension may be prepared fresh. If not freshly prepared, it should be held at $6^\circ \pm 4^\circ C$ ($43^\circ \pm 7^\circ F$) for not more than 7 days.

II-3.1.3 Control items. Two types of control tests are required. Using the procedure of II-3.1.3a, verify the viability of the spore suspension and its preparation. By the procedure of II-3.1.3b, verify the suitability of the chamber environment.

a. Viability of spore suspension

(1) Before preparing the composite spore suspension, inoculate sterile potato dextrose agar plates with 0.2 to 0.3 ml of the spore suspension of each of the individual fungal species. Use separate potato dextrose agar plates for each species.

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

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

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(4) After the incubation period, check the fungal growth.

NOTE: The absence of copious growth of any of the test organisms over the entire surface in each container will invalidate the results of any tests using these spores.

b. Test chamber environment

(1) Prepare the following solution:

(a) 10.0g glycerol.

(b) 0.1g potassium dihydrogen orthophosphate (KH_2PO_4).

(c) 0.1g ammonium nitrate (NH_4NO_3).

(d) 0.025g magnesium sulfate heptahydrate ($MgSO_4 \cdot 7H_2O$).

(e) 0.05g yeast extract.

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

(g) 0.005g of a nontoxic wetting agent such as sodium dioctyl sulfosuccinate or sodium lauryl sulfate.

(h) HCl and NaOH to adjust the final solution pH to 5.3.

(2) Dip cotton strips conforming to MIL-T-43566A (Tape, Textile, Cotton, General Purpose, Natural or in Colors, Type 1a, Class 2, bleached, white flat construction) into the above solution. After dipping, remove the excess liquid from the strips and hang them to dry before placing them in the chamber and inoculating.

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

(4) These strips are installed and inoculated along with the test item to insure that proper conditions are present in the incubation chamber to promote fungal growth.

II-3.2 Test performance

II-3.2.1 Preparation for incubation

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

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

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c. Hold the test item in the operating chamber (at 24° to 31°C (75° to 80°F) and 95 ± 5% RH) for at least 4 hours immediately before inoculation.

d. Inoculate the test item and the cotton fabric chamber control items with the mixed fungal spore suspension by spraying the suspension on the control items and on and into the test item(s) (if not permanently or hermetically sealed) in the form of a fine mist from an atomizer or nebulizer. Personnel with appropriate knowledge of the test item should be available to aid in exposing its interior surfaces for inoculation.

NOTE: In spraying the test and control items with composite spore suspension, take care to cover all external and internal surfaces which are exposed during use or maintenance. If the surfaces are nonwetting, spray until drops begin to form on them.

e. Replace covers of the test items without tightening the fasteners (so that air can penetrate).

f. Start incubation immediately following the inoculation.

II-3.2.2 Incubation of the test item

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

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

c. After 7 days, inspect the growth on the control cotton strips to verify that the environmental conditions in the chamber are suitable for growth. At this time, at least 90 percent of the part of the surface area of each test strip located at the level of the test item should be covered by fungi. If it is not, repeat the entire test with the adjustments of the chamber required to produce conditions suitable for growth. Leave the control strips in the chamber for the duration of the test.

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

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II-3.2.3 Inspection. At the end of the incubation period, inspect the test item immediately. If possible, inspect the item within the chamber. If the inspection is conducted outside of the chamber and is not completed in 8 hours, return the test item to the test chamber or to a similar humid environment for a minimum of 12 hours. Except for hermetically sealed equipment, open the equipment enclosure and examine both the interior and exterior of the test item. Record the results of the inspection, including information listed in II-4, as applicable.

NOTE: Data shall be used for comparison with the data obtained in II-3.1.

II-3.3 Operation/usage (to be conducted only if required). If operation of the test item is required (e.g., electrical equipment), conduct the operation in the period as specified in II-3.2.3. Data shall be recorded for comparison with the baseline data obtained in II-3.1. Personnel with appropriate knowledge of the test item should be available to aid in exposing its interior surfaces for inspection and in making operation and use decisions.

II-4 INFORMATION TO BE RECORDED

a. Presence of evidence of fungal growth at the 7-day check and at the end of the test.

b. Location of fungi.

c. Narrative description of growth, including colors, areas covered, growth patterns, density of growth, and thickness of growth (and photographs, if necessary).

d. Test period.

e. Effect of fungi on performance or use:

(1) As received from chamber.

(2) After-use maintenance.

f. Test conditions.

g. Condition of test item at time of test.

h. All deviations from specified test conditions:

(1) Temperature.

(2) Humidity.

(3) Time.

(4) Air velocity.

(5) Other.

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i. Whether the test item arrived directly from the manufacturer.

j. Test item history (previous tests).

k. Physiological or aesthetic considerations.

l. Types of fungi used.

m. Results of performance checks:

(1) Pretest.

(2) Post-test.

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METHOD 509.2

SALT FOG

Page

SECTION I

I-1 PURPOSE. Salt fog climatic chamber tests are performed to determine the resistance of equipment to the effects of an aqueous salt atmosphere.

I-2. ENVIRONMENTAL EFFECTS. The effects of exposure of materiel to an environment where there is an aqueous salt atmosphere can be divided into three broad categories: corrosion effects, electrical effects, and physical effects.

I-2.1 Corrosion effects

a. Corrosion due to electrochemical reaction.

b. Accelerated stress corrosion.

c. Formation of acidic/alkaline solutions following salt ionization in water.

I-2.2 Electrical effects

a. Impairment of electrical equipment due to salt deposits.

b. Production of conductive coatings.

c. Corrosion of insulating materials and metals.

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I-2.3 Physical effects

a. Clogging or binding of moving parts of mechanical components and assemblies.

b. Blistering of paint as a result of electrolysis.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS

NOTE: This test method should be applied only after the end of the tailoring process described in section 4 of this standard.

a. Application. Salt is one of the most pervasive chemical compounds in the world. It is found in the oceans, the atmosphere, ground surfaces, and lakes and rivers. It is impossible to avoid exposure to salt. In coastal regions, this exposure is intensified; in a marine environment, the exposure reaches a maximum. As a consequence, all military materiel will be exposed to some form of salt during its life cycle that may affect its performance.

b. Restrictions

(1) The procedure in this method has deficiencies and limitations, such as:

(a) The procedure may not duplicate the effects of a marine atmosphere.

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

(c) It has not been demonstrated that withstanding the effects of this test guarantees that the test item will prove to be satisfactory under all corrosive conditions.

(d) This test has proven to be generally unreliable for comparing the service life of different materials or coating conditions.

(2) Salt fog may cause corrosion of susceptible materials. Humidity and fungus can also cause corrosion; however, their effects differ from salt fog effects and the tests are not interchangeable.

c. Sequence. (See General Requirements, 4.4.4.) The salt fog test procedure is potentially damaging to materiel. In most cases, the salt fog test should be conducted after other climatic tests, especially fungus and humidity (although it is generally inappropriate to conduct these tests on the same test sample). Sand and dust testing should follow salt fog testing.

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d. Test variations. Before conducting this test, determine any required variations of the test procedure. The choices for varying the test procedure are primarily limited to the test duration, cycling of exposure and drying periods, salt concentration, and test item configuration, as outlined in I-3.2.

I-3.1 Choice of test procedure. Procedure I should be used only as a screening test. Its primary value lies in testing coatings and finishes on materiel. In a relatively short period of time, the procedure can be used to locate potential problem areas, quality control deficiencies, design flaws, etc., that result from exposure to a salt atmosphere.

I-3.2 Choice of related test conditions

a. Salt concentration. Concentrations exceeding 20% are not uncommon, but a 5 ± 1% solution is recommended, since this has proven to have the most significant effect on material.

b. Test item configuration. The configuration of the test item during the exposure period of the salt fog test is an important factor in determining the effect of the environment on the test item. Unless otherwise directed, the test item shall be configured as it would be during its storage, shipment, or use. The following represent the most likely configurations that military equipment would assume when exposed to salt fog:

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

(2) Outside of its shipping/storage container but provided with an effective environmental control system that partly excludes the salt fog environment.

(3) Outside of its shipping/storage container and set up in its normal operating mode.

(4) Modified with kits for special application or to compensate for mating components that are normally present but are not used for this specific test.

c. Duration. A minimum exposure period of 48 hours is recommended, followed by a 48-hour drying period. The exposure period may be lengthened to provide a higher degree of confidence in the ability of the materials involved to withstand a corrosive environment.

d. Cycling. An alternative to the continuous salt fog exposure period is to subject the test item to alternating 24-hour periods of salt fog exposure and standard ambient (drying) conditions for a minimum of four 24-hour periods. This alternative provides more damage potential than does the continuous exposure.

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I-4 SPECIAL CONSIDERATIONS

I-4.1 Failure criteria. In addition to the failure criteria of General Requirements, 4.5.7, the following must be considered: Any corrosion must be analyzed for its immediate or potential effect on the proper functioning of the test item. Satisfactory operation following this test is not the sole criterion for pass/fail.

I-4.2 Summary of test information required. The following information is required in the test plan for the adequate conduct of the test of section II.

a. Test duration.

b. Test item configuration.

c. Cyclic conditions (if required).

d. Salt concentration if other than 5%.

e. Additional guidelines.

I-5 REFERENCES

a. AR 70-38, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions.

b. MIL-STD-210, Climatic Extremes for Military Equipment.

c. Army Materiel Command Pamphlet AMCP-706-116, Engineering Design Handbook, Environmental Factors.

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METHOD 509.2

SALT FOG

SECTION II

II-1 APPARATUS

II-1.1 Test facility. The apparatus used in performing the salt fog test in this method shall include:

a. A test chamber with:

(1) Supporting racks designed and constructed so that they will not affect the characteristics of the salt fog mist. All parts of the test chamber and the supporting racks that come into contact with the test item shall be constructed of material or will be buffered with material that will not cause electrolytic corrosion. Condensation shall not be allowed to drip on the test item. No liquid that comes in contact with either the exposure chamber or the test item shall return to the salt solution reservoir. The exposure chamber shall be properly vented to prevent pressure buildup.

(2) The capability to maintain temperatures in the exposure zone at 35°C (95°F). Satisfactory methods for controlling the temperature accurately are by housing the apparatus in a properly controlled constant-temperature room, by thoroughly insulating the apparatus and preheating the air to the proper temperature before the atomization, or by jacketing the apparatus and controlling the temperature of the water or the air used in the jacket. The use of immersion heaters within the chamber exposure area for the purpose of maintaining the temperature within the exposure zone is prohibited.

b. A salt solution reservoir made of material that is nonreactive with the salt solution, e.g., glass, hard rubber, or plastic.

c. A means for injecting the salt solution into the test chamber. Caution must be exercised to prevent clogging of the nozzles from salt buildup. Atomizers used shall be of such design and construction as to produce a finely divided, wet, dense fog. Atomizing nozzles and the piping system shall be made of material that is nonreactive to the salt solution. Suitable atomization has been obtained in chambers having a volume of less than 12 ft^3 under the following conditions:

(1) Nozzle pressure as low as practical to produce fog at the required rate.

(2) Orifices between 0.5 and 0.76 mm (0.02 and 0.03 inches) in diameter.

(3) Atomization of approximately 2.8 liters of salt solution per $0.28 m^3$ (10 ft^3) of chamber volume per 24 hours.

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When chambers with a volume considerably in excess of $0.34 m^3$ ($12 ft^3$), are used the conditions specified may require modification.

NOTE: A filter fabricated of noncorrosive materials similar to that shown in figure 509.2-1 shall be provided in the supply line and immersed in the salt solution reservoir as illustrated in figure 509.2-2.

d. Salt fog collection receptacles placed so that a clean receptacle 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 cm diameter) in an average test of at least 16 hours. A minimum of 2 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 the test item and will collect no drops of solution from the test item or other sources.

II-1.2 Controls

a. The salt solution shall be heated before injection into the test section to within ±6°C (±10°F) of the test section temperature at the time of injection.

b. All water used during the salt fog test(s) shall be from steam or distilled, demineralized, or deionized water with a resistance of not less than 500,000 ohms/cm.

c. Test section air circulation: Air velocity in test chambers designed for only procedure I shall be minimal (essentially zero).

II-1.3 Test interruptions. (See General Requirements, 4.5.4.)

a. Undertest interruptions. If an unscheduled test interruption occurs that causes the test conditions to exceed allowable tolerances toward standard ambient conditions, the test item should be given a complete visual examination, and a technical evaluation should be made of the impact of the interruption on the test results. The test must be restarted at the point of interruption and the test item restabilized at the test conditions.

b. Overtest interruptions. If an unscheduled test interruption occurs that causes the test conditions to exceed allowable tolerances away from standard ambient conditions, the test conditions should be stabilized to within tolerances and held at that level until a complete visual examination and technical evaluation can be made to determine the impact of the interruption on test results. If the visual examination or technical evaluation results in a conclusion that the test interruption did not adversely affect the final test results, or if the effects of the interruption can be nullified with confidence, pre-interruption conditions should be reestablished and the

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MIL-STD-810D

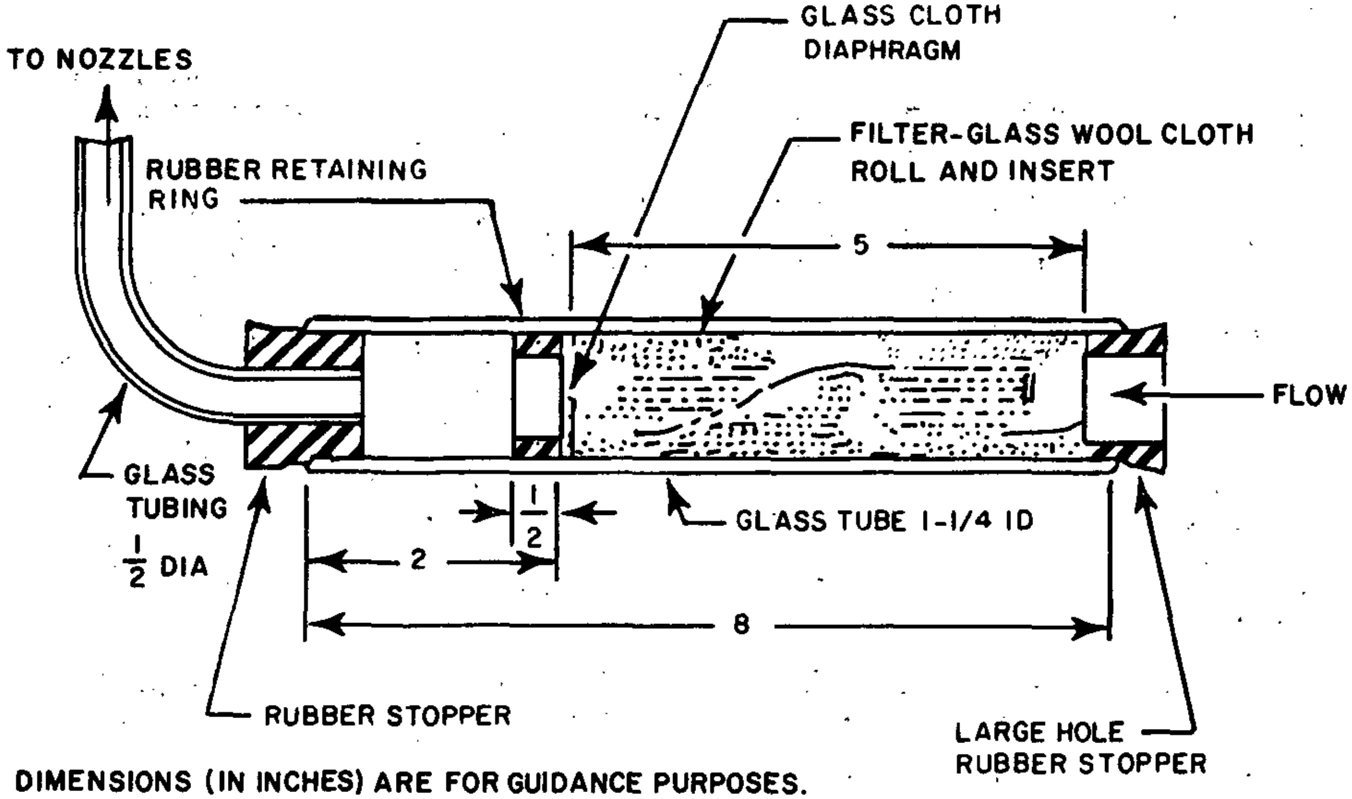

FIGURE 509.2-1. Salt solution filter.

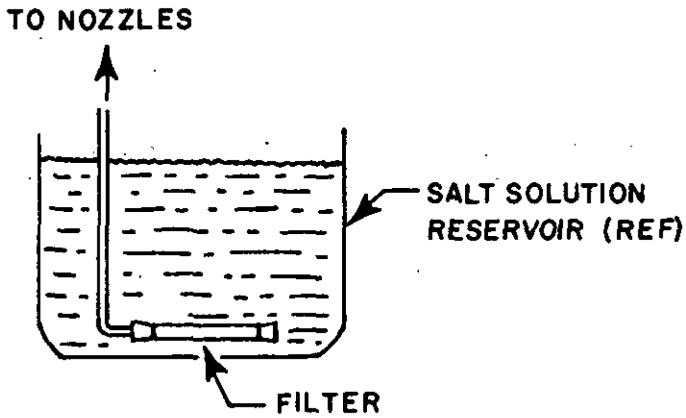

FIGURE 509.2-2 Location of salt solution filter.

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test continued from the point where the test tolerances were exceeded.

II-2 PREPARATION FOR TEST

II-2.1 Preliminary steps. Before initiating any testing, determine the required test conditions (see I-3.2).

II-2.2 Preparation of salt solution. The salt used for this test shall be sodium chloride containing (on a dry basis) not more than 0.1 percent sodium iodide and not more than 0.5 percent total impurities. Unless otherwise specified, a 5 ± 1 percent solution shall be prepared by dissolving 5 parts by weight of salt in 95 parts by weight of water. The solution shall be adjusted to, and maintained at, a specific gravity (figure 509.2-3) by using the measured temperature and density of the salt solution. Sodium tetraborate (borax) may be added to the salt solution as a pH stabilization agent in a ratio not to exceed 0.7g sodium tetraborate to 75 liters of salt solution. The pH of the salt solution, as collected as fallout in the exposure chamber, shall be maintained between 6.5 and 7.2 with the solution temperature at +35°C (+95°F). Only diluted chemically pure hydrochloric acid or chemically pure sodium hydroxide shall be used to adjust the pH. The pH measurement shall be made electrometrically or colorimetrically.

II-2.3 Chamber operation verification. Unless the chamber has been used within 5 days, immediately before the test, and with the exposure chamber empty, adjust all test parameters to those required for the test. Maintain these conditions for one 24-hour period. Continuously monitor all test parameters to verify that the test chamber is operating properly.

II-2.4 Pretest standard ambient checkout. All items require a pretest checkout at room ambient conditions to provide baseline data. Conduct the checkout as follows:

Step 1. Prepare the test item in its required configuration in accordance with General Requirements, 4.5.2.

Step 2. Record the room ambient conditions.

Step 3. Conduct a complete visual examination of the test item with attention to:

a. High-stress areas.

b. Areas where dissimilar metals are in contact.

c. Electrical and electronic components - especially those having closely spaced, unpainted, or exposed circuitry.

d. Metallic surfaces.

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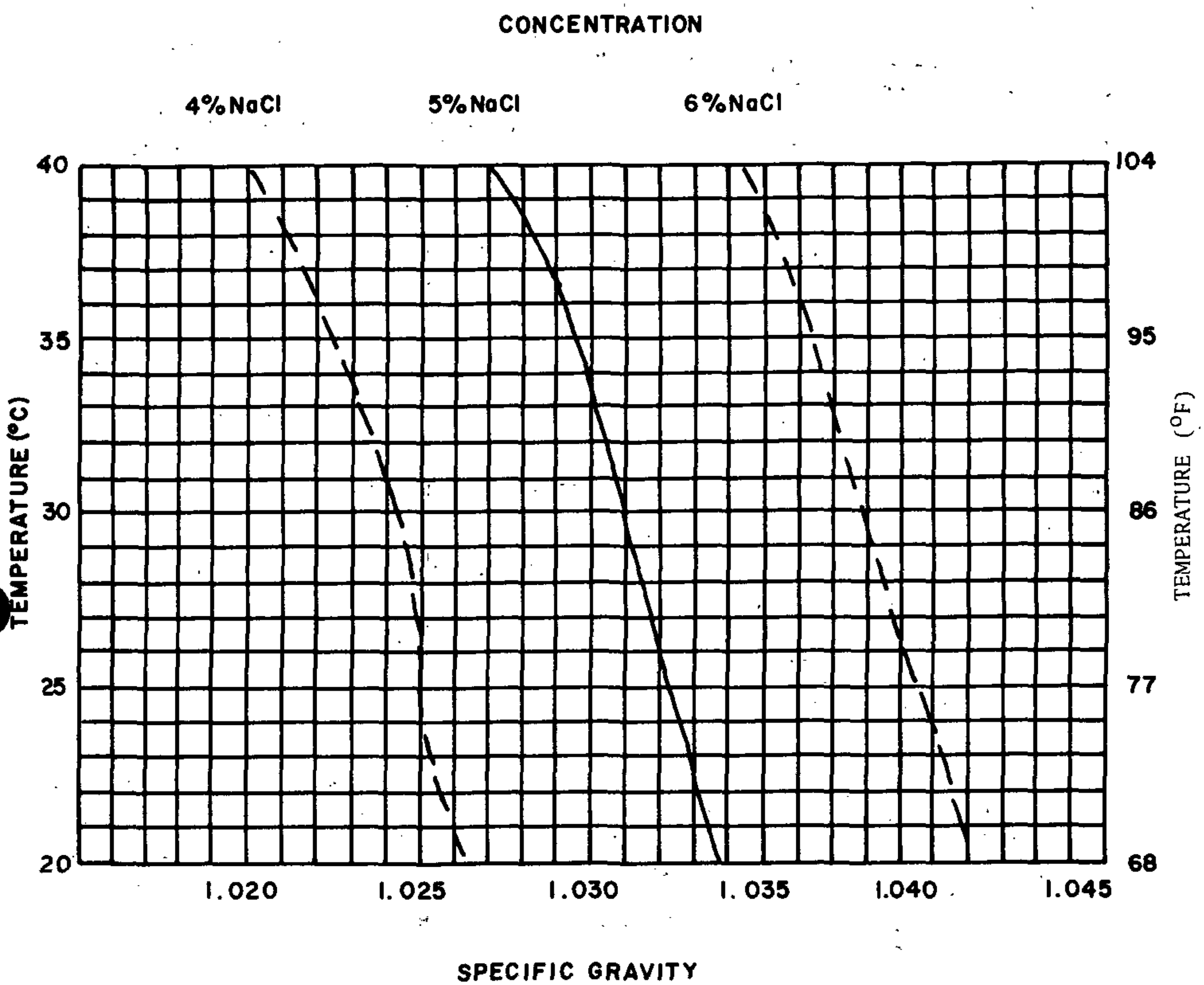

FIGURE 509.2-3 Variations of specific gravity of salt (NaCl) solution with temperature.

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e. Enclosed volumes where condensation has occurred or may occur.

f. Components or surfaces provided with coatings or surface treatments for corrosion protection.

g. Cathodic protection systems; mechanical systems subject to malfunction if clogged or coated with salt deposits.

h. Electrical and thermal insulators.

NOTE: Partial or complete disassembly of the test item should be considered if a complete visual examination is required. Care must be taken not to damage any protective coatings, etc.

Step 4. Document the results. (Use photographs, if necessary.)

Step 5. Conduct an operational checkout in accordance with the approved test plan.

Step 6. Record the results for compliance with General Requirements, 4.5.1.1.

Step 7. If the test item meets General Requirements, the approved test plan, or other applicable documents, proceed to step 1 of the test procedure below. If not, resolve any problems and restart the pretest standard ambient checkout at the most reasonable step above.

II-2.5 <u>Preparation of the test item</u>

a. The test item shall be given a minimum of handling, particularly on the significant surfaces, and will be prepared for test immediately before exposure. Unless otherwise specified, test items shall be free of surface contamination such as oil, grease, or dirt, which could cause a water break. The cleaning methods shall not include the use of corrosive solvents, solvents which deposit either corrosive or protective films, or abrasives other than a paste of pure magnesium oxide. Test items having an organic coating shall be cleaned with a solvent.

b. Arrange the test item configuration as specified in the test plan.

c. Insert the test item into the test chamber (General Requirements, 4.5.2).

II-3 <u>PROCEDURE I - AGGRAVATED SCREENING</u>

Step 1. Adjust the test chamber temperature to 35°C (95°F) and condition the test item for at least 2 hours before introducing the salt fog.

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Step 2. Continuously atomize a salt solution of a composition as given in II-2.2 into the test chamber for a period of 48 hours or as specified in the test plan.1/ During the entire exposure period, the salt fog fallout rate and pH of the fallout solution shall be measured at least at 24-hour intervals.2/ Fallout shall be between 0.5 and 3 ml/80cm^2/hr.

Step 3. Store the test item in a standard ambient atmosphere for 48 hours, or as specified in the equipment specification, for drying.

Step 4. At the end of the drying period, unless otherwise specified, the test item shall be operated and the results documented for comparison with pretest data.

Step 5. The test item shall be visually inspected in accordance with the guidelines given in II-2.4. If necessary to aid in examination, a gentle wash in running water not warmer than 38°C (100°F) may be used.

II-4 INFORMATION TO BE RECORDED

a. Previous test methods to which the test item was subjected.

b. Results of each visual examination and performance checkout performed on the test item.

c. Areas of the test item visually and functionally examined and an explanation of their inclusion.

d. Areas of the test item not visually and functionally examined and an explanation of their exclusion.

e. Test chamber operational information (interruptions, time schedule, etc.).

f. Test variables:

(1) Salt solution pH.

(2) Salt solution specific gravity.

1/ Cycling periods of 24 hours each (wet and dry) may be required instead of constant wetting for 48 hours or longer.

2/ More frequent intervals are recommended. If fallout quantity requirements are not met, that interval must be repeated.

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(3) Salt solution fallout rate ($ml/cm^2/hr$).

(4) Resistance of initial water and type of water.

g. Preliminary failure analysis.

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METHOD 510.2

SAND AND DUST

Page

SECTION I

I-1 PURPOSE. This test method is divided into two procedures. The small-particle procedure (dust, fine sand) is performed to ascertain the ability of equipment to resist the effects of dust particles which may penetrate into cracks, crevices, bearings, and joints. The blowing sand test is performed to determine whether materiel can be stored and operated under blowing sand (149 to 850 μm particle size) conditions without experiencing degradation of its performance, effectiveness, reliability, and maintainability due to the abrasion (erosion) or clogging effect of large, sharp-edged particles.

I-2 ENVIRONMENTAL EFFECTS. An airborne sand and dust environment, associated most often with the hot-dry regions of Earth, exists seasonally in other regions. Naturally occurring sand and dust storms are an important factor in the deployment of materiel, but with the increased mechanization of military operations, these cause less of a problem than does sand and dust associated with man's activities. Examples of some problems that could occur as a result of exposure of materiel to blowing sand and dust are:

a. Abrasion of surfaces.

b. Penetration of seals.

c. Erosion of surfaces.

d. Degradation of electrical circuits.

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e. Clogging of openings and filters.

f. Physical interference with mating parts.

g. Fouling of moving parts.

h. Exothermal reaction (thermite effects) of clay particles (with aluminum oxide) at high temperatures, producing heat which could cause high-temperature corrosion and produce extremely hard, erosive particles.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS

NOTE: This test method should be applied at the end of the tailoring process described in section 4 of this standard.

a. Application. This method is applicable to all mechanical, electrical, electronic, electrochemical, and electromechanical devices for which exposure to the effects of a dry sand- or dust-laden atmosphere is anticipated.

b. Restrictions. This method does not apply to any chemical reaction that may occur in the presence of moisture.

c. Sequence. (See General Requirements, 4.4.) This method can produce a dust coating on, or severe abrasion of, a test item, which could influence the results of other MIL-STD-810 methods such as Fungus (method 508.2), Humidity (507.2), and Salt Fog (509.2). Therefore, this method should be applied following such tests. Additionally, this method should follow method 501.2 (High Temperature), since the temperature derived is used in this method.

d. Test variations. The variables associated with the blowing sand and dust test procedures include:

(1) Air velocity.

(2) Temperature.

(3) Test item configuration and orientation.

(4) Sand and dust composition.

(5) Sand and dust concentration.

(6) Test duration.

(7) Additional guidelines as appropriate.

I-3.1 Choice of test procedures. Two test procedures are included in this method: Blowing Dust and Blowing Sand. Based on the test item's deployment exposure, and function, determine whether both procedures are applicable.

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I-3.2 Choice of related test conditions. After choosing the test procedure, choose the values of the test variables and decide whether or not the test item is to operate during the test. The specific test conditions to be used in these tests should be based on field data (General Requirements, 4.3). If field data are not available, the test conditions should preferably be selected from the applicable requirements documents. If this information is not available, the following may be used as guidance.

a. Temperature. Unless otherwise specified, these tests should be conducted at the operating or storage temperature obtained from the temperature response of the test item from method 501.2.

b. Relative humidity. High levels of relative humidity may cause caking of dust particles. Consequently, the test chamber RH should not exceed 30%.

c. Air velocity

(1) Blowing dust. The air velocities used in the blowing dust (small particle) test procedure include a minimum air velocity to maintain test conditions (1.5 m/s or 300 ft/min) and a higher air velocity typical of desert winds (8.9 m/s or 1750 ft/min) that shall be used for most tests. Other air velocities may be used, but test chamber limitations must be considered. Excessively high air velocities may lessen the caking or clogging caused by lower air velocities.

(2) Blowing sand. An air velocity in the range of 18 to 29 m/s (3540 to 5700 ft/min) is suggested for most blowing sand applications.1/ Winds of 18 m/s that would blow the large particles are common, and gusts up to 29 m/s are not uncommon. Other air velocities may be used if the induced flow velocity around the equipment in its field application is known.

d. Sand and dust composition.

(1) The small-particle (blowing dust) procedure may be conducted with either of the following dust compositions, by weight.

(a) Red china clay is common throughout much of the world and contains:

$CaCO_3$, $MgCO_3$, CaO, MgO, Na_2O, TiO_2, etc.	5%
Ferric oxide (Fe_2O_3)	10 ± 5%
Aluminum oxide (Al_2O_3)	20 ± 10%
Silicon dioxide (SiO_2)	remaining percentage

1/ From MIL-STD-210.

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(b) Silica flour has been widely used in dust testing and contains 97 to 99 percent (by weight) silicon dioxide (SiO_2). The following size distribution applies to both red china clay and silica flour:

100 percent shall pass through a 100 mesh screen.

98 ± 2 percent shall pass through a 140 mesh screen.

90 ± 2 percent shall pass through a 200 mesh screen.

75 ± 2 percent shall pass through a 325 mesh screen.

(2) Unless otherwise specified, the sand suggested to be used in the large-particle test is silica sand[2/] (at least 95% by weight SiO_2). The amount 1.0% ± 0.5% of the sand shall be retained by a 20 mesh screen (850 µm), 1.7% ± 0.5% by a 30 mesh screen (590 µm), 14.8% ± 1% by a 40 mesh screen (420 µm), 37.0% ± 1% by a 50 mesh screen (297 µm), 28.6% ± 1% by a 70 mesh screen (210 µm), 12.7% ± 1% by a 100 mesh screen (149 µm), and 5.2% ± 1% shall pass a 100 mesh screen. The sand shall be of subangular structure with a mean Krumbein number (roundness factor) equal to 0.2 and a hardness factor of 7 mohs.

e. Sand and dust concentrations

(1) The dust concentration for the blowing dust test shall be maintained at 10.6 ± 7 g/m^3 (0.3 ± 0.2 g/ft^3) unless otherwise specified. This figure is not unrealistic and is used because of the limitations of most chambers.

(2) The sand concentrations[3/] shall be as follows unless otherwise specified.

(a) For test items likely to be used close to aircraft (such as helicopters) operating over unpaved surfaces, 2.2 ± 0.5 g/m^3 (0.0623 ± 0.015 g/ft^3).

(b) For test items never used or never exposed close to operating aircraft, but which may be found near operating surface vehicles, 1.1 ± 0.25 g/m^3 (0.033 ± 0.0075 g/ft^3).

(c) For test items that will be subjected only to natural conditions, 0.177 g/m^3 (0.0065 g/ft^3).

f. Test item configuration. The configuration of the test item must reproduce, as closely as technically possible, the configuration that it would assume during storage or use, such as:

2/ Naval Weapons Center Large Particle Blowing Sand Procedure.

3/ MIL-STD-210.

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

(2) Protected or not protected.

(3) Deployed realistically or with restraints, such as with openings that are normally covered.

g. Orientation. The test item should be so oriented with respect to the blowing sand that the most vulnerable surface(s) faces the blowing sand. The test item may be reoriented at 90-minute intervals.

h. Duration

(1) For blowing sand tests, 90 minutes per face is considered to be a minimum (see I-3.2g).

(2) For blowing dust tests, 6 hours at 23°C (73°F) and 6 hours at the high storage or operating temperature are required. Additionally, sufficient time must be allowed at the low air velocity to stabilize the test item at the higher temperature.

NOTE: The period of time that the test item is exposed to the environmental conditions may be as significant as the conditions themselves. The length of time spent at the extreme conditions of each procedure should be at least long enough to insure stabilization of the test item at the specified conditions.

i. Operation during test. Operation of the test item during the test period should be based on the use requirements of the specific test item. For example, environmental control equipment would be operated while exposed to extreme ambient environments, whereas certain equipment, although exposed to severe environments, might be operated only in an environmentally controlled shelter. If operation of the test item during the test is required by the requirements document, the test plan shall contain a schedule describing the time periods of operation, the settings of controls, and the types and amounts of stresses to be placed on the test item during testing. This schedule shall contain at least one 10-minute period of continuous operation of the test item during the last hour of the test.

I-4 SPECIAL CONSIDERATIONS

I-4.1 Failure analysis. The failure of a test item to meet the requirements of the equipment specification must be analyzed, and related information must be considered, such as:

a. Degradation allowed in operating characteristics while at the extreme conditions.

b. Necessity for use of special operating procedures or special kits during extreme conditions.

c. The test item shall be considered to have failed the dust (fine sand) test when:

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(1) Dust has penetrated the test item in sufficient quantity to cause binding or blocking of moving parts, nonoperation of contacts or relays, formation of electrically conductive bridges with resulting shorts, clogging, or the accumulation of dust which will act as a nucleus for the collection of water vapor.

(2) The performance results obtained in accordance with the test plan are not within the tolerance limits established.

d. The test item shall be considered to have failed the large-particle test when:

(1) Abrasion of the test item exceeds the amount described in its requirements document.

(2) The test item does not perform safely or operate adequately as described in its requirements document.

NOTE: The test plan shall contain procedures for determining the test item's degradation due to abrasion. These procedures shall describe parameters (such as amount of wear or loss of weight) or observable attributes (such as change of shape) which, if not within specified limits, are indications that the test item has failed because of abrasion effects. The permissible tolerances of the parameters and attributes shall be provided.

I-4.2 Summary of test information required. The following information is required in the test plan for the to adequate conduct of the tests of section II.

a. Test procedure.

b. Test temperature.

c. Relative humidity.

d. Air velocity.

e. Sand or dust composition.

f. Sand or dust concentration.

g. Test item configuration.

h. Operational requirements.

i. Test item orientation and time of exposure per orientation.

j. Additional guidelines.

I-5 REFERENCES

a. Hafer, Carl A., A Survey and Study of the Factors Which Affect the Dust Environment Created by a Vehicle Operating Over Unsurfaced Terrain, Southwest Research Institute, Contract DA-23-072-ORD-1210 final report.

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b. Kuletz, Edward, and Schafer, Howard, Survey and Study on Sand and Dust, Naval Weapons Center Report NWC TP5170, August 1971.

c. The Dust Environment and Its Effects on Dust Penetration. WADC TR 56-556. DTIC number AD-110-472.

d. MIL-STD-210, Climatic Extremes for Military Equipment, 15 December 1973.

e. Synopsis of Background Material for MIL-STD-210, Climatic Extremes for Military Equipment. Bedford, MA: Air Force Cambridge Research Laboratories, January 1974. DTIC number AD-780-508.

f. Industrial Ventilation, A Manual of Recommended Practice, Committee on Industrial Ventilation, P.O. Box 16153, Lansing, MI 48901.

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METHOD 510.2

SECTION II

SAND AND DUST

II-1 APPARATUS

II-1.1 Test facility

II-1.1.1 Blowing dust

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

WARNING NOTE: Silica flour may present a health hazard. When using silica flour, assure that the chamber is functioning properly and not leaking; if a failure of containment is noted and people might have been exposed, air samples should be obtained and compared to the current threshold limit values of the American Conference of Government and Industrial Hygienists. Chamber repair and/or other appropriate action should be taken before continuing use of the chamber. Care should be taken during all steps where exposure of people to the silica dust is possible.

b. The dust used in this test shall be as outlined in I-3.2d(1).

II-1.1.2 Blowing sand

a. The required apparatus consists of a chamber or cabinet, together with necessary air conditioning and circulation equipment with its auxiliary control instrumentation, sand storage and moving equipment, and sand concentration measuring equipment, capable of maintaining and continuously monitoring the required conditions throughout an envelope of air surrounding the test item(s). (See General Requirements, 4.4.1.) Figures 510.2-1 and 510.2-2 are schematic diagrams of typical facilities for this test.

b. A data collection system, separate from the chamber controllers, shall be employed to measure test space conditions. Readout charts shall be readable to within at least 0.6°C (1°F).

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c. Dehumidification, heating, and cooling of chamber test volume air for control of test conditions shall be achieved by methods that do not alter the chemical composition of the air, sand, or water vapor within the chamber test volume air.

d. Test facility design considerations.

(1) The vibratory or screw type sand feeder shall be controlled to emit the sand at the specified concentrations. The feeder shall be located in such a manner as to insure that the sand is uniformly in suspension in the air stream when it strikes the test item, to simulate the same effects as in the field.

NOTE: Uniform sand distribution is usually easier to obtain when the sand-air mixture is directed downward, as in figure 510.2-1.

(2) Because of the extremely abrasive characteristics of blowing sand at high velocity, it is not recommended that the sand be recirculated through the fan or air conditioning equipment. Instead, it should be separated from the air downstream from the test chamber in a sand separator, collected in a separate receiver, and reintroduced into the sand tank or hopper. The fan should recirculate only the sand-free conditioned air.

NOTE: The sand collected in the separator may be reused for other tests if, after analysis, it still conforms to the requirements of I-3.2d(2) of this method.

II-1.2 <u>Controls</u>

a. <u>Test parameters</u>. Unless otherwise specified in the requirements document, temperature and relative humidity measurements made during testing shall be continuous if measurements are in analog form, or at intervals of one every 15 minutes or less if measurements are in digital form. All instrumentation used with the test chamber shall be capable of meeting the accuracies, tolerances, etc., of General Requirements, 4.4.1 and 4.4.2. Any significant change of the test item temperature or chamber conditions shall result in the test item being reestablished at the required environmental conditions before continuation.

b. <u>Relative humidity</u>. Relative humidity in the test section shall be less than 30 percent throughout the conduct of the test.

c. <u>Test variables</u>. The test variables (temperature, air velocity, and dust concentration) shall be continuously monitored during the test. Humidity shall be verified just before or during each test.

II-1.3 <u>Test interruption</u>. (See General Requirements, 4.5.4.)

a. <u>Undertest interruption</u>. The abrasion, penetration, and collection of dust are cumulative effects that are not affected by interruption. The test item shall be reestablished at the prescribed temperature and the test continued from the point of interruption.

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b. Overtest interruption. Any interruption that results in more extreme exposure of the test item than required by the equipment specifications should be followed by a complete physical examination and operational check (where possible) before continuation of testing. If a problem is encountered, the test should be reinitiated with a new test item.

II-2 PREPARATION FOR TEST

II-2.1 Preliminary steps. Before starting any test:

a. Determine from the test plan which test procedure is required.

b. Determine from the test plan the test variables to be used.

c. Operate the test chamber without the test item to make sure it is working properly.

II-2.2 Pretest standard ambient checkout. All test items require a pretest checkout at standard ambient conditions to provide baseline data. Conduct the pretest checkout as follows:

Step 1. Position the test item in the test chamber as near the center of the test section as practicable. The test item shall have a minimum clearance of 15 cm (6 inches) from any wall of the test chamber and from any other test item (if more than one item is being tested). Orient the test item so as to expose the most critical or vulnerable parts to the sand or dust stream.

NOTE: The orientation of the test item may be changed during the test if required by the test plan.

Step 2. Prepare the test item in its operational configuration in accordance with General Requirements, 4.5.2.

Step 3. Stabilize the test item at standard ambient conditions (General Requirements, 4.4a).

Step 4. Conduct a complete visual examination of the test item with special attention to sealed areas and minute openings.

Step 5. Document the results.

Step 6. Conduct an operational checkout in accordance with the approved test plan.

Step 7. Record results for compliance with General Requirements, 4.5.1.

Step 8. If the test item operates satisfactorily, proceed to step 1 of the test procedure. If not, resolve the problem and restart at step 1 of pretest checkout.

II-3 PROCEDURES

II-3.1 Procedure I - Blowing dust. The following test procedure provides the basis for collecting the necessary information concerning the test item in a dust-laden environment.

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Step 1. With the test item in the chamber, adjust the test section temperature to 23°C (73°F) and the relative humidity to less than 30%. (Maintain less than 30% relative humidity throughout the test.)

Step 2. Adjust the air velocity to the required value, determined from the test plan.

Step 3. Adjust the dust feed control for a dust concentration of 10.6 ± 7 g/m^3 (0.3 + 0.2 g/ft^3).

Step 4. Maintain the conditions of steps 1 through 3 for at least 6 hours.

Step 5. Stop the dust feed, reduce the test section air velocity to that required to maintain the climatic conditions, and adjust the temperature to that determined from the test plan.

Step 6. Maintain the step 5 conditions at least until stabilization of the test item temperature occurs or for up to 16 hours.

Step 7. Adjust the air velocity to that used in step 2 and restart the dust feed to maintain the dust concentration as in step 3.

Step 8. If required, operate the test item in accordance with the approved test plan. Continue the exposure for at least 6 hours.

Step 9. Turn off all chamber controls and allow the test item to return to standard ambient conditions.

Step 10. Remove accumulated dust from the test item by brushing, wiping, or shaking, taking care to avoid introduction of additional dust into the test item. Do not remove dust by either air blast or vacuum cleaning.

Step 11. Operate the test item in accordance with the approved test plan.

Step 12. Document the results.

Step 13. Inspect the test item giving special attention to bearings, grease seals, lubricants, etc.

Step 14. Document the results.

II-3.2 <u>Procedure II - Blowing sand</u>

Step 1. Adjust the chamber temperature to the high operating temperature of the test item and maintain until temperature stabilization of the test item is achieved.

Step 2. Adjust the air velocity to that required by the test plan.

Step 3. Adjust the sand feeder to obtain the sand concentration specified in the test plan, depending upon the application of the test item.

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Step 4. Maintain the conditions of Steps 1 through 3 for the duration specified in the test plan.

Step 5. If operation of the test item during the test is required, perform an operational test of the item during the last hour of the test and document the results. If not, proceed to step 6.

Step 6. Turn off all chamber controls and allow the test item to return to standard ambient conditions. Remove accumulated sand from the test unit by brushing, wiping, or shaking, taking care to avoid introduction of additional sand into the test unit.

Step 7. Conduct an operational checkout of the test item in accordance with the approved test plan.

Step 8. Document the results.

Step 9. Visually inspect the test item looking for abrasion and clogging effects and any evidence of sand penetration.

Step 10. Compare these data with the pretest data.

II-4 <u>INFORMATION TO BE RECORDED</u>.

a. Previous test methods to which the specific test item has been subjected.

b. Orientation and any change in orientation during test.

c. Results of each performance check (pretest, during test, and post-test).

d. Whether the second 6-hour test was performed immediately after the test item stabilized (see step 6 of small-particle procedure).

e. Values of the test variables for each section of the test.

f. Results of each visual inspection.

g. Duration of each section of test.

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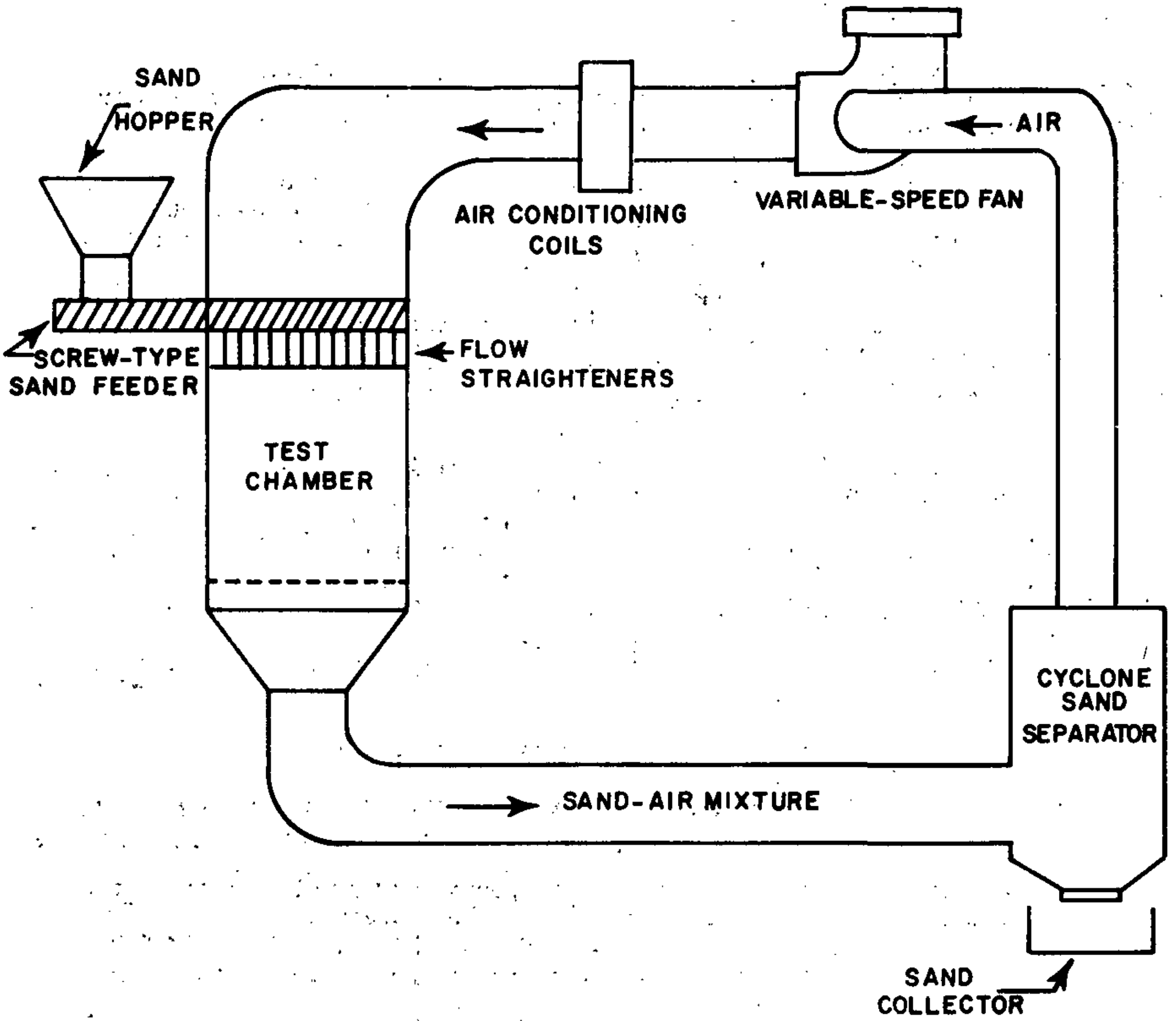

FIGURE 510.2-1. Blowing sand test facility (vertical flow).

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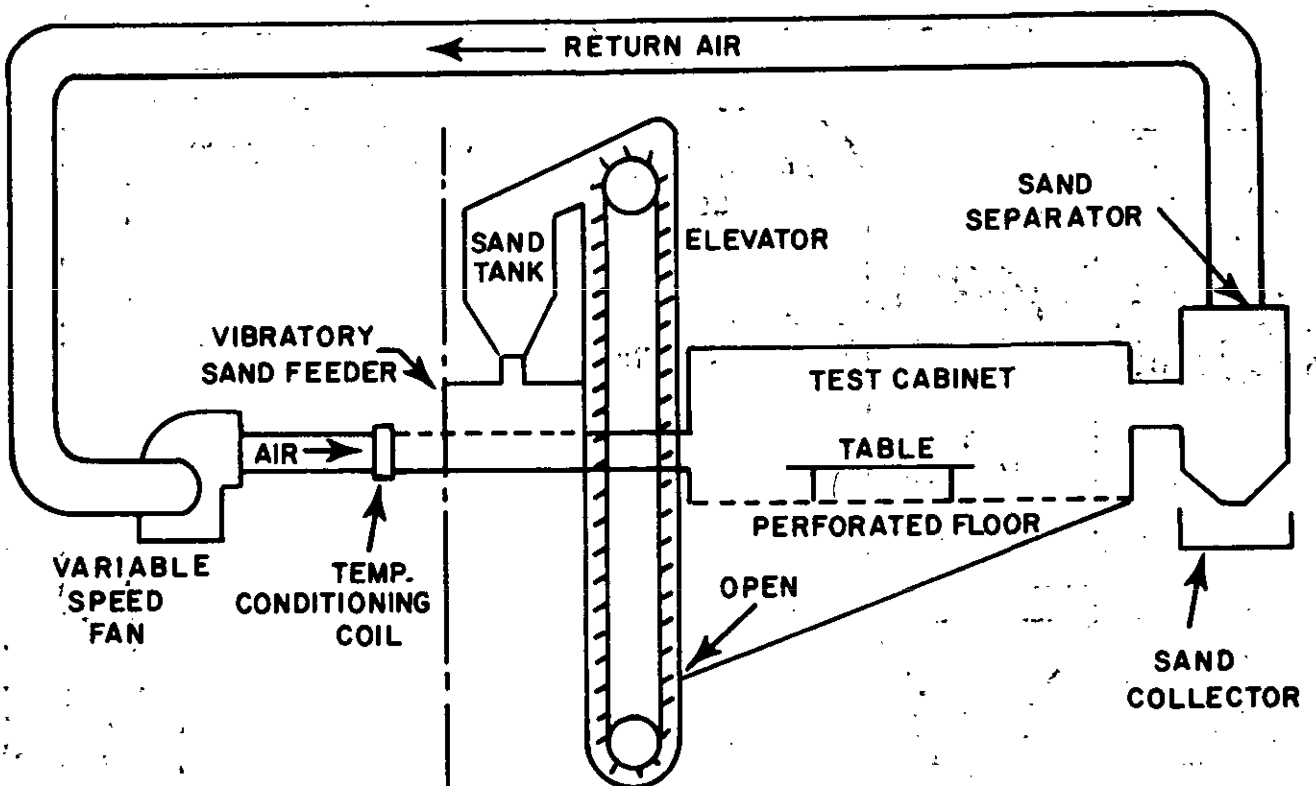

NOTE: THE LAYOUT OF THIS SYSTEM IS NOT DRAWN TO SCALE; IT IS INTENDED TO ILLUSTRATE THE ARRANGEMENT OF THE COMPONENTS. THE SPECIFICATIONS OF ALL COMPONENTS ARE NOT PROVIDED IN THIS TEST DESCRIPTION. THEY MUST BE CALCULATED BY THE ORGANIZATION SUPPLYING THE COMPONENTS. "INDUSTRIAL VENTILATION, A MANUAL OF RECOMMENDED PRACTICE" WILL PROVIDE DATA AND GUIDANCE FOR DESIGNING THE REQUIRED EQUIPMENT.

FIGURE 510.2-2. Blowing sand test facility (horizontal flow).

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METHOD 511.2

EXPLOSIVE ATMOSPHERE

SECTION I

I.1 PURPOSE. This test is performed to demonstrate the ability of equipment to operate in flammable atmospheres without causing an explosion, or to prove that a flame reaction occurring within an encased equipment will be contained and will not propagate outside the test item.

I-2 ENVIRONMENTAL EFFECTS. Low levels of energy discharge or electrical arc from devices as simple as pocket transistor radios can ignite mixtures of fuel vapor and air. A "hot spot" on the surface of a hermetically sealed, apparently inert equipment case can ignite fuel vapor and air mixtures. Fuel vapors in compartments can be ignited by a low energy discharge like a spark from a shorted flashlight cell, switch contacts, etc.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS

NOTE: This test method should be applied at the end of the tailoring process described in section 4 of this standard.

a. Application. This method applies to all military items designed for use in or near flight vehicles, ground vehicles, or equipment used to maintain fuel-handling or fuel-using vehicles.

b. Restrictions. None.

c. Sequence. It is recommended that the items used in this test first undergo vibration and/or temperature testing. Vibration and temperature stresses may reduce the effectiveness of seals, thus producing flammable atmosphere sensitivities not observable on untested items.

d. Test variations. The test variables are temperature, pressure, humidity, test item configuration, and fuel-vapor mixture.

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I-3.1 Choice of test procedures

I-3.1.1 Procedure I - Equipment operation in flammable atmosphere. This procedure is applicable to all types of sealed and unsealed equipment. This test evaluates the ability of the test item to be operated in a fuel-vapor-laden environment without igniting the environment.

I-3.1.2 Procedure II - Explosion containment. This procedure is used to determine the ability of the test item's case or other enclosures to contain an explosion or flame that is a result of an internal equipment malfunction.

I-3.2 Choice of test conditions. The explosive atmosphere test is a conservative test. If the test item does not ignite the test fuel-air mixture, there is a low probability that the item will ignite fuel vapor mixtures that can occur in actual use. Conversely, the ignition of the test fuel-air mixture by the test item does not mean that the test item will always ignite fuel vapors that occur in actual deployment.

I-3.2.1 Fuel for test. The fuel recommended for explosive atmosphere testing shall be the single-component hydrocarbon n-hexane (i.e., normal hexane). This fuel is used because its ignition properties for flammable atmosphere testing are equal to or better than the similar properties of both 100/130 octane aviation gasoline and JP-4 jet engine fuel. Optimum mixtures of n-hexane and air will ignite from hot-spot temperatures as low as 222.8°C (433°F) while optimum JP-4 jet engine fuel-air mixtures require at least a 229.4°C (445°F) temperature level for autoignition and 100/130 octane aviation gasoline and air requires 440.6°C (825°F) for hot-spot ignition. Minimum spark energy inputs for ignition of optimum fuel vapor and air mixtures are essentially the same for n-hexane and for 100/130 octane aviation gasoline. Much higher minimum spark energy input is required to ignite JP-4 jet engine fuel and air mixtures.

I-3.2.2 Fuel vapor mixture. The fuel vapor mixture used in the explosive atmosphere test shall be homogeneous.

I-3.2.3 Test temperature. The fuel vapor mixture is heated to the highest ambient air temperature at which the test item is required to operate during actual deployment. Heating the ambient air to this temperature gives the fuel vapor/air mixture its greatest likelihood of ignition. All testing should be done at this maximum air temperature. For forced-air-cooled equipment, the test temperature shall be the highest temperature at which equipment performance can be evaluated in the absence of cooling air.

I-3.2.4 Quantity of fuel. Unless otherwise specified, the fuel used shall be n-hexane, either reagent grade or 95 percent. The 95 percent n-hexane fuel actually is nearly 100 percent hexane, because the remaining 5 percent consists of hexane isomers. Fuel weight calculated to total 3.8 percent by volume of the test atmosphere represents 1.8 stoichiometric equivalents of n-hexane in air, giving a mixture needing only minimum energy for ignition.

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a. Required information to determine fuel weight:

(1) Chamber air temperature during the test.

(2) Fuel temperature.

(3) Specific gravity of n-hexane (see figure 511.2-1).

(4) Test altitude: e.g., 6100 meters (20,000 feet). Atmospheric pressure in pascals: 46.6 kPa (6.76 psia).

(5) Net volume of the test chamber: free volume less test item displacement expressed in liters or cubic feet.

b. Calculation of the volume of liquid n-hexane fuel for each test altitude:

(1) In metric units:

Volume of 95 percent n-hexane (ml) =

$$(396 \times 10^{-6}) \frac{\text{[net chamber vol (liters)] [chamber pressure (pascals)]}}{\text{[chamber temp (K)] [specific gravity, n-hexane]}}$$

(2) In English units:

Volume of 95 percent n-hexane (ml) =

$$(77.16) \frac{\text{[net chamber vol (ft}^3\text{)] [chamber pressure (psia)]}}{\text{[chamber temp (K)] [specific gravity of n-hexane]}}$$

I-3.2.5 Effect of humidity on flammable atmosphere. Humidity is always present in an explosive atmosphere test. The effect of humidity upon the fuel-air mixture percent composition need not be considered in the test if the ambient air dewpoint is 10°C (50°F) or less because this concentration of water vapor only increases the n-hexane fuel concentration from 3.82 percent to 3.85 percent of the test atmosphere. If the atmospheric pressure is cycled from 1525 meters (5000 ft.) above the test level to 1525 meters below (a 34-percent change in pressure), the volume of n-hexane will decrease from 4.61 percent to 3.08 percent. This decrease will compensate for the fuel enrichment effect that results from water vapor dilution of the test air supply.

I-3.2.6 Altitude simulation. The maximum altitude at which the test item will be exposed to fuel vapors during operation shall be the maximum test altitude, unless otherwise specified. If the test facility is not at sea level and the test is for shipboard equipment, the test chamber shall be pressurized to simulate sea level, unless otherwise specified.

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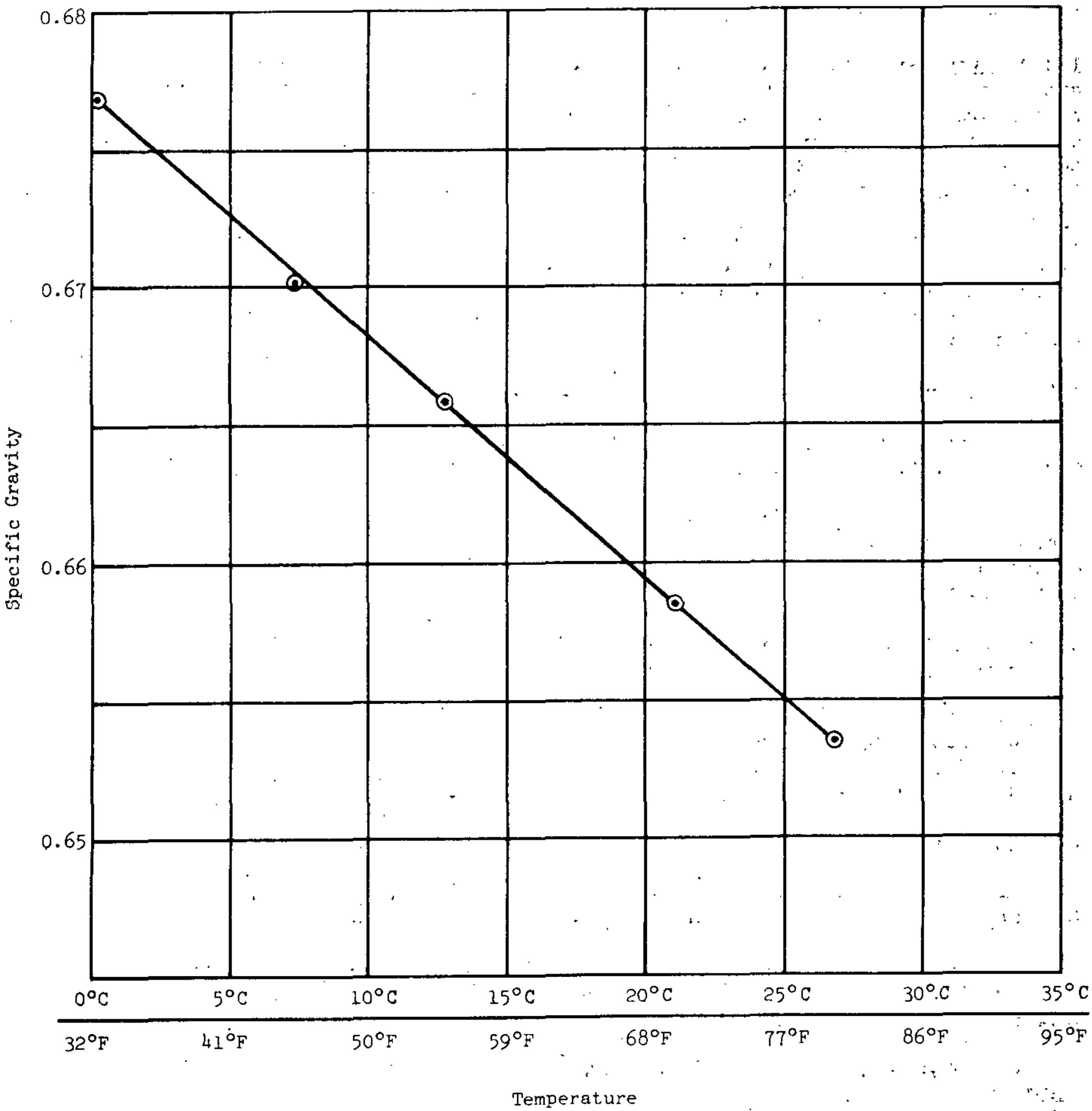

FIGURE 511.2-1. Specific gravity of n-hexane.

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I-4 SPECIAL CONSIDERATIONS

I-4.1 Test interruption. If there is an unscheduled test interruption, the chamber shall be returned to ground level and purged to remove the flammable atmoshpere. The test shall be reinitiated from the point of interruption using the same test item.

I-4.2 Overtest. Any interruption in the test that results in a more extreme exposure of the test item than required by the equipment specification should be followed by a complete physical inspection of the test item and an operational check prior to continuation of test. An engineering judgment shall be made whether to continue testing with the specific item given the overtest, to obtain a new item, or to consider the test completed.

I-4.3 Failure analysis. All failures (see I-4.4) and incidents where the test items do not meet the equipment operating requirements shall be analyzed to determine the cause and impact of such occurrences. Corrective actions shall be proposed or implemented as required to meet equipment performance requirements.

I-4.4 Failure criteria

a. Procedure I - Ignition of test fuel vapor and air environment constitues failure of the test.

b. Procedure II - Propagation of flame to, or ignition of, a flammable atmosphere surrounding the test item when the test atmosphere within the enclosure or case of the test item is intentionally ignited constitutes failure of the test.

I-4.5 Summary of information required. The following information is required in the test plan for the conduct of the tests of Section II:

a. Test altitudes
b. Test temperatures
c. Fuel volume and/or weight
d. Test item configuration

I-5 REFERENCES

a. Haskin, W.L. Explosion-Proof Testing Techniques. 1963. ASD-TDR-62-1081. DTIC number AD-400-483.

b. Zabetakis, M.G., A.L. Furno, and G.W. Jones. "Minimum Spontaneous Ignition Temperatures of Combustibles in Air," Industrial and Engineering Chemistry 46 (1954), 2173-2178.

c. Washburn, E.W., ed. International Critical Tables of Numerical Data, Chemistry, and Technology. Vol. III. New York: National Research Council/ McGraw-Hill, 1928. pp 27-29.

d. Kuchta, J.M. Summary of Ignition Properties of Jet Fuels and Other Aircraft Combustible Fluids. 1975. AFAPL-TR-75-70, pp 9-14. DTIC number AD-A021-320.

e. ASTM E 380-79. Standard for Metric Practice.

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METHOD 511.2

EXPLOSIVE ATMOSPHERE TEST

SECTION II

II-1 APPARATUS. A test chamber capable of producing the required test conditions shall be used. Appendix A describes one type of chamber that may be used.

II-1.1 Fuel. Unless otherwise specified, n-hexane (i.e., normal hexane) of at least 95 percent purity shall be used.

II-2 PREPARATION FOR TEST. The test item shall be prepared in accordance with General Requirements, 4.5.2.

II-2.1 Procedure I - Operation in explosive atmosphere

Step 1. The test item shall be installed in the test chamber 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 remainder of the associated equipment located externally.

Step 2. The equipment shall be operated to determine that it is functioning properly and to observe the location of any sparking or high temperature components which could cause an explosion.

Step 3. 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 is preferable to operate the equipment as it normally functions in the system during service use.

Step 4. A thermocouple shall be placed on the most massive component of the test item.

Step 5. At least two thermocouples shall be placed on the inside of the test chamber walls. These thermocouples (from steps 4 and 5) should be instrumented for monitoring outside the test chamber when the chamber is sealed.

II-2.2 Procedure II - Explosion containment test

Step 1. The equipment, or a model of the equipment of the same volume and configuration, shall be placed within the case and the case installed in the explosion chamber.

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Step 2. Make provision to circulate the fuel-air mixture into the case being tested. In the case of forced-air-cooled equipment, the cooling air must contain the proper fuel-air mixture. For equipment not using forced-air cooling it is necessary to drill the case for insertion of a hose from a blower, take adequate precautions to prevent ignition of the ambient mixture by backfire or release of pressure through the supply hose. Any modification to facilitate the introduction of ignitable vapor shall not alter the case by more than ±5%.

Step 3. Provide positive means of igniting the explosive mixture within the case. The case may be drilled or tapped for a spark gap, or a spark gap may be mounted internally. Points of ignition should not be more than 0.5 inch from any vent holes or flame arresting devices, and as many of such ignition sources should be installed within the case as there are vent holes or flame arresting devices. Where the design of equipment makes this impractical, use as many points of ignition as are practical.

Step 4. A thermocouple inserted into the case and attached to a sensitive galvanometer outside the test chamber may be used to detect explosions within the case.

Step 5. Insure that the air within the test chamber has a water vapor dewpoint lower than 10°C (50°F).

Step 6. If the site atmospheric pressure at the test location is less than 633 mmHg, make provisions to pressurize the test chamber to at least 633 mmHg. Ground level pressures referred to in paragraph II-3.2 step 5 shall consist of pressures from 633 to 800 mmHg, inclusive.

Step 7. Perform steps 4 and 5 of paragraph II-2.1.

II-3 PROCEDURES

II-3.1 Procedure I - Operation in explosive atmosphere

Step 1. Perform preparation for test.

Step 2. Seal chamber with test item mounted inside.

Step 3. Raise the ambient temperature of air inside the chamber to that determined in paragraph I-3.1.3. Wait until temperatures of test item and test chamber inner walls come within 11°C of chamber ambient air temperature.

Step 4. Adjust the chamber air pressure to simulate the test altitude plus 1500 meters, as given in paragraph I-3.1.5.

Step 5. Inject the required quantity of n-hexane into the test chamber.

Step 6. Circulate the test atmosphere at least three, but not more than four, minutes to allow for complete vaporization of fuel and the development of a homogeneous mixture.

Step 7. Operate the test item. Operation shall be continuous from step 7 thru step 13. Make and break electrical contacts as frequently as reasonably possible.

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Step 8. Slowly increase the air pressure in the test chamber by bleeding air into the chamber. Simulate change of altitude at a rate no faster than 100 meters per minute.

Step 9. Stop air pressure change at 1500 meters below test altitude or at ground level, whichever is reached first.

Step 10. Check the potential explosiveness of the air-vapor mixture by attempting to ignite a sample of the mixture by a spark-gap or glow plug ignition source having sufficient energy to ignite a 3.82-percent hexane mixture. If ignition does not occur, return the chamber to ambient atmospheric pressure, purge the chamber of the fuel vapor, and reinitiate the test at the most recent test altitude.

Step 11. If the lower limit of simulated altitude reached in step 9 is 3000 meters or greater above sea level, reduce the value of the test altitude by 3000 meters. If the station ambient pressure altitude (i.e., ground level) was reached, go to step 13. If the station ambient pressure was not reached, return the simulated altitude to station ambient pressure, purge the chamber to remove all fuel vapor, and then evacuate the chamber to the new value of test altitude.

Step 12. Using the new value of test altitude from step 11, conduct steps 5 through 10.

Step 13. Document test results per paragraph II-4.

II-3.2 <u>Procedure II - Explosion containment test</u>

Step 1. Perform preparation for the test as given in II-2.2.

Step 2. Seal the chamber with test item inside.

Step 3. Raise the ambient air temperature inside chamber.

Step 4. Wait until temperatures of test item and test chamber inner walls come within 11°C of chamber ambient air temperature.

Step 5. Change chamber air pressure to 1500 meters of simulated altitude above the station ambient pressure (i.e., ground level).

Step 6. Inject the required quantity of n-hexane into the test chamber to obtain optimum fuel-vapor/air mixture at station ambient pressure or as given in I-3.1.4b for n-hexane.

Step 7. Circulate the test atmosphere for at least 3 but no more than 4 minutes to allow for the complete vaporization of fuel and the development of a homogeneous mixture within the test item and within the test chamber.

Step 8. Bleed air into the chamber to return the pressure altitude to station ambient pressure (i.e., ground level).

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Step 9. Energize the internal case ignition source.

Step 10. Confirm the occurrence of an explosion within the test item using the installed thermocouple. If no explosion occurs, purge the chamber and the test item of all air/fuel vapor and return to step 2.

Step 11. If the explosion inside the test item's case did not propagate to the fuel-air mixture outside the test item, repeat steps 7 through 10 five times if the test item's case is not in excess of one fiftieth of the test chamber volume. If the test item volume is greater than one fiftieth of the chamber volume, purge the chamber and test item of air/fuel vapor and return to step 2.

Step 12. Check the potential explosiveness of the air-fuel vapor mixture by attempting to ignite a sample of the mixture by a spark or glow plug. If chamber sample does not ignite, purge the chamber of all air/fuel-vapor mixture, and repeat the entire test from step 2.

Step 13. Document the test results.

II-4 <u>INFORMATION TO BE RECORDED</u>

a. Test procedure number.

b. Chamber pressure and temperatures at each test point (simulated altitude).

c. For Procedure II, the locations of glow plugs or spark gaps installed inside test items.

d. For Procedure II, energy requirement for the glow plug or spark gaps for operation.

e. The quantity of fuel required at each test point.

f. The off/on cycling rate for the test equipment.

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APPENDIX A

METHOD 511.2

EXPLOSIVE ATMOSPHERE

CHAMBER, FLAMMABLE ATMOSPHERE TESTING

A-1 This appendix describes one test chamber capable of producing the flammable atmosphere conditions required for this test method.

A-1.1 Component parts. The facility shall consist preferably of a steel test chamber and associated pumps, ignition system, fuel metering system, power source, and any other equipment necessary to meet the requirements for test method 511.2 for flammable atmosphere testing.

A-1.2 Design and construction. The explosive atmosphere testing facility shall be a portable self-contained unit or a permanent installation consisting of a well-lighted test chamber equipped with a system for mixing and circulation of explosive air-fuel vapor mixtures, a means of ignition of air-vapor mixture, an explosion relief valve system (figure A1 is a drawing of a differential pressure explosion-relief valve), and a vacuum pump to permit the simulation of altitude. Adequate controls and instrumentation shall be provided. The facility shall be assembled on a chassis or frame and could be mounted on pneumatic-tired wheels for portability. The design may conform in general to figure A2 and shall be capable of compliance with the requirements of this method.

A-1.2.1 Chamber. A practically sized test chamber should provide a minimum clear working space 3 feet in diameter and 5 feet long and should be capable of maintaining any desired pressure altitude within performance limits specified in paragraph A-1.3.5 below.

A-1.2.1.1 Openings. The chamber shall have pressure relief valves and shall be capable of conformance with the applicable requirements of A-1.3 below. Pressure-tight jacks for transmission of power to and from the test item shall be provided, together with openings for the insertion of sealed mechanical controls, as required. Observation windows shall be provided in both sides of the chamber.

A-1.2.1.2 Floor. A removable floor, having a minimum area of 0.75 square meter (8 square feet) and capable of supporting 4880 kilograms per square meter (100 pounds per square foot) within the chamber.

A-1.2.1.3 Lighting. The test chamber shall be lighted with two 150-watt lamps of explosion-proof design, one located at each end of the chamber, to provide uniform illumination.

A-1.2.1.4 Stuffing boxes. Two stuffing boxes shall be provided to facilitate the penetration of cabling connectors and control shafts.

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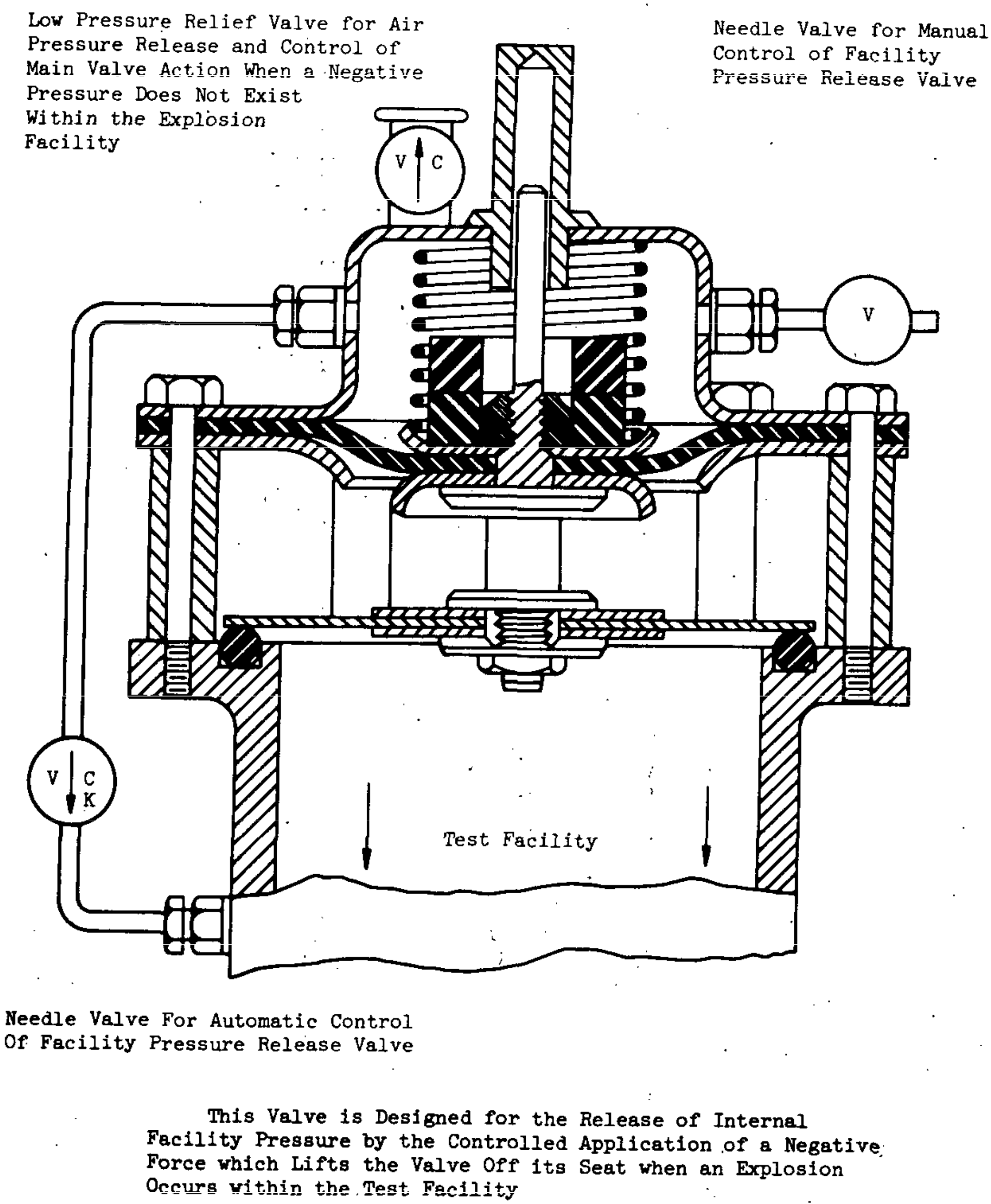

FIGURE A1. An example of differential pressure explosion-relief valve.

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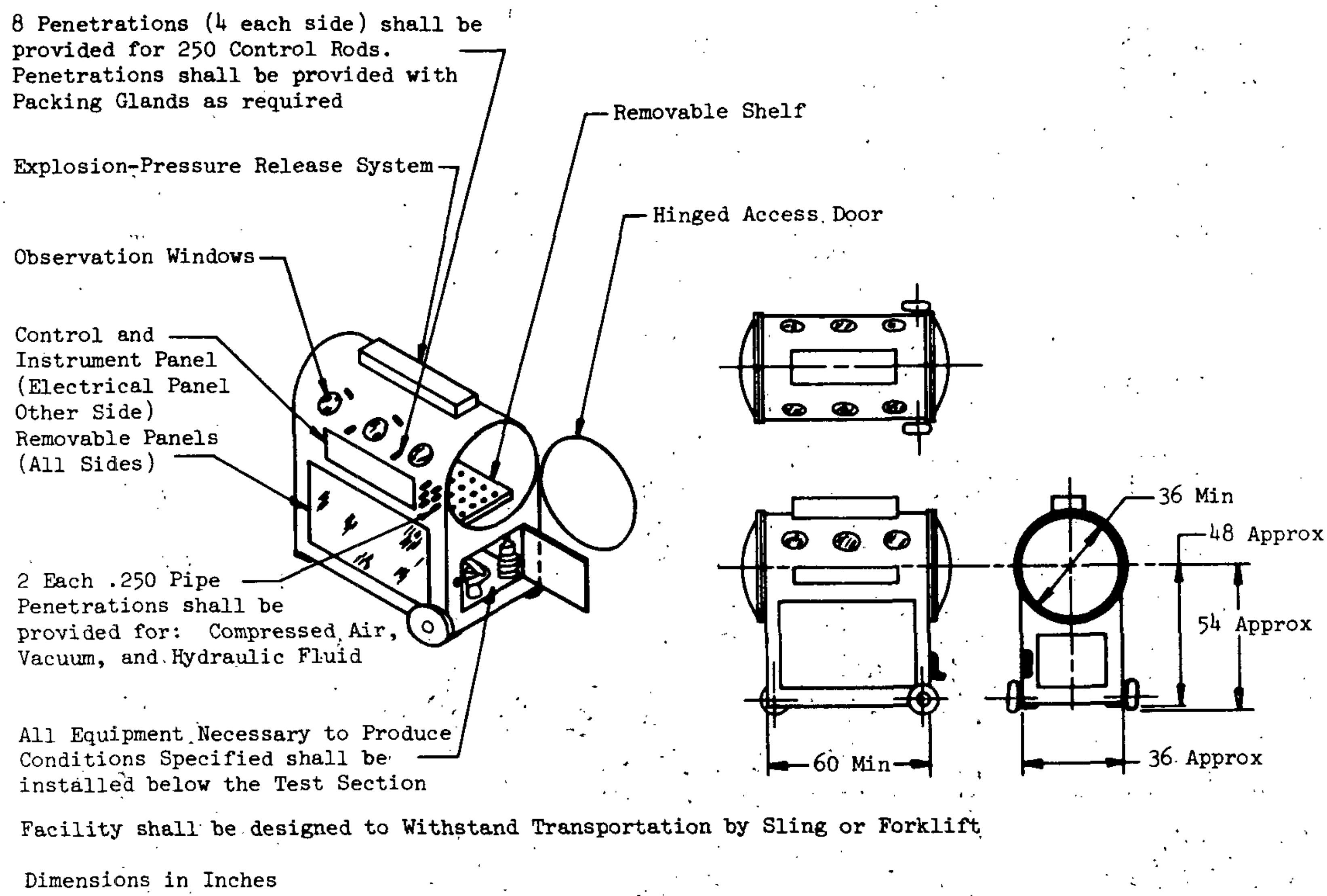

FIGURE A2. Chamber, flammable atmosphere testing.

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A-1.2.1.5 Mixing and circulation system. A system shall be provided for the mixing of air and fuel to produce flammable air-vapor mixtures, and for the circulation into the test chamber of the mixtures so produced. The system shall consist of a closed-duct circuit of which the test chamber shall form a part. The circuit shall be equipped with a mixing blower capable of producing an air velocity in conformance with the performance limits of A-1.3.3 below. An additional blower of similar capability shall be provided to insure thorough circulation of air-vapor mixtures within the test chamber. The system shall be equipped with valves to permit safe and practical scavenging of the test chamber and test item, and to bring in outside air for mixing. The outside incoming air port should be equipped with a drying chamber which contains silica gel or some other drying agent. An air bypass system shall also be connected to the downstream side of the drying chamber through a control valve and into the chamber, to permit air to be bled into the chamber during a test run. The complete injection and mixing operation shall require not more than 3 minutes.

A-1.2.1.6 Fuel metering system. A means shall be provided whereby fuel vapor can be metered into the mixing and circulation system in controlled quantities to produce explosive mixtures of any desired air-vapor ratio.

A-1.2.1.7 Fuel vaporizer. A vaporizer shall be provided in the mixing and circulation system to vaporize liquid fuel for mixing with air. The vaporizer should consist of a heat exchanger using water as an exchange media. The water shall be heated by immersion type heaters in order to warm the mixing air prior to initial contact between the air and the atomized fuel from the fuel injectors.

A-1.2.1.8 Explosion relief valves. Three pressure relief valves (see an example type in figure 1) shall be provided for the size chamber described herein. The valves shall be designed to open at the minimum chamber operating pressure and, when opened by an explosion, shall remain in that position until released. Closure should be either by manual actuation of hand valves or by automatic pressure equalization of the test area and the surrounding atmosphere through suitable restrictive orifices. Each valve shall have a minimum cross-sectional area of 0.13 square meters (200 square inches).

A-1.2.1.9 Fuel. The explosion facility shall be capable of utilizing n-hexane fuel to produce flammable vapor mixtures.

A.1.2.1.10 Ignition system. An ignition system shall be provided to permit ignition of the atmospheres within the main chamber, the sampling chamber and the case of the test item, as required. This shall be accomplished by spark plugs installed in appropriate locations within the chamber and with leads provided for plugs installed in test item cases. Spark plugs shall be positioned so as to eliminate any effect by wall conditions on spark temperature.

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A-1.2.1.11 Electrical system. All electrical components of this facility shall be explosionproof and conform to the applicable portion of the National Fire Underwriters Code. The chamber shall be equipped with sealed male plugs and female jack feedthroughs to transmit power as required through the chamber wall to the item under test. For example:

12 - 150 amp. jack and plug terminals
12 - 75 amp. jack and plug terminals
12 - 40 amp. jack and plug terminals
12 - 10 amp. jack and plug terminals (male jack and female plug).

Studs may be used through the chamber wall provided they are wired to jacks located on a panel mounted on the facility. Jacks and plugs should be similar to and interchangeable with existing laboratory equipment.

A-1.2.1.12 Vacuum pump. A vacuum pump capable of producing and maintaining within the test chamber any desired pressure altitude within the performance limits specified in A-1.3.2 shall be provided. The pump shall be mounted on the same chassis as the chamber. Five minutes shall be the maximum allowable time to produce any pressure altitude desired.

A-1.2.1.13 Sampling chamber. A sampling chamber equipped with a blower and a spark plug shall be provided. The blower shall be capable of mixture circulation at the velocity specified in A-1.3.3 and shall be appropriately located. The volume of the sampling chamber shall be not less than 1 cubic foot and the configuration symmetrical, to prevent end effects resulting from ignition of explosive mixtures. The sampling chamber shall be of a strength equal to that of the main test chamber. A maximum pressure indicator shall be furnished for the sampling chamber. The sampling chamber shall be external to the main chamber but in as close proximity thereto as possible. The inlet side of the sampling chamber mixing blower shall be provided with a flexible probe which can be placed in the vicinity of any potential arcing sources on the test item. Provision should be made to insure that sampling chamber wall temperature will be equal to main chamber wall temperature.

A-1.2.1.14 Heater system. A thermostatically regulated heater system capable of controlling the air temperature in the chamber within performance limits specified in A-1.3.4 shall be provided. The heater system shall be built into the chamber walls so that the chamber air temperature is controlled by heat from the walls. The time required to attain any desired temperature shall not exceed 1 hour. Temperature fluctuations due to the introduction into the test chamber of air-vapor mixtures shall not exceed 5.5°C (10.0°F) in magnitude nor 2 minutes in duration.

A-1.2.1.15 Instruments. The following instruments shall be provided:

a. Altimeter 0-25,000 meters (0-80,000 feet)

b. Maximum pressure indicators (2) 0-2400 pascals (0-350 psi)

c. Chamber air temperature indicator 0-260°C (0-500°F)

d. Chamber wall temperature indicator 0-260°C (0-500°F)

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e. Fuel temperature indicator 0-40°C (0-100°F)

f. Vaporizer air temperature indicator 0-260°C (0-500°F)

g. Vaporizer media temperature indicator 0-260°C (0-500°F)

h. Fuel quantity gage (calibrated for n-hexane of 0.659 specific gravity at 20°C relative to water at 4°C and reading in milliliters of fuel)

i. Fuel inert pressure indicator 0-700 kPa (6.76 psia)

j. Heater thermostat 0-260°C (0-500°F)

A-1.2.1.16 Controls. The facility shall be provided with switches, valves, etc. for control of all components and systems of the test chamber. Controls shall be mounted so that their use is convenient.

A-1.2.1.17 Safety provisions

A-1.2.1.17.1 Indicator lights. Panel-mounted individual lights shall be provided and installed on the test facility in a location readily visible to the operator, each light being indicative of the status or condition of a system or piece of equipment not in an observable position. All conditions involving operational safety shall be so indicated and any others will be included if specified by the procuring activity.

A-1.2.1.17.2 Safety interlock system. An automatic mechanical or electrical interlock device shall be provided to prevent the premature actuation of the ignition system. The design of the system shall be such that all openings to the main test chamber, including the main door, the explosion relief valves, the circulation system inlet and outlet ports, and the sampling chamber ports, must be securely closed before energy can be transmitted from the ignition system to the spark plugs. An audible signal shall be provided to sound if actuation of the ignition system is attempted before all the above listed chamber vents are closed.

A-1.2.1.17.3 Emergency pressure relief device. A rupture disk or other suitable type of fast acting pressure relief device shall be provided. The device shall be designed to rupture or otherwise relieve, when subjected to a pressure in excess of the chamber design pressure. The pressure relief device shall be located on top of the test chamber and protected by a vented dome to prevent fragmentation hazard.

A-1.3 Performance

A-1.3.1 Chamber design pressure. The test chamber shall be capable of withstanding any explosion pressure up to and including 2 megapascals (300 pounds per square inch).

A-1.3.2 Pressure altitude. The chamber shall be capable of maintaining any desired pressure altitude from sea level to 18,250 meters (0-60,000 feet) within the limits specified in A-1.3.2.1.

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A-1.3.2.1 Chamber leakage. With the vacuum pump turned off, the chamber shall be capable of maintaining any pressure altitude from sea level to 3000 meters (10,000 feet) for a period of 10 minutes, and any altitude from 3000 meters (10,000 feet) to 18,000 meters (60,000 feet) for a period of 20 minutes, with a loss not to exceed 5 percent of the total pressure altitude during either time.

A-1.3.3 Blower air velocity. The blowers employed for mixing and circulation of air-vapor mixtures within the mixing circuit, the main chamber and the sampling chamber shall be capable of producing outlet air velocities between 300 and 600 meters per minute (1,000 and 2,000 feet per minute).

A-1.3.4 Chamber air temperature. The air temperature within the test chamber shall be controllable between 20°C and 240°C ±3°C (70°F and 450°F ±5°F) at all points 1-1/2 inches or further from the chamber walls. Within the 20°C to the 120°C (70°F to 250°F) temperature range, no hot spots in excess of 40°C (75°F) over the thermostat setting shall exist in the chamber atmosphere. For the 120°C to 240°C (250°F to 450°F) temperature range hot spots in excess of 15°C (25°F) above the thermostat setting are not permissible in the chamber atmosphere. Time required to raise the ambient air temperature from 20°C (70°F) to any desired value within the specified range shall not exceed 60 minutes.

A-1.3.5 Tolerances

A-1.3.5.1 Instruments and controls. Unless otherwise specified, instruments and controls shall be accurate within the following limits:

a. Temperature indicator (including thermostats): ±1°C (±2°F)

b. Pressure indicator: ±5 kPa (±1 psi)

c. Altimeter: ±1 percent

d. Thermostat: ±1°C (±2°F)

A-1.3.5.2 Environments. Unless otherwise specified, environmental conditions induced within the chamber shall not vary in excess of the following limits:

a. Air or mixture velocity: 1.5 percent (in meters per minute)

b. Altitudes: ±2 percent (in meters)

c. Temperature: ±3°C (±5°F)

NOTES

1. Intended use. The explosion-proof testing chamber described herein is intended for use in the accomplishment of explosion-proof tests in accordance with this standard.

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2. Instruction manual. An instruction manual should be available to provide the following information concerning the explosive atmosphere test chamber:

a. Operating instructions.

b. Maintenance instruction.

c. Assembly and disassembly procedure.

d. List and description of all replaceable parts.

e. Detailed assembly drawings.

f. Wiring diagrams.

3. Facility capability data. The following information should be stamped on data plates, which should be attached to the test facility at the location specified:

a. Maximum chamber design pressure: By chamber pressure indicator.

b. Vaporizer mixing air velocity: By vaporizer control switch.

c. Outlet air velocities of blowers: On side of test facility in a clearly visible location.

d. Emergency relief pressure: On dome of emergency pressure relief device.

e. Identification by name and purpose of each instrument, control, or indicating light: On or near the item concerned.

f. Explosion relief valve minimum opening pressure: On base of middle valve.

g. Free-volume (in cubic feet) of main and sampling chambers: On sides of chambers.

4. Facility calibration charts and data. Calibration charts and other data should be available as follows:

a. Calibration chart to correct the fuel quantity gage for use with fuels of other than the gravity for which the gage was originally calibrated.

b. Calibration chart for altimeter.

c. Calibration charts for correction of scale error of various indicators.

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METHOD 512.2

LEAKAGE (IMMERSION)

SECTION I

I-1 PURPOSE. Leakage (immersion) tests are conducted to determine whether materiel is constructed so that it can be immersed in water without leakage of the water into the enclosure.

I-2 ENVIRONMENTAL EFFECTS. Penetration (seepage) of water into equipment enclosures can result in problems such as:

a. Fouling of lubricants between moving parts.

b. Formation of electrically conductive bridges which may cause electronic equipment to malfunction or become unsafe to operate.

c. Corrosion due to direct exposure to the water or to the relatively high humidity levels caused by the water.

d. Diminishment of the burning qualities of explosives, propellants, fuels, etc.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS

NOTE: This test method should be applied at the end of the tailoring process described in section 4 of this standard.

a. Application. This method is used when the test item is designed to be watertight and may be exposed to partial or complete immersion in water. This test may, in some cases, be used to verify watertightness in lieu of a rain test, provided that the test item configuration is the same and erosion is not a problem.

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b. Restriction. This method does not necessarily duplicate service conditions but is used to verify the integrity of the test item's seals.

c. Sequence. (See General Requirements, 4.4.4.) This test should be performed before and after structural tests such as shock and vibration to aid in determining the test item's watertightness after dynamic tests.

d. Test variations. This method consists of one test procedure with several related test conditions that must be given values before the test is initiated, such as:

(1) Test item configuration.

(2) Preheat temperature.

(3) Depth of immersion.

(4) Duration of immersion.

(5) Additional guidelines as appropriate.

I-3.1 Choice of test procedure

a. Test objectives. The primary objectives of the leakage (immersion) test are to determine whether:

(1) The test item can be immersed in water without penetration of the water into the test item.

(2) The penetration of any water into the test item will cause operational degradation of the test item.

(3) The test item can be operated safely following immersion.

(4) Other possible effects may be caused by water leaking into the test item.

Based on this information and the purpose of the test item, determine any variations to the basic test that are required.

b. Procedure I - Basic leakage. This procedure is used to test relatively small test items (man-packed or man-portable for the most part) that employ seals or gaskets to prevent water penetration into the interior.1/

I-3.2 Choice of related test conditions

a. Test item configuration. The configuration of the test item is an important factor affecting water penetration into the test item. The following are examples of configurations to consider:

(1) In a shipping/storage container or transit case:

1/ Shelter-size test items may be subjected to the fording tests of MIL-S-55286 or MIL-S-55541.

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(2) Sealed with protective covers, caps, plugs, etc.

(3) Modified with kits for special applications.

(4) Normal operating configuration.

b. Conditioning. This test usually includes heating of the test item to induce expansion of materials and, after cooling, to establish a pressure differential to determine whether the seals or gaskets leak under relatively low pressure.

(1) The test item temperature of 27°C (49°F) above (Δt) the water temperature is used to produce a pressure differential inside the test item following immersion.

(2) The temperature of the water shall be 18° ± 10°C (64° ± 18°F).

(3) Duration. The test item shall be heated until temperature stabilization of the test item has occurred or for 2 hours, whichever occurs first (a sufficient time to raise the internal air temperature to a value approaching 45°C (113°F)).

c. Depth of immersion. The depth of immersion affects the pressure differential that develops on the test item. Since this method is designed to test the effectiveness of seals or gaskets, a 1-meter test depth is suggested. This, combined with the initial test item temperature, should result in twice the pressure differential of immersion to 1m without heating. Other values such as those shown in table 512.2-I may be used if appropriate.

TABLE 512.2-I. Water pressures at various depths.

Head of Water (meters)	Pressure Difference (kPa) (1 psi = 6.895 kPa)
0.15	14.7
0.91	90
1.0	98
1.5	147
4.0	392
6.0	588
10.0	980

NOTE: The equivalent head of sea water is 0.975 times the head of fresh water for the same pressure difference.

d. Duration of immersion. Just as the test item is heated for at least 2 hours before immersion to insure thorough heating, the immersion period of 2 hours is considered adequate to develop leakage if it is to occur.

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e. Additional guidelines. Review the equipment specification and requirements documents. Apply any additional guidelines necessary.

I-4 SPECIAL CONSIDERATIONS

I-4.1 Failure analysis. Based on the individual test item and the requirement for its leakage resistance, the following failure criteria apply:

a. Water penetration. Determine which of the following is applicable:

(1) Unconditional failure. Any evidence of water penetration into the test item enclosure following the immersion test shall be a basis for failure.

(2) Acceptable water penetration. Water penetration of not more than 4 cm^3 per 28,000 cm^3 (1 ft^3) of test item enclosure 2/ shall be acceptable, provided the following conditions are met:

(a) The water has no immediate effect on the operation of the test item.

(b) The test item in its operational configuration (transit/storage case open or removed) shall successfully complete the induced temperature/humidity (procedure II) of method 507.2 for the geographical area in which it is designed to be deployed.

b. Operational failure. Failure of the test item to satisfy its functional requirements shall constitute an immersion test failure.

c. Safety. The test item must be safe to operate following the immersion test.

I-4.2 Additional considerations

a. When testing a shipping/storage container or transit case without the test items enclosed, all dunnage, packing, padding material, etc., that may absorb water shall be removed, if possible, before the test.

b. Extreme caution must be exercised when using the test item handles, protrusions, etc., to pull the test item under the water. This could produce unrealistic stress and leakage into the test item.

I-4.3 Summary of test information required. The following information is required in the test plan for adequate conduct of the tests of section II:

a. Test procedure number.

2/ This quantity of water (4 cm^3) is approximately the quantity required to raise the relative humidity of 1 cubic foot of air from 50% at 21°C (70°F) to saturation at 49°C (120°F). The 49°C value is realistic for equipment exposed to high-temperature and solar-radiation effects.

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b. Physical size of the test item (to determine test facility requirements).

c. Tiedown precautions (to prevent unrealistic stress).

d. Test item configuration.

e. Conditioning temperature and duration.

f. Covering/immersion depth.

g. Duration of immersion.

h. Additional guidelines.

I-5 <u>REFERENCES</u>

a. MIL-S-55286, <u>Shelter, Electrical Equipment S-280( )/G</u>

b. MIL-S-55541, <u>Shelter, Electrical Equipment S-250( )/G</u>

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METHOD 512.2

LEAKAGE (IMMERSION)

SECTION II

II-1 APPARATUS

II-1.1 Test facility

a. The required test apparatus should include a water container that can achieve a covering depth of 1m (3.3 ft) (or other required depths) of water over the uppermost point of the test item and maintain the test item at that depth. Also required is a chamber or cabinet capable of heating the test item to the required temperature.

b. A water-soluble dye such as fluorescein may be added to the water to aid in locating and analyzing water leaks.

II-1.2 Controls

a. The temperature of the water shall be $18^{\circ} \pm 10^{\circ}C$ ($64^{\circ} \pm 18^{\circ}F$).

b. The temperature of the test item shall be $27^{\circ} \pm 2^{\circ}C$ ($49^{\circ} \pm 4^{\circ}F$) above (t) the temperature of the water.

c. The temperature of the water shall not change more than $3^{\circ}C$ ($5^{\circ}F$) throughout the duration of the test.

II-1.3 Test interruption (See General Requirements, 4.5.4.)

a. Undertest interruptions. An interruption that results in less severe conditions than specified should be treated as a "no test." The test item should be dried and stabilized at standard ambient conditions and the entire test procedure repeated from the beginning. Any failure discovered during an undertest condition should be treated as a failure.

b. Overtest interruptions. Any interruption that results in more severe conditions than specified should be followed by a complete examination of the test item and an operational check (where possible) before continuation of testing. If no problem is evident, the test should be restarted, preferably with a new test item.

II-2 PREPARATION FOR TEST

II-2.1 Preliminary steps. Before initiating any testing, determine from the test plan:

a. The immersion depth and time and, if applicable, the preheat temperature and duration.

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b. The means to be used to secure the test item at the appropriate depth.

c. The test item configuration.

II-2.2 Pretest checkout. All test items require a pretest checkout to provide baseline data. Conduct the checkout as follows:

Step 1. Prepare the test item in accordance with General Requirements, 4.5.2.

Step 2. Examine the test item for evidence of free water. If any is found, dry the test item completely before continuing.

Step 3. Visually examine the test item, giving special attention to areas around seals.

Step 4. Document the results.

Step 5. Conduct an operational check in accordance with the requirements document.

Step 6. Document the results.

Step 7. Proceed to step 1 if no problems are found; otherwise, correct the problem and restart at step 1 above.

II-3 PROCEDURE I - Basic Leakage

Step 1. Three times, immediately before the test, open and close (or remove and replace) any doors, covers, etc., that would be opened during normal use to insure that any seals are functioning properly and are not adhering to the sealing surfaces.

Step 2. Condition the test item as in I-3.2b. The test item's sealed areas (where practicable) shall remain open throughout the heating cycle. Also, equipment occasionally incorporates valves or venting devices which may or may not be opened in normal service use. If the test item incorporates such a device, it should be opened throughout the heating portion of the test.

Step 3. Measure and record the immersion water temperature. If not in accordance with II-1.2b, adjust as required.

Step 4. Close all sealed areas and valves, assemble the test item in its test configuration and, as quickly as possible, immerse the test item in water so that the uppermost point of the test item is 1m ± 0.1m (3.3 ft ± 3.0 in) below the surface of the water, or as otherwise required by the test plan.

Step 5. Measure and record the water temperature at 30-minute intervals following immersion of the test item.

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Step 6. The test item shall remain immersed for 120 ± 5 minutes.

Step 7. Remove the test item from the water.

Step 8. Wipe the exterior surfaces of the test item dry, giving special attention to areas around seals and relief valves.

Step 9. If applicable, equalize the air pressure inside the test container by activating any manual valve(s).

Step 10. Open the test item and examine the interior and contents for evidence of and quantity of leakage and for probable areas where the leakage occurred.

Step 11. Document the results.

Step 12. Conduct an operational check of the test item, if applicable.

Step 13. Document the results.

Step 14. Compare the results with the baseline data obtained in II-2.2.

II-4 <u>INFORMATION TO BE RECORDED</u>

a. Previous test methods to which the test item has been subjected.

b. Amount of leakage into the test item.

c. Point(s) of leakage.

d. Water and test item temperatures.

e. Test item configuration.

f. Depth of immersion.

g. Duration of immersion.

h. Results of performance checks (pretest and post-test).

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METHOD 513.3

ACCELERATION

SECTION I

I-1 PURPOSE. The acceleration test is performed to assure that equipment can structurally withstand the g forces that are expected to be induced by acceleration in the service environment, and function without degradation during and following exposure to these forces.

I-2 ENVIRONMENTAL EFFECTS. Acceleration generally increases the forces acting on equipment and the hardware used to mount the equipment. An exception is acceleration that induces forces in opposition to gravitation forces, in which case the equipment can approach or attain a state of weightlessness and become reverse loaded in excess of the opposing gravitational forces. The forces induced by acceleration can cause:

a. Structural deflections that interfere with equipment operation.

b. Permanent deformations and fractures that disable or destroy the equipment.

c. Broken fasteners and mounting hardware that cause equipment to become loose projectiles.

d. Electronic circuit boards to short out and circuits to open up.

e. Inductances and capacitances to change values.

f. Relays to open or close.

g. Actuators and other mechanisms to bind.

h. Seals to leak.

i. Pressure and flow regulators to change value.

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j. Pumps to cavitate.

k. Spools in servo valves to be displaced and cause erratic and dangerous control system response.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS

NOTE: This test method should be applied at the end of the tailoring process described in section 4 of this standard.

a. Applications. This test method is applicable to equipment and devices that are installed in aircraft, helicopters, manned aerospace vehicles, air-carried stores, and ground-launched missiles.

b. Restrictions. None.

c. Sequence. The high temperature test should be conducted prior to acceleration.

d. Test variations. The tests vary in acceleration, axis of acceleration, duration, test apparatus, and on/off state of item.

I-3.1 Choice of test procedures. There are two test procedures. Procedure I (Structural Test) is used to demonstrate that equipment will structurally withstand the loads induced by in-service accelerations. Procedure II (Operational Test) is used to demonstrate that equipment will operate without degradation during and after being subjected to loads induced by in-service acceleration. Equipment to be tested should be subjected to both Procedure I and Procedure II tests unless otherwise specified.

I-3.2 Choice of test conditions. Acceleration values for individual equipment items should be obtained from the aircraft structural loads analyses. When the applicable aircraft is unknown, the values of tables 513.3-I and 513.3-II and the following paragraphs may be used.

For the purpose of these tests, the direction of forward acceleration is always considered to be the direction of forward acceleration of the host vehicle. The test item is tested in each direction along three mutually perpendicular axes for both test procedures. One axis is alined with the forward acceleration of the vehicle, one axis is alined with the spanwise direction of the vehicle, and the third axis is perpendicular to the plane of the other two axes. Figure 513.3-1 shows the six acceleration test directions.

Except for helicopters, the test levels for the six test directions are always based on the forward acceleration of the vehicle. In the case of helicopters, forward acceleration is unrelated to acceleration in the other directions. Tables 513.3-I and 513.3-II list test levels for Procedure I (Structural Test) and Procedure II (Operational Test), respectively. Factors which influence the test levels are:

a. Forward acceleration of the vehicle, known or unknown?

b. Orientation of test item in the vehicle, known or unknown?

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c. For fighter and attack aircraft, acceleration loads induced by roll, pitch, and yaw change maneuvers.

These factors are accounted for as follows.

I-3.3 Forward acceleration known and test item orientation known. When the forward acceleration of the vehicle is known and the orientation of the test item is known, the acceleration test levels for Procedure I tests are those values that are obtained from table 513.3-I when the known forward acceleration is substituted for A in the table. The acceleration test levels for Procedure II tests are obtained in the same manner using table 513.3-II. For helicopters, the test levels in the tables apply regardless of forward acceleration.

I-3.4 Forward acceleration known and test item orientation unknown. When the forward acceleration of the vehicle is known and the orientation of the test item is unknown, the acceleration test levels for Procedure I tests are the values obtained from table 513.3-I, which gives the highest test level when the known forward acceleration is substituted for A in the table. Use this value to test the item in each of the six test directions. The acceleration test levels for Procedure II tests are obtained in the same manner using table 513.3-II. For helicopters, the highest test level in each of the tables applies regardless of the forward acceleration.

I-3.5 Forward acceleration unknown and the test item orientation known. When the forward acceleration of the vehicle is unknown and the orientation of the test item is known, the acceleration tests levels for Procedure I tests are those values obtained from table 513.3-I when the probable forward acceleration as listed in the table for the relevant vehicle category is substituted for A. The acceleration test levels for Procedure II tests are obtained in the same manner using table 513.3-II. (Not applicable to helicopters.)

I-3.6 Forward acceleration unknown and the test item orientation unknown. When the forward acceleration is unknown and the orientation of the test item is unknown, the acceleration test level for Procedure I tests is the highest value obtained from table 513.3-I when the probable forward acceleration as listed in the table for the relevant vehicle category is substituted for A. Use this level to test the item in each of the six directions. The acceleration test level for Procedure II tests is obtained in the same manner using table 513.3-II. (Not applicable to helicopters.)

I-3.7 Fighter and attack aircraft. The test levels as determined from tables 513.3-I and 513.3-II are based on accelerations at the center of gravity (CG) of the host vehicle. For fighter and attack aircraft, the test levels in general must be increased for equipment that is located away from the vehicle CG to account for loads induced by roll and pitch change maneuvers. Roll impacts the up and down and lateral left and lateral right acceleration loads. Pitch change impacts the up and down and fore and aft acceleration loads.

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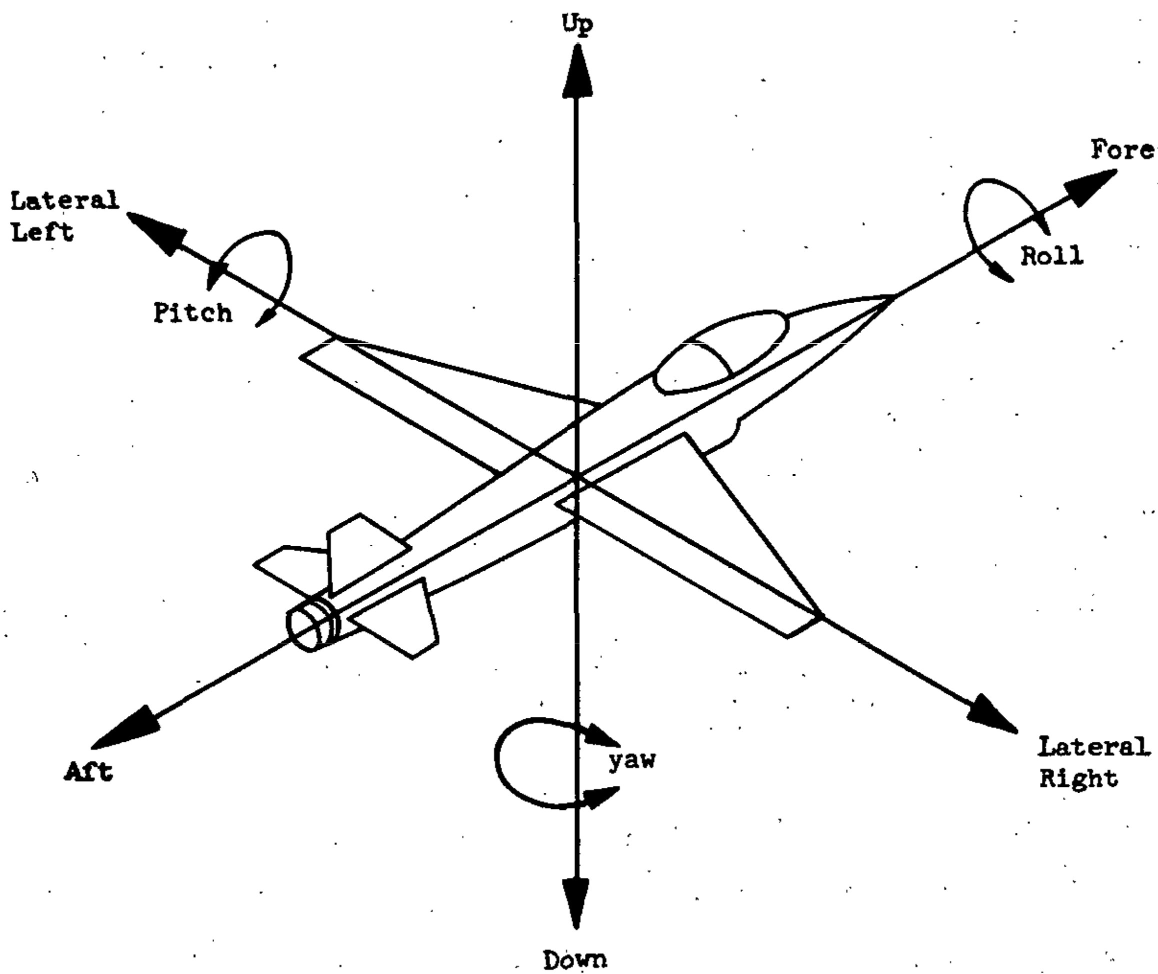

FIGURE 513.3-1. Directions of vehicle acceleration.

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TABLE 513.3-I Suggested G-levels for Procedure I - Structural test.

Vehicle Category		Forward Acceleration A in g's 1/	Test Level					
			Direction of Vehicle Acceleration (See figure 513.3-1)					
			Fore	Aft	Up	Down	Lateral	
							Left	Right
Aircraft 2/, 3/		2.0	1.5A	4.5A	6.75A	2.25A	3.0A	3.0A
Helicopters		4/	4.0	4.0	10.5	4.5	6.0	6.0
Manned Aerospace Vehicles		6.0 to 12.0 5/	1.5A	0.5A	2.25A	0.75A	1.0A	1.0A
Aircraft Stores	Wing/ Sponson Mounted	2.0	7.5A	7.5A	9.0A	4.9A	5.6A	5.6A
	Fuselage Mounted	2.0	5.25A	6.0A	6.75A	4.1A	2.25A	2.25A
Ground-Launched Missiles		6/, 8/	1.2A	0.5A	1.2A' 7/	1.2A' 7/	1.2A' 7/	1.2A' 7/

1/ Levels in this column should be used when forward acceleration is unknown. When the forward acceleration of the vehicle is known, that value shall be used for A.
2/ For carrier-based aircraft, the minimum value to be used for A is 4, representing a basic condition associated with catapult launches.
3/ For attack and fighter aircraft, add pitch, yaw, and roll accelerations as applicable.
4/ For helicopters, forward acceleration is unrelated to acceleration in other directions. Test levels are based on current and near future helicopter design requirements.
5/ When forward acceleration is not known, the high value of the acceleration range should be used.
6/ A is derived from the thrust curve data for maximum firing temperature.
7/ Where A' is the maximum maneuver acceleration.
8/ In some cases, the maximum maneuver acceleration and the maximum longitudinal acceleration will occur at the same time. When this occurs, the test item should be tested with the appropriate factors using the orientation and levels for the maximum (vectorial) acceleration.

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TABLE 513.3-II Suggested G levels for Procedure II - Operational test.

Vehicle Category		Forward Acceleration A in g's 1/	Test Level					
			Direction of Vehicle Acceleration (See figure 513.3-1)					
			Fore	Aft	Up	Down	Lateral Left	Lateral Right
Aircraft 2/, 3/		2.0	1.0A	3.0A	4.5A	1.5A	2.0A	2.0A
Helicopters		4/	2.0	2.0	7.0	3.0	4.0	4.0
Manned Aerospace Vehicles		6.0 to 12.0 5/	1.0A	0.33A	1.5A	0.5A	0.66A	0.66A
Aircraft Stores	Wing/ Sponson Mounted	2.0	5.0A	5.0A	6.0A	3.25A	3.75A	3.75A
Aircraft Stores	Fuselage Mounted	2.0	3.5A	4.0A	4.5A	2.7A	1.5A	1.5A
Ground-Launched Missiles		6/, 8/	1.1A	0.33A	1.1A' 7/	1.1A' 7/	1.1A' 7/	1.1A' 7/

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

2/ For carrier-based aircraft, the minimum value to be used for A is 4, representing a basic condition associated with catapult launches.

3/ For attack and fighter aircraft, add pitch, yaw, and roll accelerations as applicable.

4/ For helicopters, forward acceleration is unrelated to acceleration in other directions. Test levels are based on current and near future helicopter design requirements.

5/ When forward acceleration is not known, the high value of the acceleration range should be used.

6/ A is derived from the thrust curve data for maximum firing temperature.

7/ Where A' is the maximum maneuver acceleration.

8/ In some cases, the maximum maneuver acceleration and the maximum longitudinal acceleration will occur at the same time. When this occurs, the test item should be tested with the appropriate factors using the orientation and levels for the maximum (vectorial) acceleration.

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I-3.7.1 Roll maneuver loads, up and down test direction. For wing mounted equipment, the test levels for Procedure I (Structural Test) are the up and down levels as determined in table 513.3-I, plus 1.5 times N_z, the additional load induced by roll; where 1.5 is a safety factor and N_z is computed as follows.

$$\Delta N_z = \frac{d\ddot{\phi}}{g}$$

Where: d = lateral distance of equipment from aircraft CG in meters
$\ddot{\phi}$ = absolute value of maximum roll acceleration in rad/s² (if unknown, use $\ddot{\phi}$ = 20 rad/s²)
g = 9.80 m/s²

For Procedure II (Operational Test), the test levels are the up and down levels as determined in table 513.3-II plus ΔN_z.

I-3.7.2 Roll maneuver loads, lateral left and lateral right directions. For wing mounted equipment, the test levels for Procedure I (Structural Test) are the lateral left and lateral right levels as determined in table 513.3-I or 1.5 times ΔN_y, the load induced by roll, whichever is the higher, where 1.5 is a safety factor and ΔN_y is computed as follows.

$$\Delta N_y = \frac{d\dot{\phi}^2}{g}$$

Where: d = lateral distance of equipment from aircraft CG in meters
$\dot{\phi}$ = absolute value of maximum roll velocity, rad/s (if unknown, use $\dot{\phi}$ = 5 rad/s)
g = 9.80 m/s²

For Procedure II (Operational Test), the test levels are the lateral left and lateral right test levels as determined in table 513.3-II or ΔN_y, whichever is the higher.

I-3.7.3 Pitch change maneuver load, up and down test directions. For fuselage mounted equipment, the test levels for Procedure I (Structural Test) are the up and down acceleration levels as determined in table 513.3-I plus 1.5 times ΔN_z, the additional load induced by pitch change, where 1.5 is a safety factor and ΔN_z is computed as follows.

$$\Delta N_z = \frac{d\ddot{\phi}}{g}$$

Where: d = fore or aft distance of equipment from CG in meters
$\ddot{\phi}$ = maximum pitch acceleration in rad/s² (if unknown, use $\ddot{\phi}$ = 5 rad/s²)
g = 9.80 m/s²)

For Procedure II (Operational Test), the test levels are the up and down levels as determined in table 513.3-II plus ΔN_z.

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I-3.7.4 Pitch change maneuver load, fore and aft test directions. For fuselage-mounted equipment, the test levels for Procedure I (Structural Test) are the fore and aft levels as determined from table 513.3-I or 1.5 times ΔN_x, the load induced by pitch change, whichever is higher, where 1.5 is a safety factor and ΔN_x is computed as follows.

$$\Delta N_x = \frac{d\dot{\phi}^2}{g}$$

Where: d = fore or aft distance of equipment from aircraft CG in meters
$\dot{\phi}$ = maximum pitch velocity in rad/s (if unknown, use 2.5 rad/s)
g = 9.80 m/s^2

For Procedure II (Operational Test), the test levels are the fore and aft test levels as determined from table 513.3-II or ΔN_x, whichever is higher.

I-3.7.5 Yaw maneuver loads lateral left and right directions. For wing-mounted equipment, the test levels for Procedure I (Structural Test) are the lateral left and lateral right levels as determined in table 513.3-I or 1.5 times ΔN_y, the load induced by yaw, whichever is higher, where 1.5 is a safety factor and ΔN_y is computed as follows:

$$\Delta N_y = \frac{d\ddot{\psi}}{g}$$

Where: d = lateral distance of equipment from aircraft CG in meters
$\ddot{\psi}$ = absolute value of maximum yaw acceleration in rad/sec^2 (if unknown, use $\ddot{\psi} = 3\ rad/s^2$)
g = 9.80 m/s^2

For Procedure II (Operational Test), the test levels are lateral right test levels as determined in table 513.3-II or ΔN_y, whichever is the higher.

I-3.7.6 Yaw maneuver loads fore and aft test directions. For fuselage-mounted equipment, the test levels for Procedure I (Structural Test) are the fore and aft levels as determined from table 513.3-I or 1.5 times ΔN_x the load induced by yaw change, whichever is higher, where 1.5 is a safety factor and ΔN_x is computed as follows:

$$\Delta N_x = \frac{d\dot{\psi}}{g}$$

Where: d = fore and aft distance of equipment from aircraft CG in meters
$\dot{\psi}$ = absolute value of maximum yaw velocity in rad/sec (if unknown, use $\dot{\psi}$ = 4 rad/s)
g = 9.80 m/s^2

For Procedure II (Operational Test), the test levels are fore and aft test levels as determined from table 513.3-II or ΔN_x, whichever is higher.

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I-4. SPECIAL CONSIDERATIONS

I-4.1 Test interruption. If an unscheduled interruption occurs while the test item is at a specified test level, the test should resume at the test level. The test duration time should be the sum of the times at the test level prior to and following the interruption.

I-4.2 Over-acceleration. If the test item is subjected to acceleration loads in excess of the level specified for the test, the test must be stopped and the test item inspected and functional-tested. Based on the inspection and functional test, an engineering decision should be made as to whether testing should be resumed with the same test item or a new test item.

I-4.3 Sway space measurements. If a piece of equipment is mounted on isolators, the test should be run with the equipment mounted on the isolators and the sway space should be measured to indicate potential interference with adjacent equipment.

I-4.4 Acceleration simulation. Careful assessment of the function and characteristics of the test item has to be made in selecting the apparatus on which the acceleration tests are to be performed due to the differences in the manner in which acceleration loads are produced. There are two types of apparatus that are commonly used: the centrifuge and a track/rocket-powered sled combination.

I-4.4.1 Centrifuge. The centrifuge generates acceleration loads by rotation about a fixed axis. The direction of acceleration is always radially toward the center of rotation of the centrifuge, whereas the direction of the load induced by acceleration is always radially away from the axis of rotation. When mounted directly on the test arm, the test item experiences both rotational and translational motion. The direction of the acceleration and the load induced is constant with respect to the test item for a given rotational speed, but the test item rotates 360 degrees for each revolution of the arm. Certain centrifuges have counter-rotating fixtures mounted on the test arm to correct for rotation of the test item. With this arrangement, the test item maintains a fixed direction with respect to space, but the direction of the acceleration and the induced load rotates 360 degrees around the specimen for each revolution of the arm. Another characteristic is that the acceleration and induced load are in direct proportion to the distance from the center of rotation. This necessitates the selection of a centrifuge of adequate size so that the portions of the test item nearest to and furthest from the center of rotation are subjected to not less than 90 percent or more than 110 percent, respectively, of the specified test level.

I-4.4.2 Track/Rocket-powered sled. The track/rocket-powered sled arrangement generates linear acceleration in the direction of the sled acceleration. The test item mounted on the sled is uniformly subjected to the same acceleration level as the sled experiences. The acceleration test level and the time duration at the test level is dependent upon the length of the track, the power of the rocket, and the rocket charge. The sled track generally will produce a significant vibration environment due to track roughness. Typically this vibration is significantly more severe that the normal service use environment.

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Careful attention to the attachment design may be needed to isolate the test item from this vibration environment. In performing Procedure II tests, the support equipment necessary to operate the test item is mounted on the sled and traverses the track with the test item. This requires the use of self-contained power units and a remote control system to operate the test item while traversing the track. Telemetering or ruggedized instrumentation is required to measure the performance of the test item while it is exposed to the test load.

I-5. REFERENCES

a. Junker, V.J. The Evolution of USAF Environmental Testing. October 1975. AFFDL-TR-65-197. DTIC number AD-625-543.

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METHOD 513.3

ACCELERATION
SECTION II

II-1 APPARATUS. Either a centrifuge of adequate size or a track/rocket-powered sled arrangement may be used. A centrifuge is recommended for all Procedure I (Structural Test) and most of Procedure II (Operational Test) evaluations. A track/rocket-powered sled arrangement is recommended for Procedure II evaluations when strictly linear accelerations are required.

II-2 PREPARATION FOR TEST

II-2.1 Inspection. The test item shall be configured for service application. The item should be visually inspected for evidence of mishandling and in-transit damage. Any damage observed must be noted on a pretest data sheet and may be cause for rejection of the item for test. Sufficient dimensional measurements of the item shall be obtained to provide a reference guide for the evaluation of physical damage that may be induced during the tests.

II-2.2 Mounting of the test item. The test item shall be mounted on the test apparatus using the hardware that is normally used to mount the item in its service installation.

II-2.2.1 Centrifuge mounting. For centrifuges, the location for the test item is normally determined by measurement from the center of rotation of the centrifuge to the location on the centrifuge arm that will provide the g level established for the test. The test item is mounted so that its geometric center is at the location on the arm determined for the g level. G levels may be calculated as follows.

$$G_L = KRN^2$$

Where: G_L = g level to be applied
K = 1.12×10^{-3} for metric calculations
R = radial distance from the center of rotation to the mounting location on centrifuge arm in meters
N = centrifuge arm revolutions per minute

The orientation of the test item on the centrifuge for the six test directions is as follows:

a. Fore: Front or forward end of test item facing toward center of centrifuge.

b. Aft: Reverse item 180 degrees from fore position.

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c. Up: Top of test item facing toward center of centrifuge.

d. Down: Reverse item 180 degrees from up position.

e. Lateral left: Left side of test item facing toward center of centrifuge.

f. Lateral right: Right side of test item facing toward center of centrifuge.

After the test item is properly oriented and mounted on the centrifuge, measurements and calculations must be made to assure that the end of the test item nearest to the center of the centrifuge will be subjected to no less than 90 percent of the g level established for the test. If the g level is found to be less than 90 percent of the established g level, the test item must be mounted further out on the centrifuge arm and the rotational speed adjusted accordingly or a larger centrifuge used so that the end of the test item nearest to the center of the centrifuge is subjected to at least 90 percent of the established g level. However, the opposite end of the test item (the end farthest from the center of the centrifuge) should not be subjected to over 110 percent of the established g level. For large test items, exceptions should be made for load gradients based on the existing availability of large centrifuges in commercial or government test facilities.

II-2.2.2 Rocket-powered sled mounting. For rocket-powered sled mounting, the test item and associated test fixture or apparatus shall be mounted on the sled platform in accordance with the controlled acceleration direction of the sled. (The test fixture or apparatus should have been designed to isolate sled vibrations from the test item.) Since the sled and test item experience the same g levels, only the orientation of the test item on the sled is critical. The orientation of the test item on the sled shall be according to the acceleration directions shown in figure 513.3-1 and the controlled acceleration direction of the sled for the six test directions.

II-2.3 Functional pretest. After the test item is mounted on the test apparatus, a complete functional test shall be made on the test item to assure that the test item complies to the specification requirements. Record functional performance, observed data, and other pertinent information. Failure of the item to comply to specifications is cause for rejection for test.

For Procedure I (Structural Test), the functional pretest may be performed prior to mounting the test item on the test apparatus. However, for Procedure II (Operational Test), the functional pretest should be performed after the test item is mounted on the test apparatus to assure that the test item is properly installed for operation during the Procedure II tests.

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II-3 PROCEDURES

II-3.1 Procedure I - Structural test. Bring the centrifuge to the speed required to induce the specified g level in the test item as determined from I-4 and table 513.3-I for the particular test item orientation. Maintain this g level for at least one minute after the centrifuge rpm has stabilized. Repeat this test procedure for the remaining five test directions. Upon completing the tests in the six test directions, the item should be functionally tested as specified in II-2.3 and inspected as specified in II-2.1.

II-3.2 Procedure II - Operational test (centrifuge). Turn on the test item and place it in its operational mode. With the test item operating, bring the centrifuge to the speed required to induce the specified g level in the test item as determined from I-4 and table 513.3-II for the particular test item orientation. Maintain this g level for at least one minute after the centrifuge rpm has stabilized. Check the functional performance of the test item before, during, and after the test and record the results. Repeat this test procedure for the five remaining test directions. Upon completing the tests in the six test directions, the test item shall be inspected according to II-2.1.

II-3.3 Procedure II - Operational test (track/rocket-powered sled). Turn on the test item and place it in its operational mode. With the test item operating, accelerate the sled to the level required to induce the specified g level in the test item as determined from I-4 and table 513.3-II for the particular test item orientation. Check the functional performance of the test item before, during, and after the test and record the results. Due to the dynamic limitations of track and sled facilities, additional test runs may be required to adequately demonstrate acceptable performance of the test item while under the test loading. Repeat this test procedure for the five remaining test directions. Upon completing the tests in the six test directions, the test item shall be inspected according to II-2.1.

II-4 INFORMATION TO BE RECORDED

a. Pretest inspection observations and dimensional measurements made of the test item.

b. Pretest operational performance data obtained for the test item.

c. Test procedure number, test apparatus, test item orientation, test level, and time duration at the test level.

d. For Procedure II tests, the operational performance data of the test item while it is under load.

e. Post test inspection and operational test of the test item.

f. Failure analysis or deviations from specification, if appropriate.

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METHOD 514.3

VIBRATION

SECTION I

Page

I-1 PURPOSE. Vibration testing is performed to determine the resistance of equipment to vibrational stresses expected in its shipment and application environments.

I-2 ENVIRONMENTAL EFFECTS. Vibration can cause:

a. Wire chafing.

b. Loosening of fasteners.

c. Intermittent electrical contacts.

d. Touching and shorting of electrical parts.

e. Seal deformation.

f. Component fatigue.

g. Optical misalignment.

h. Cracking and rupturing.

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i. Loosening of particles or parts that may become lodged in circuits or mechanisms.

j. Excessive electrical noise.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS. This test method should be applied at the end of the tailoring process described in section 4 of this standard.

a. Application. This method is intended for all types of military equipment except as noted in the foreword to this standard.

b. Restrictions. None.

c. Sequence. Vibration testing may be performed anytime in the test program. The accumulated effects of vibration-induced stress may affect equipment performance under other environmental conditions, such as temperature, altitude, humidity, leakage or EMI/EMC. When it is desired to evaluate the cumulative environmental effects of vibration and other environments, a single test item should be exposed to all environmental conditions, with vibration testing generally performed first.

d. Test variations.

(1) Test apparatus.

(2) Test item configuration.

(3) On/off state of test item.

(4) Vibration spectrum and intensity.

(5) Duration of exposure.

(6) Axes of exposure.

(7) Location of accelerometers.

I-3.1 Choice of test procedures. The choice of test procedure is governed by the vibration environments to be tested for. These environments should all be identified during the part of the tailoring process described in 4.2.2.2 of General Requirements.

Table 514.3-I divides vibration environments into twelve categories--three transportation-induced and nine application-induced. Procedure I is used for testing an item to nine of these categories. Procedures II, III, and IV are each used for one of the three remaining categories.

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TABLE 514.3-I. Vibration environment categories.1/

DIVISION	CATEGORY	DESCRIPTION	TEST PROCEDURE	TEST CONDITIONS2/
Transportation/ Cargo-Induced Vibration	1. Basic Transportation	Equipment carried as secured cargo.	I	I-3.2.1
	2. Large Assembly Transport	Very large shelters, van, & trailer systems as an alternative to shaker testing.	III	I-3.2.2
	3. Loose Cargo Transport	Equipment carried on ground vehicles as unrestrained cargo.	II	I-3.2.3
Application-Induced Vibration	4. Propeller Aircraft	Equipment installed in propeller aircraft manned and unmanned.	I	I-3.2.4
	5. Jet Aircraft/ Tactical Missiles	Equipment installed in jet aircraft, manned and unmanned, and installed in tactical missiles - free flight phase.	I	I-3.2.5
	6. Helicopter	Equipment installed in helicopters.	I	I-3.2.6
	7A. External Stores	Assembled stores externally carried on jet aircraft (including captive missile flight).	IV	I-3.2.7
	7B. External Stores	Equipment installed in stores externally carried on jet aircraft.	I	I-3.2.8
	7C. External Stores	Assembled stores externally carried on helicopters.	I	I-3.2.9
	8. Ground Mobile	Equipment installed in wheeled vehicles, trailers, and tracked vehicles.	I	I-3.2.10
	9. Marine	Equipment installed in ships or other naval watercraft.	I	I-3.2.11
	10. Minimum Integrity Test	a. All other. b. Vibration-isolated equipment.	I	I-3.2.12

1/ Also referred to as "equipment categories".

2/ The provisions of section I-4 apply to all vibration tests.

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An item should be tested to a category when the item is either

a. intended for use within that category as a mission requirement or

b. expected to spend a significant portion of its service life within that category as a consequence of its deployment, storage, or use.

An item will probably be tested to more than one category. For example, equipment installed in jet aircraft is covered by categories 1 (Basic Transportation) and 5 (Jet Aircraft/Tactical Missiles) and may be tested in both environments.

I-3.1.1 Comparison of environments prior to test

I-3.1.1.1 More than one application environment. If an item is expected to encounter more than one vibration environment as a consequence of its intended use, the environments should be compared. If any of them would apply similar stress levels or similar bandwidths, the most severe category test should be applied as representative.

I-3.1.1.2 Transportation and application environments. If the transportation vibration levels are more severe than the application-induced vibration levels, as is often true for ground-based and some shipboard equipment, both transportation and platform vibration tests should be performed. This is because the transportation test is performed with the equipment nonoperating and the platform test is performed with the equipment on.

If the application vibration levels are more severe than the transportation levels, further analysis must be performed to compare the fatigue potential of both environments over the life cycle. If the platform environment is still found to be more severe, the transportation test can be deleted.

I-3.2 Choice of related test conditions. Guidance for setting test values is given below with the discussion of each vibration environment category. The provisions of section I-4 of this method apply for each test designed under this method.

For categories I thru III, the following definitions apply:

a. Secured cargo. Cargo which is securely tied or blocked in all three axes with respect to the bed of the transport vehicle.

b. Restrained cargo. Cargo which is blocked or tied in the two horizontal axes with respect to the bed of the transport vehicle.

c. Loose cargo. Cargo which is not tied, blocked, or restrained when placed on the bed of the transport vehicle.

A test for restrained cargo is not included in the categories below. Such a test may be devised by using field measurements to tailor the most appropriate procedure.

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TRANSPORTATION VIBRATION

I-3.2.1 Category 1 - Basic transportation

All equipment shipped as secured cargo by land, sea or air will encounter this environment. The test levels are based upon land transport stress levels because these are higher than air or sea stresses, and all air and sea transport scenarios include prior or subsequent land transport.

This test is tailorable to the maximum extent of available data. The test levels shown in figures 514.3-1 thru 514.3-22 represent real, measured stresses. The land mobile environment is characterized by broadband vibration resulting from the interaction of vehicle suspension and structures with road and surface discontinuities. Representative conditions experienced in moving materiel from point of manufacture to end use are depicted in figure 1 of General Requirements. These conditions may be divided into two phases, common carrier transportation and mission/field transportation. Common carrier transportation is movement from the manufacturer's plant to any continental United States storage or user installation. This movement is usually accomplished by large truck and/or tractor-trailer combination. Mileage for this transportation generally ranges from 2000 to 4000 miles over improved or paved highways.

Mission/field transportation is that movement of materiel as cargo where the platform may be two wheeled trailers, 2-1/2 ton to 10-ton trucks, semitrailers, and/or tracked vehicles. Typical distances for this phase are 300 to 500 miles. Road conditions for mission/field transport differ from the common carrier in that, in addition to the paved highway, the vehicles will traverse unimproved roads and unprepared terrain (off-the-road) under combat conditions.

a. Test levels. Whenever possible, measured data should be collected on a variety of large conventional trucks, semitrailers, forklifts with shipping pallets, and conventional flatbed transport vehicles used in the common carrier environment with a realistic load configuration of 75% of the vehicle load capacities by weight. For the mission/field environment, data are required from typical tactical vehicles, to include: two wheeled trailers, 2-1/2 ton to 10-ton trucks, semi-trailers, and any tracked vehicle capable of or used for transport of cargo. This data shall then be used to develop test spectra as outlined in appendix A. If measured data are not available, the vibration inputs contained in figures 514.3-1 thru 514.3-22 may be used.

In the development of the vibration test it must be determined if the test item will experience the common carrier, mission/field, or both transportation environments. For test items that will only be transported via common carrier, test levels and conditions shall be derived from the measured data of the common carriers or from figures 514.3-1 thru 514.3-3. Test items that will experience both transportation environments should be tested at the higher levels associated with the mission/field transportation. The levels for this environment can be obtained from figures 514.3-4 thru 514.3-22. The test must be developed from a typical mission/field transportation scenario to obtain the proper mix and representative combination of platform and mileage requirements.

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Figures 514.3-1 thru 514.3-3 depict the common carrier environment. These figures are based upon data measured at the cargo floor of seven different configurations of trucks and tractor-trailer combinations. Both coventional suspensions and air-cusioned suspensions are represented. The data was collected from typical interstate highways with rough portions as part of the data base.

Figures 514.3-4 thru 514.3-6 represent the cargo environment at the floor of the M105 two-wheeled trailer. The data include differing vehicle load conditions traversing over specially designed courses ranging from paved highway to offroad conditions at various vehicle speeds. As seen, the spectrum is broadband random with peaks and notches at various discrete frequency bands. The break points of the peaks and notches are given for establishing the spectrum shape. Two-wheeled trailers of significantly different size and design may provide substantially different input to the cargo loaded on the bed than displayed in figures 514.3-4 thru 514.3-6 and spectra should be adjusted accordingly.

Figures 514.3-7 thru 514.3-9 represent the cargo environment at the cargo bed of a composite of tactical wheeled vehicles, the 5-ton M813 truck and the 12-ton M127 semi-trailer. The data include differing vehicle loading conditions traversing over specially designed courses ranging from paved highway to offroad conditions at various vehicle speeds. Again the spectrum is broadband random with peaks and notches at various discrete frequency bands. Break points are provided for establishing the spectrum shape. Tactical wheeled vehicles of significantly different size and design from the M813 and M127 may provide substantially different input to the cargo loaded on the bed than displayed in figures 514.3-7 thru 514.3-9 and spectra should be adjusted accordingly.

Figures 514.3-10 thru 514.3-22 represent the environment at the floor of the M548 tracked vehicle. The data utilized for establishing these spectra were derived from measurements of the vehicle operating at various speeds over specially designed courses ranging from paved highway to offroad conditions. This environment contains a low level of broadband random upon which is superimposed narrowband random at discrete frequency bands. The broadband random base is from the basic movement of the vehicle, suspension system and road discontinuities. The narrowband random excitation is associated with the track-laying pattern and road surface.

b. Test durations. The test duration for Basic Transportation should be based upon total miles of expected transportation. A method for development of test durations is included in appendix 1. The common carrier spectra given in figures 514.3-1 thru 514.3-3 have a test time duration of 60 minutes per 1000 miles. For tests which utilize the test spectra contained in figures 514.3-4 thru 514.3-22, the time durations per test axis are given on the individual figures, with the exception of the M548 Cargo Carrier. The total test time for that particular vehicle is 60 minutes per 16 miles, which consists of testing in several phases per axis (the test time per phase is given on the appropriate figure) to accommodate the total swept narrowband random-on-random environment.

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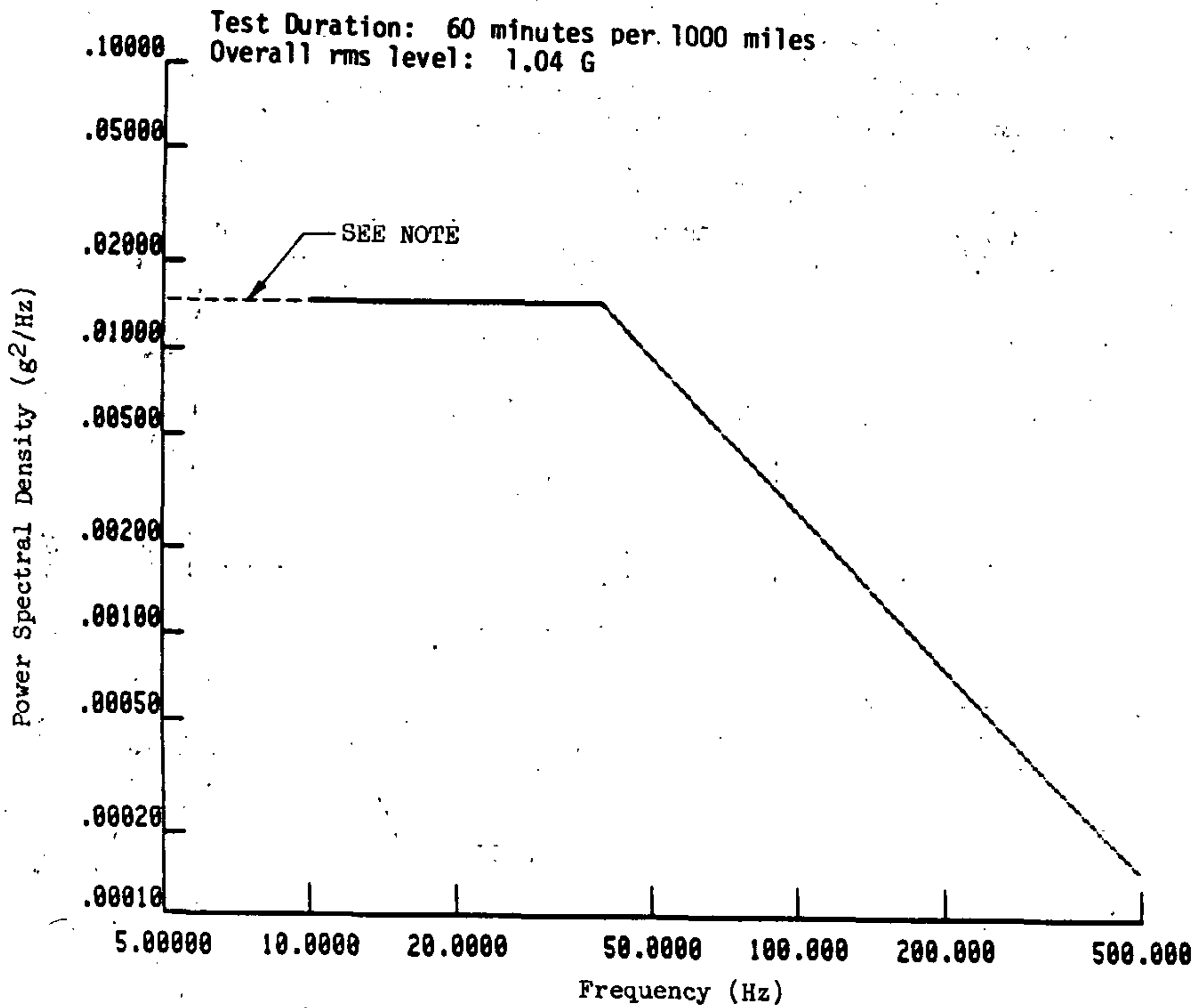

BREAKPOINTS

FREQ	PSD VALUE
10	.01500
40	.01500
500	.00015

NOTE: If it is known that excitation is expected below 10 Hz, the curve shall be extended and shaped to comply with the available data.

FIGURE 514.3-1. Basic transportation, common carrier environment, vertical axis.

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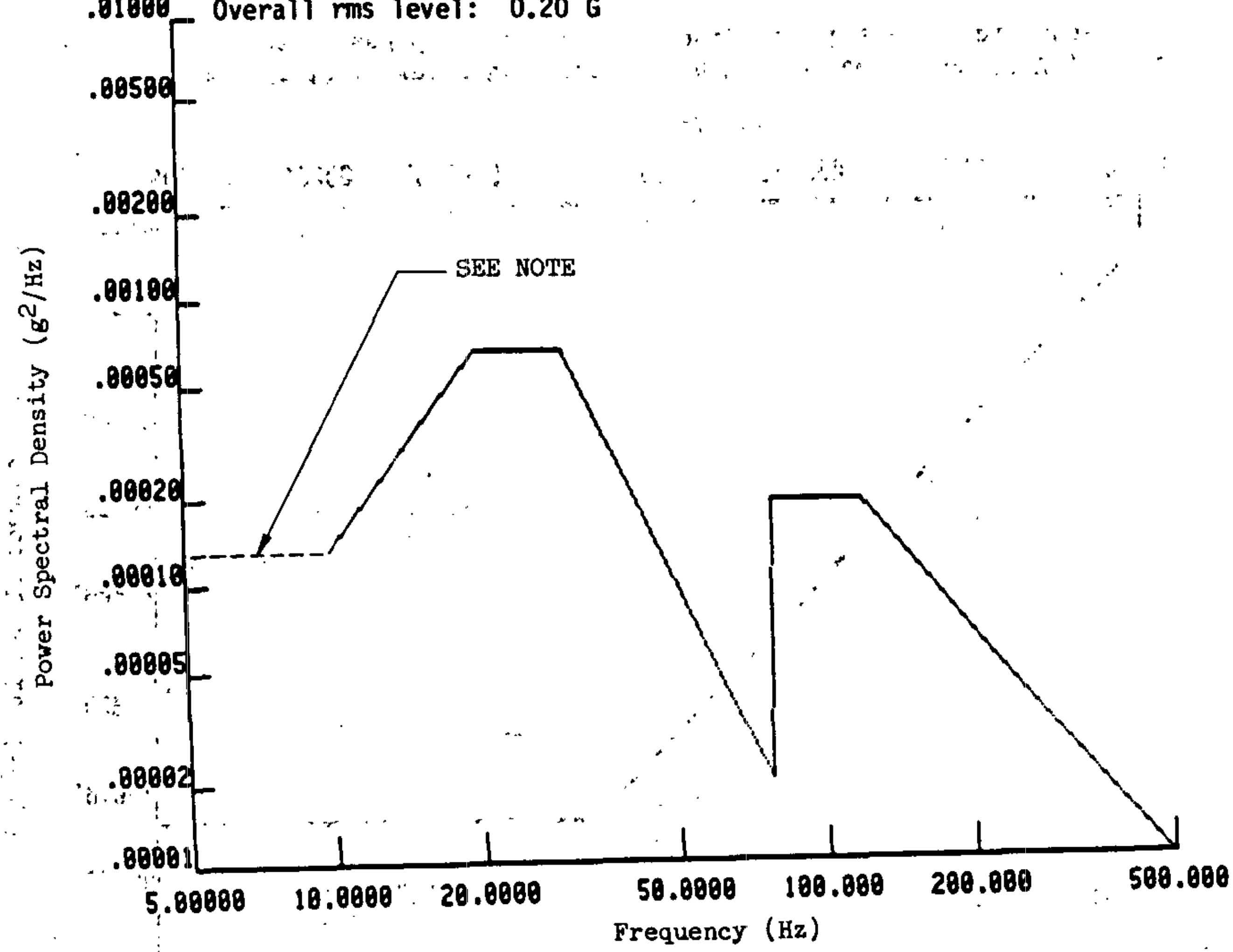
Test Duration: 60 minutes per 1000 miles
Overall rms level: 0.20 G

BREAKPOINTS

FREQ	PSD VALUE
10	.00013
20	.00065
30	.00065
78	.00002
79	.00019
120	.00019
500	.00001



NOTE: If it is known that excitation is expected below 10 Hz, the curve shall be extended and shaped to comply with the available data.

FIGURE 514.3-2. <u>Basic transportation, common carrier environment, transverse axis</u>.

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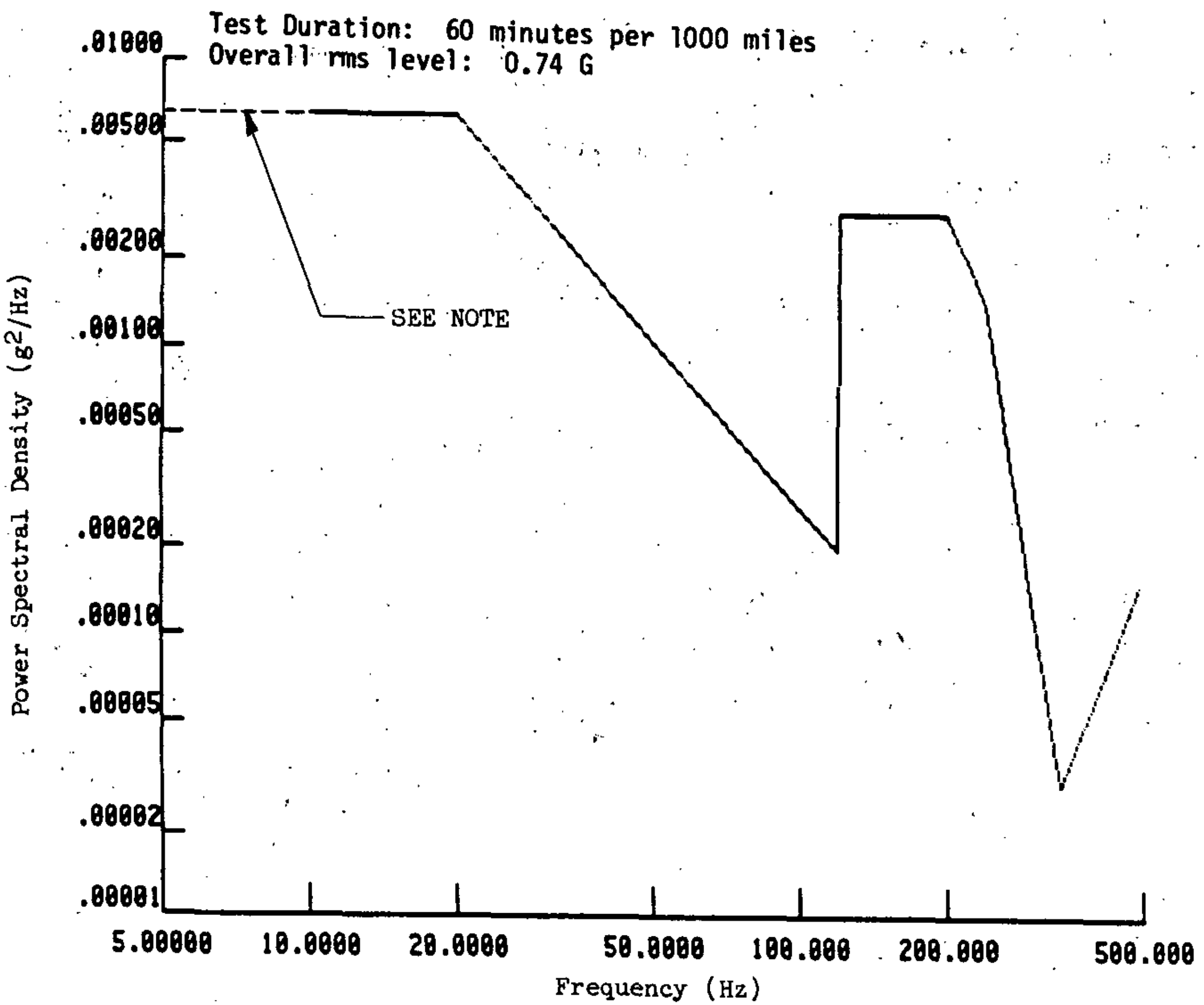

BREAKPOINTS

FREQ	PSD VALUE
10	.00650
20	.00650
120	.00020
121	.00300
200	.00300
240	.00150
340	.00003
500	.00015

NOTE: If it is known that excitation is expected below 10 Hz, the curve shall be extended and shaped to comply with the available data.

FIGURE 514.3-3. <u>Basic transportation, common carrier environment, longitudinal axis</u>.

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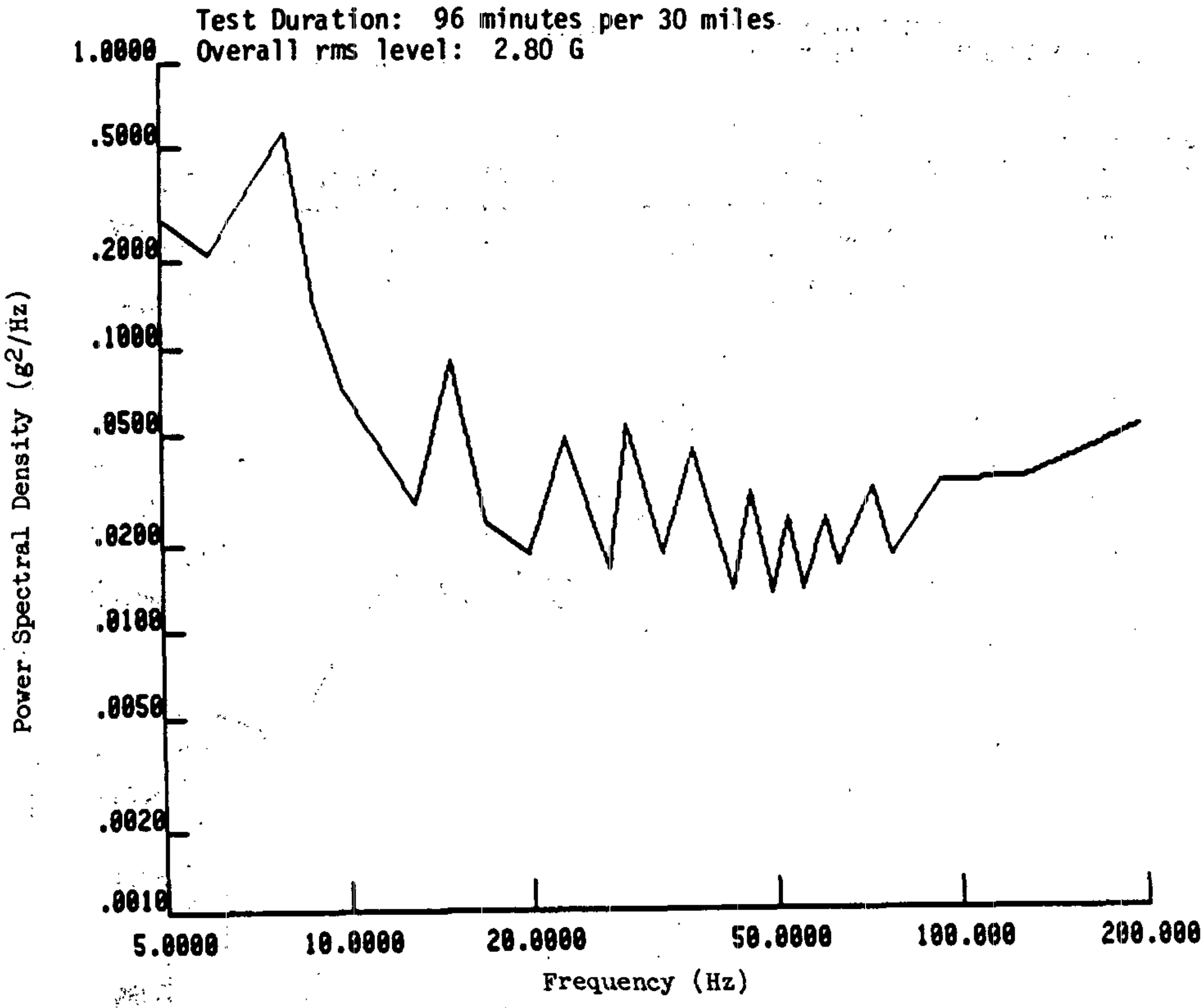

BREAKPOINTS

FREQ	PSD VALUE
5	.28470
6	.21130
8	.57090
9	.13850
10	.07080
13	.02820
15	.09080
17	.02430
20	.01850
23	.04880
27	.01640
29	.05390
33	.01850
37	.04420
43	.01370
46	.03120
50	.01340
53	.02490
56	.01370
61	.02490
64	.01680
73	.03200
78	.01810
94	.03360
128	.03450
200	.05260

FIGURE 514.3-4. Basic transportation, two wheeled trailer environment, vertical axis.

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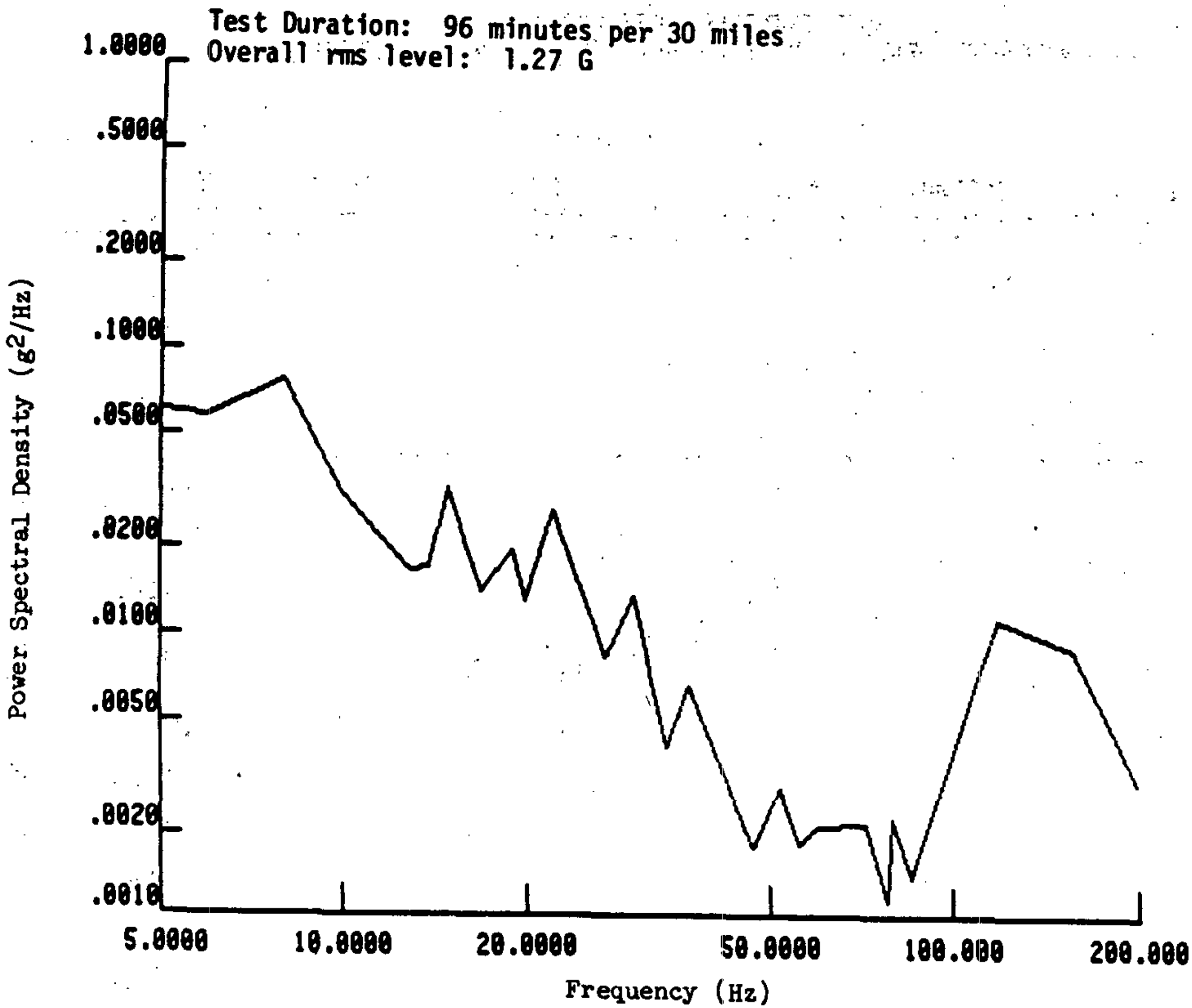

BREAKPOINTS

FREQ	PSD VALUE
5	.06084
6	.05789
8	.07800
10	.03110
13	.01671
14	.01713
15	.03269
17	.01416
19	.01989
20	.01303
22	.02747
27	.00833
30	.01370
34	.00405
37	.00666
47	.00179
52	.00294
56	.00183
60	.00212
72	.00218
78	.00114
80	.00229
86	.00139
119	.01151
158	.00898
200	.00308

FIGURE 514.3-5. Basic transportation, two wheeled trailer environment, transverse axis.

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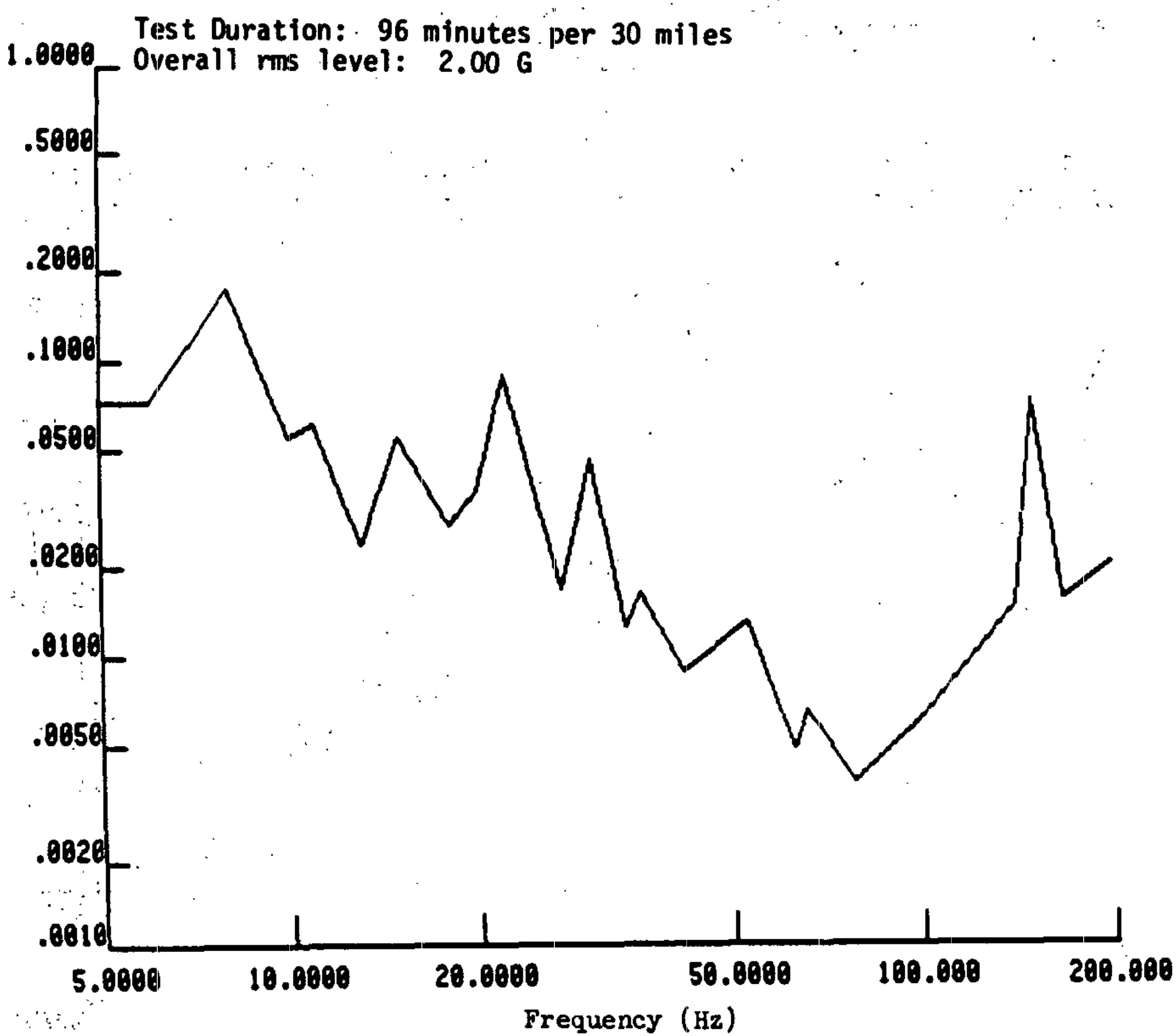
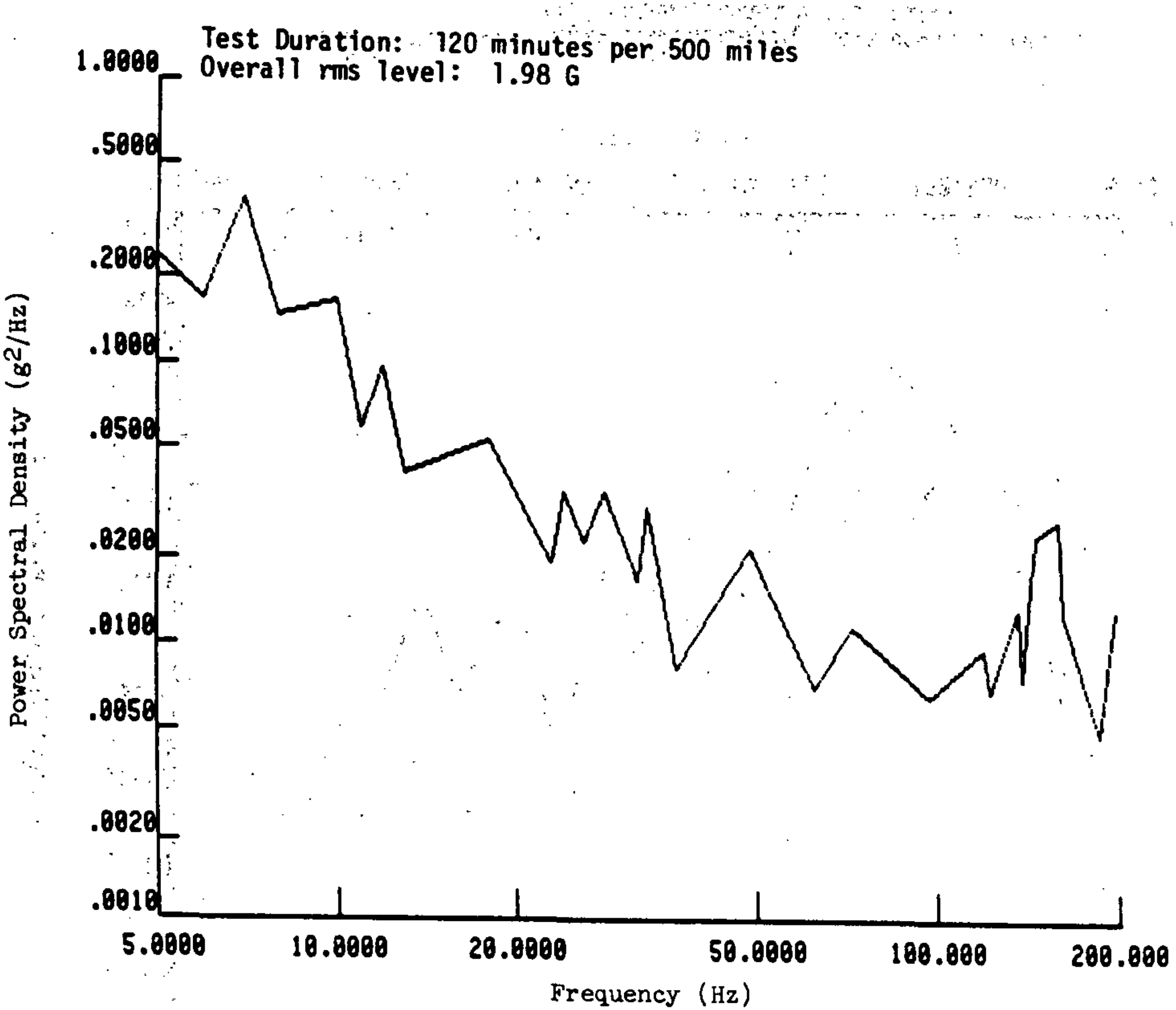


BREAKPOINTS

FREQ	PSD VALUE
5	.07220
6	.07220
8	.17660
10	.05490
11	.06070
13	.02360
15	.05490
18	.02740
20	.03600
22	.09030
27	.01670
30	.04620
34	.01240
36	.01630
42	.00870
53	.01300
63	.00480
66	.00660
78	.00370
102	.00630
141	.01470
150	.07400
167	.01550
200	.02030

FIGURE 514.3-6. Basic transportation, two wheeled trailer environment, longitudinal axis.



BREAKPOINTS

FREQ	PSD VALUE
5	.23840
6	.16840
7	.38230
8	.14870
10	.16840
11	.05930
12	.09750
13	.04090
18	.05370
23	.01940
24	.03520
26	.02310
28	.03520
32	.01670
33	.03110
37	.00810
49	.02190
63	.00700
73	.01150
98	.00660
120	.00970
123	.00680
138	.01340
140	.00760
146	.02490
159	.02820
163	.01300
188	.00480
200	.01340

FIGURE 514.3-7. Basic transportation, composite tactical wheeled environment, vertical axis.

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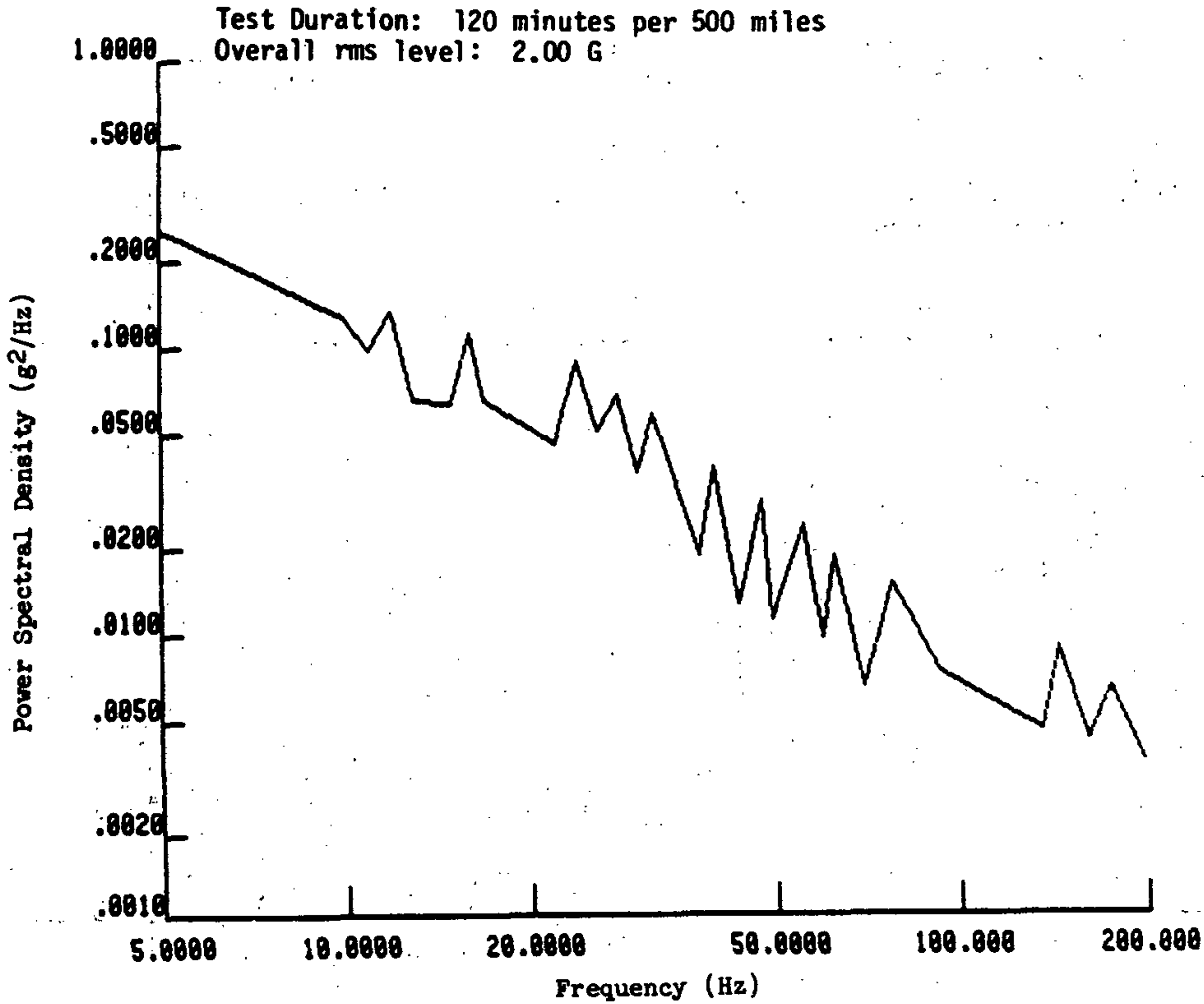

BREAKPOINTS

FREQ	PSD VALUE
5	.25490
10	.13030
11	.09670
12	.13360
13	.06500
15	.06340
16	.11230
17	.06500
22	.04590
24	.08980
26	.05070
28	.06830
30	.03670
32	.05880
38	.01920
40	.03860
44	.01290
48	.02940
50	.01140
56	.02460
60	.00960
63	.01880
70	.00660
78	.01500
93	.00730
137	.00460
145	.00910
162	.00430
176	.00660
200	.00360

FIGURE 514.3-8. Basic transportation, composite tactical wheeled environment; transverse axis.

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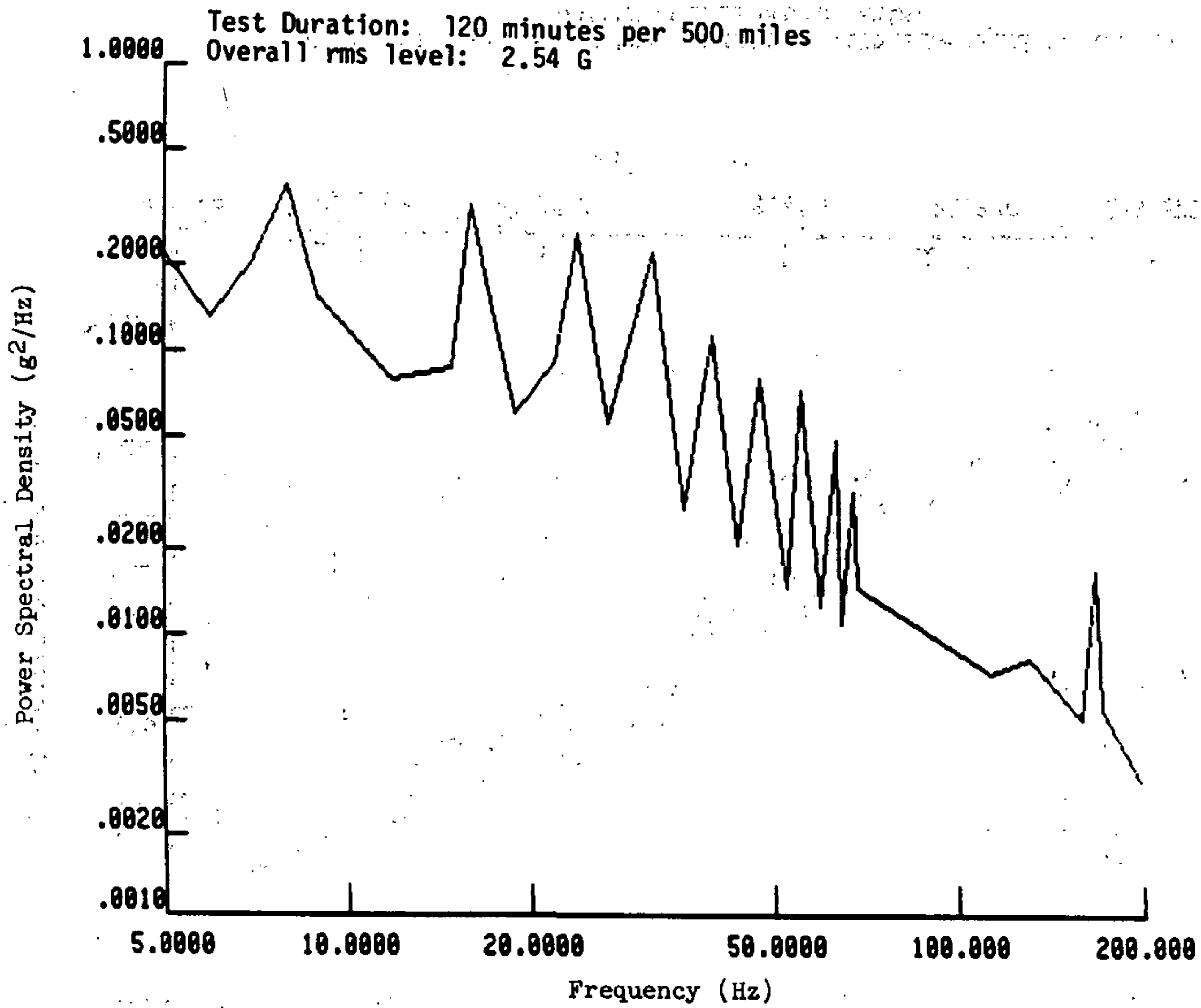
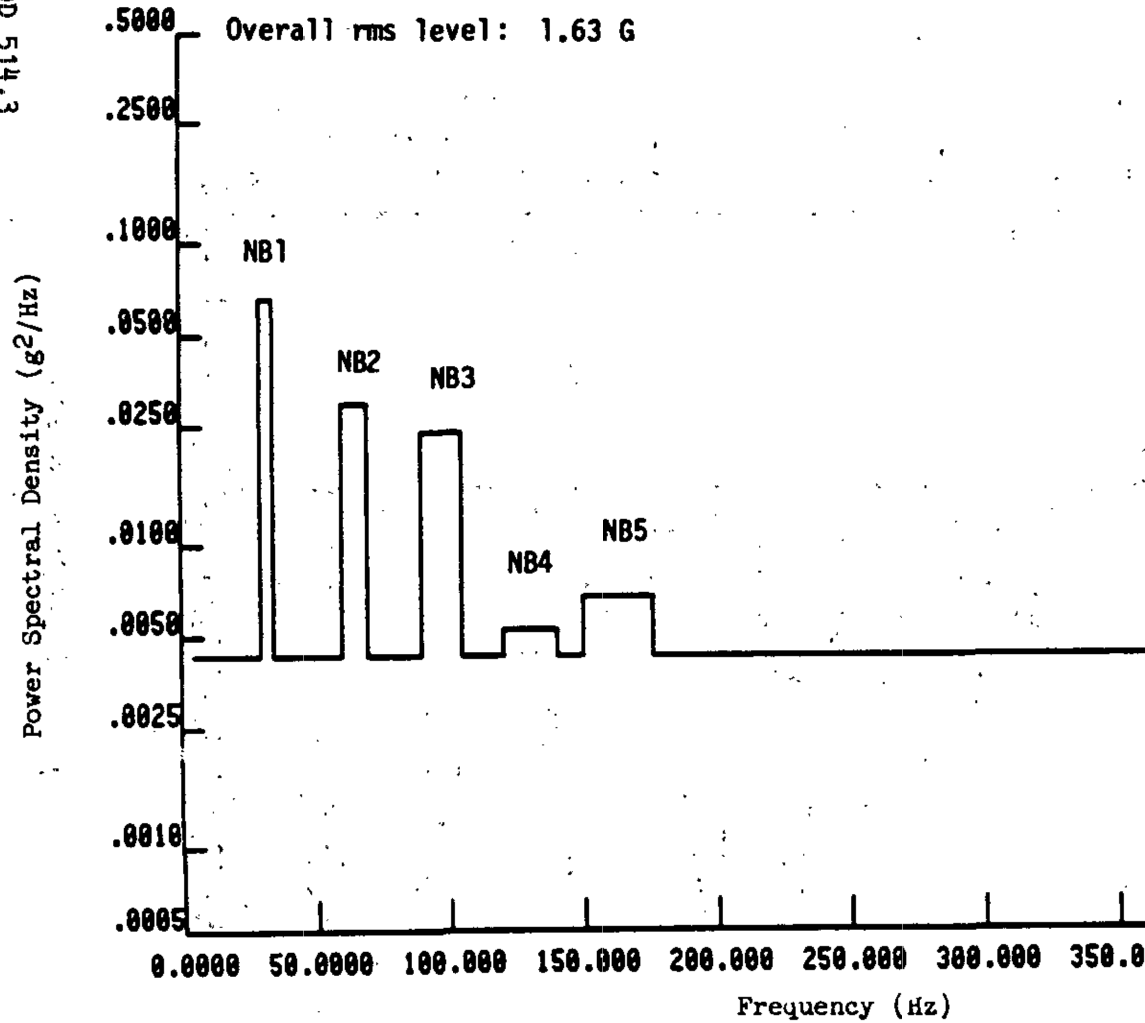


BREAKPOINTS

FREQ	PSD VALUE
5	.22130
6	.13140
7	.20540
8	.38230
9	.15630
12	.07990
15	.08830
16	.32940
19	.06080
22	.09280
24	.26340
27	.05640
32	.22690
36	.02820
40	.11600
44	.02090
48	.08190
53	.01480
56	.07420
60	.01270
64	.04980
65	.01100
68	.03260
69	.01480
114	.00740
132	.00830
160	.00510
169	.01710
173	.00550
200	.00310

FIGURE 514.3-9. Basic transportation, composite tactical wheeled environment, longitudinal axis.



Test Time = 12 minutes
No. Sweeps = 1

	Narrow BW (Hz)	Amplitude (g^2/Hz)	Sweep BW (Hz)
NB1	30-35	0.06554	2
NB2	60-70	0.02995	4
NB3	90-105	0.02358	6
NB4	120-140	0.00522	8
NB5	150-175	0.00670	10

Wide Band Data
0.00430 g^2/Hz (5-500 Hz)

FIGURE 514.3-10. Basic transportation, tracked vehicle (M548) environment, vertical axis, test phase 1.

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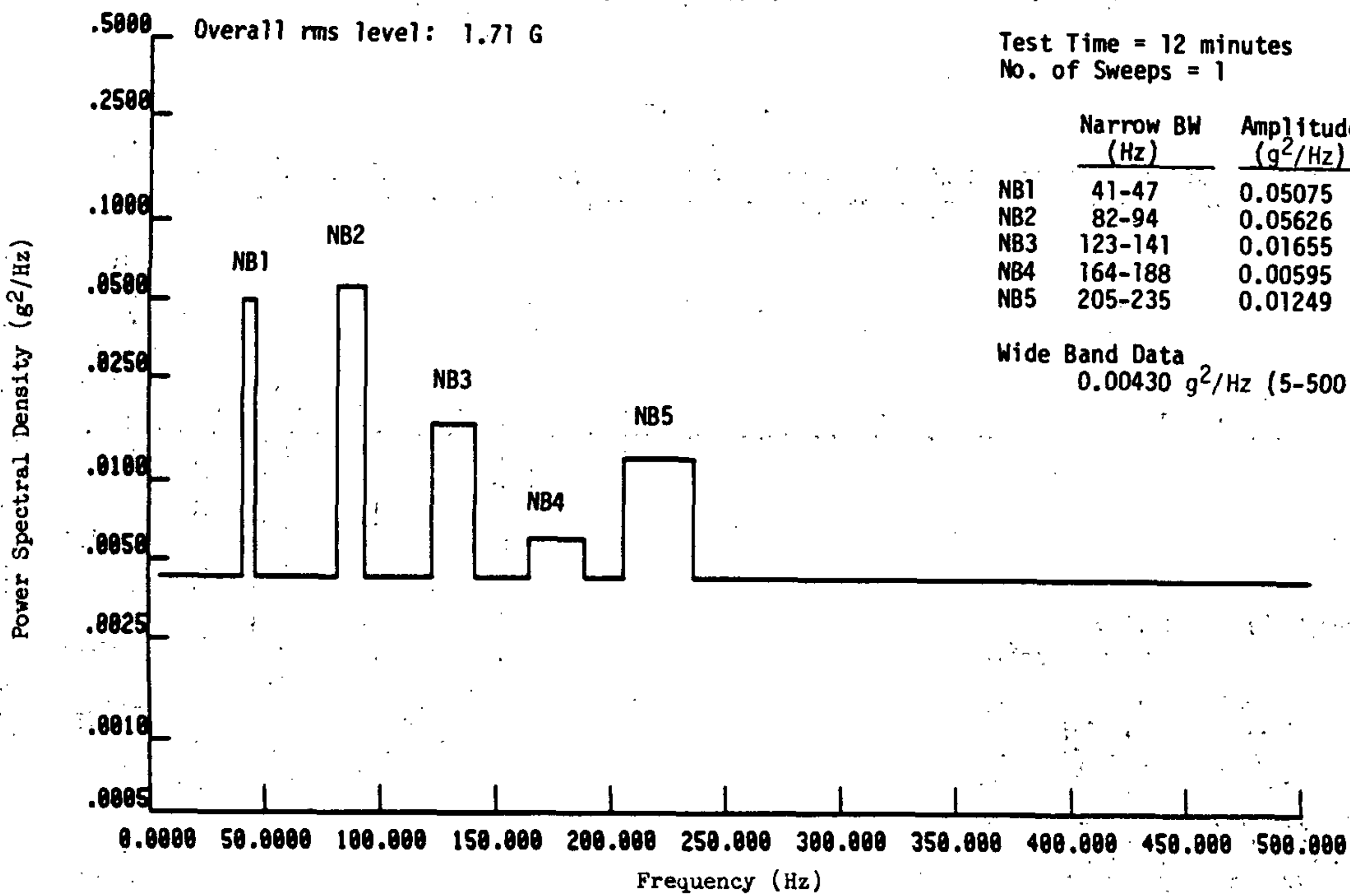

Test Time = 12 minutes
No. of Sweeps = 1

	Narrow BW (Hz)	Amplitude (g^2/Hz)	Sweep BW (Hz)
NB1	41-47	0.05075	3
NB2	82-94	0.05626	6
NB3	123-141	0.01655	9
NB4	164-188	0.00595	12
NB5	205-235	0.01249	15

Wide Band Data
0.00430 g^2/Hz (5-500 Hz)

FIGURE 514.3-11. Basic transportation, tracked vehicle (M548) environment, vertical axis, test phase 2.

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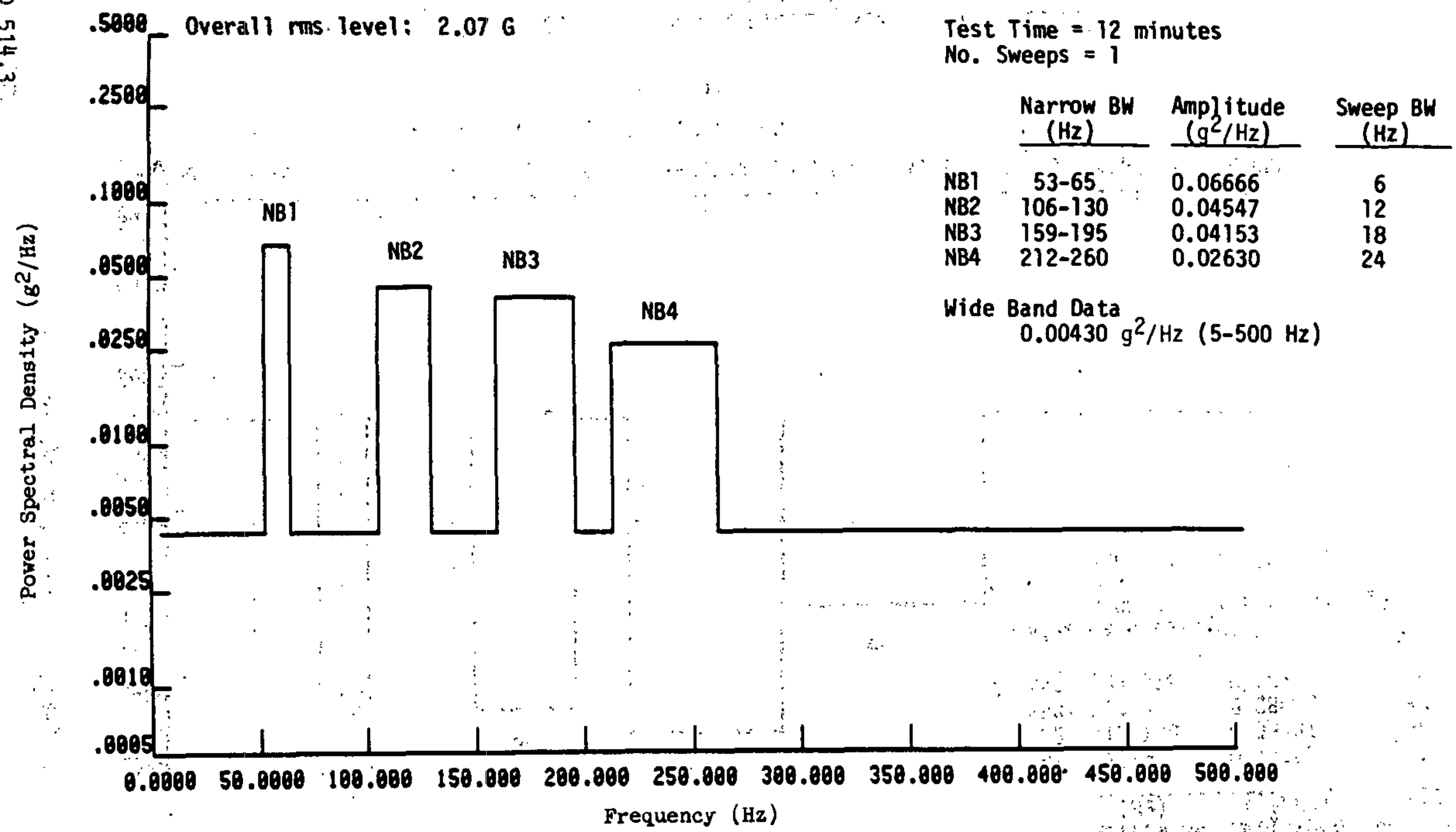

FIGURE 514.3-12. Basic transportation, tracked vehicle (M548) environment, vertical axis, test phase 3.

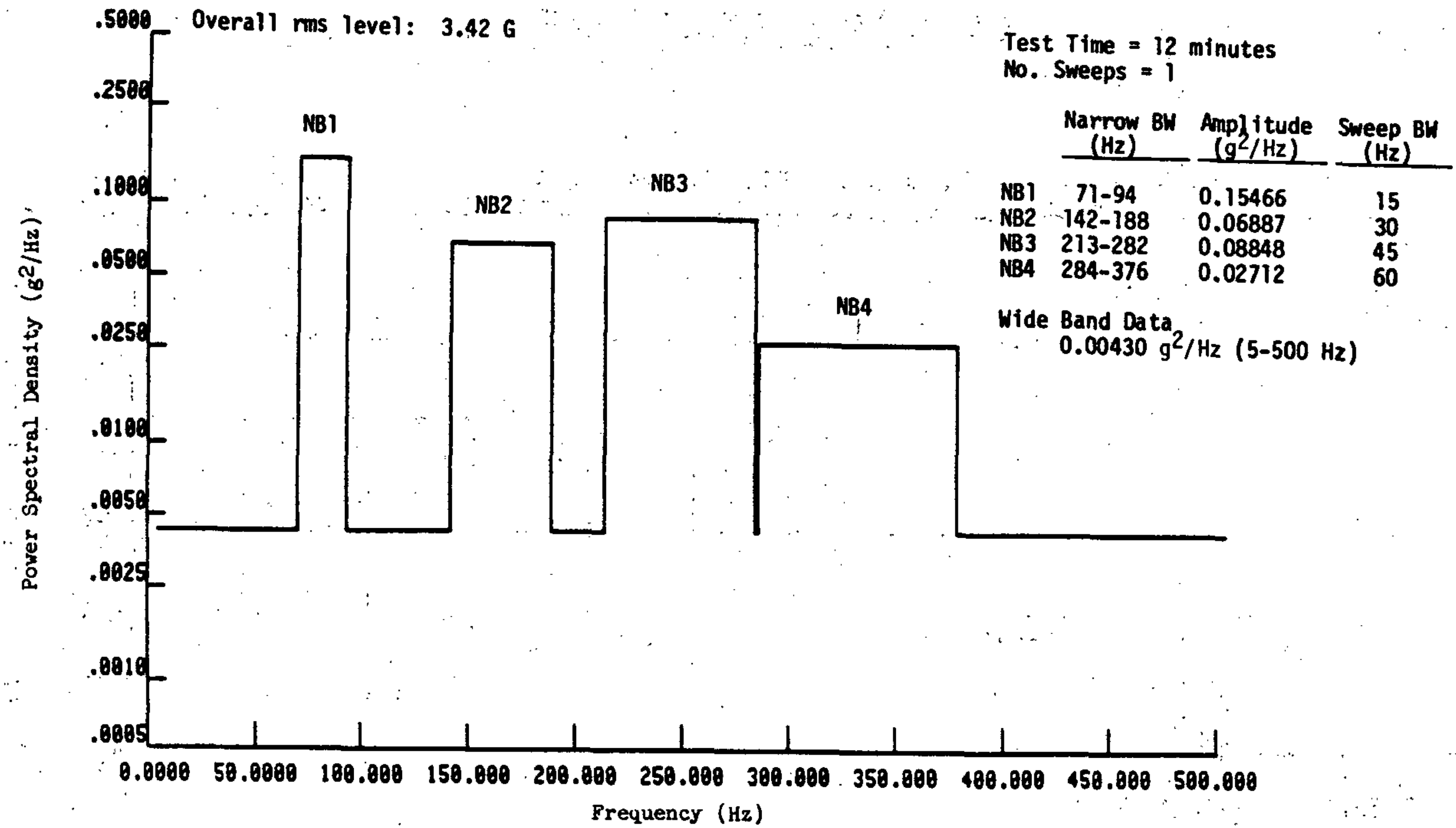

FIGURE 514.3-13. Basic transportation, tracked vehicle (M548) environment, vertical axis, test phase 4.

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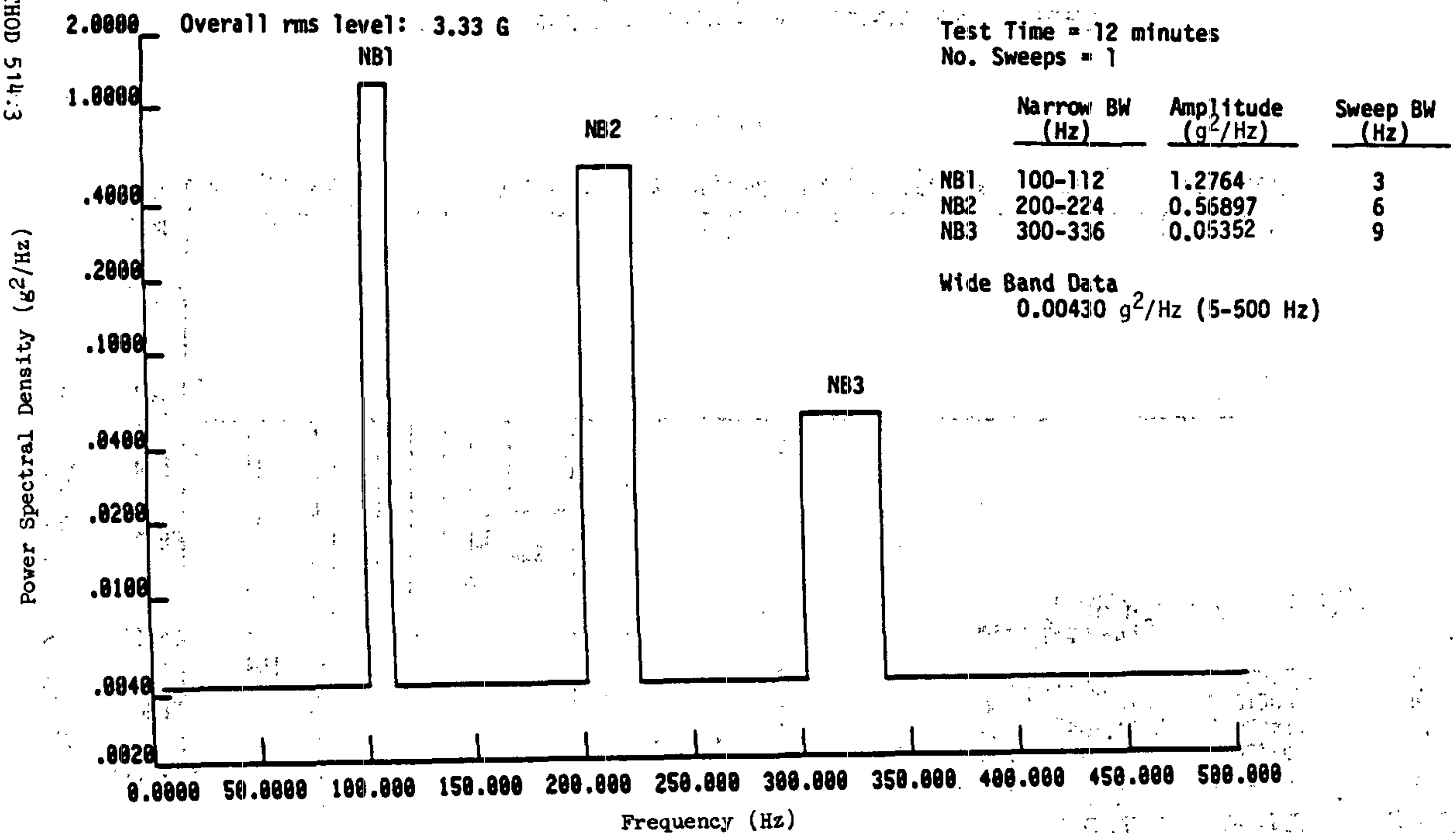

FIGURE 514.3-14. Basic transportation, tracked vehicle (M548) environment, vertical axis, test phase 5.

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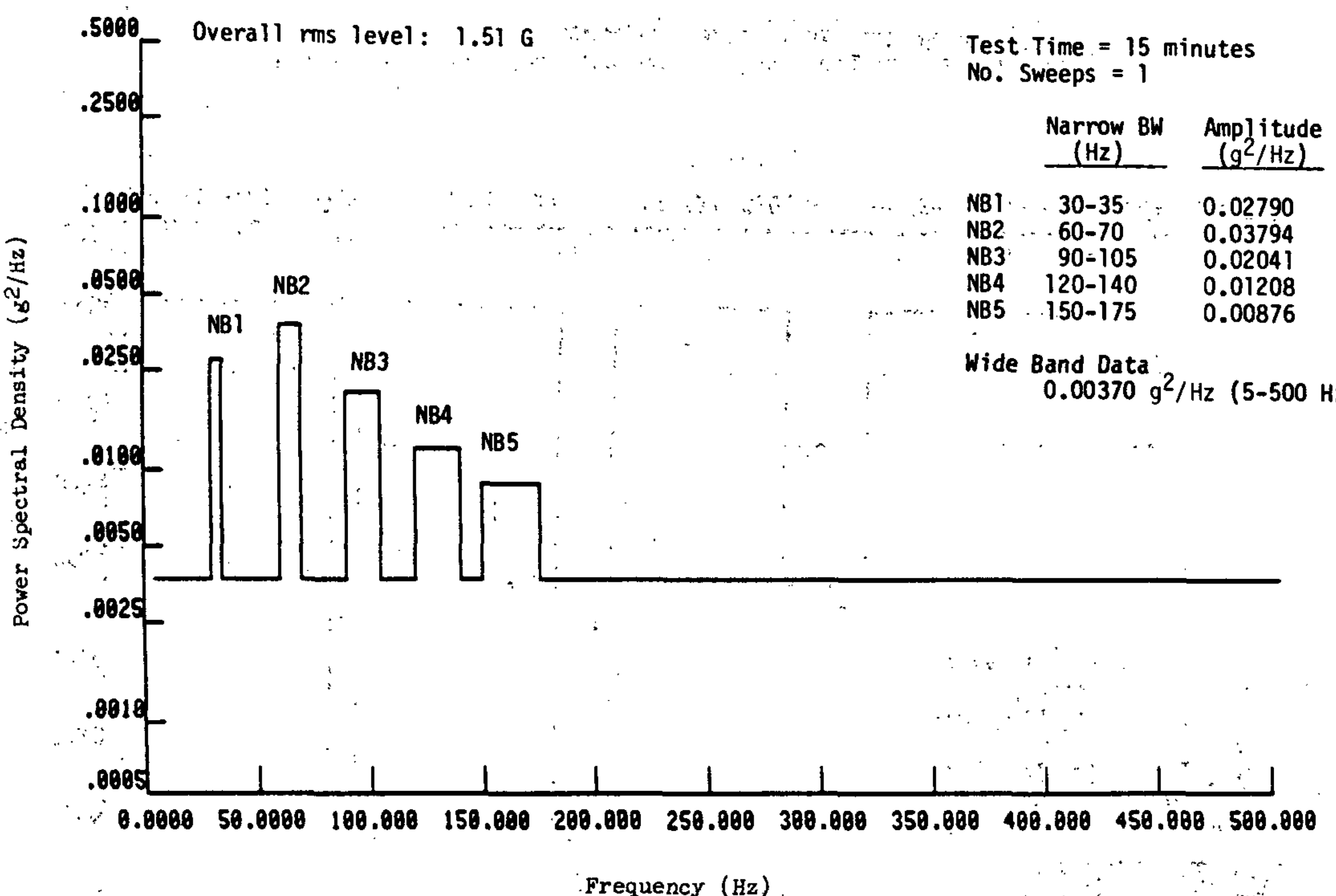

Test Time = 15 minutes
No. Sweeps = 1

	Narrow BW (Hz)	Amplitude (g^2/Hz)	Sweep BW (Hz)
NB1	30-35	0.02790	2
NB2	60-70	0.03794	4
NB3	90-105	0.02041	6
NB4	120-140	0.01208	8
NB5	150-175	0.00876	10

Wide Band Data
0.00370 g^2/Hz (5-500 Hz)

FIGURE 514.3-15. Basic transportation, tracked vehicle (M548) environment, transverse axis, test phase 1.

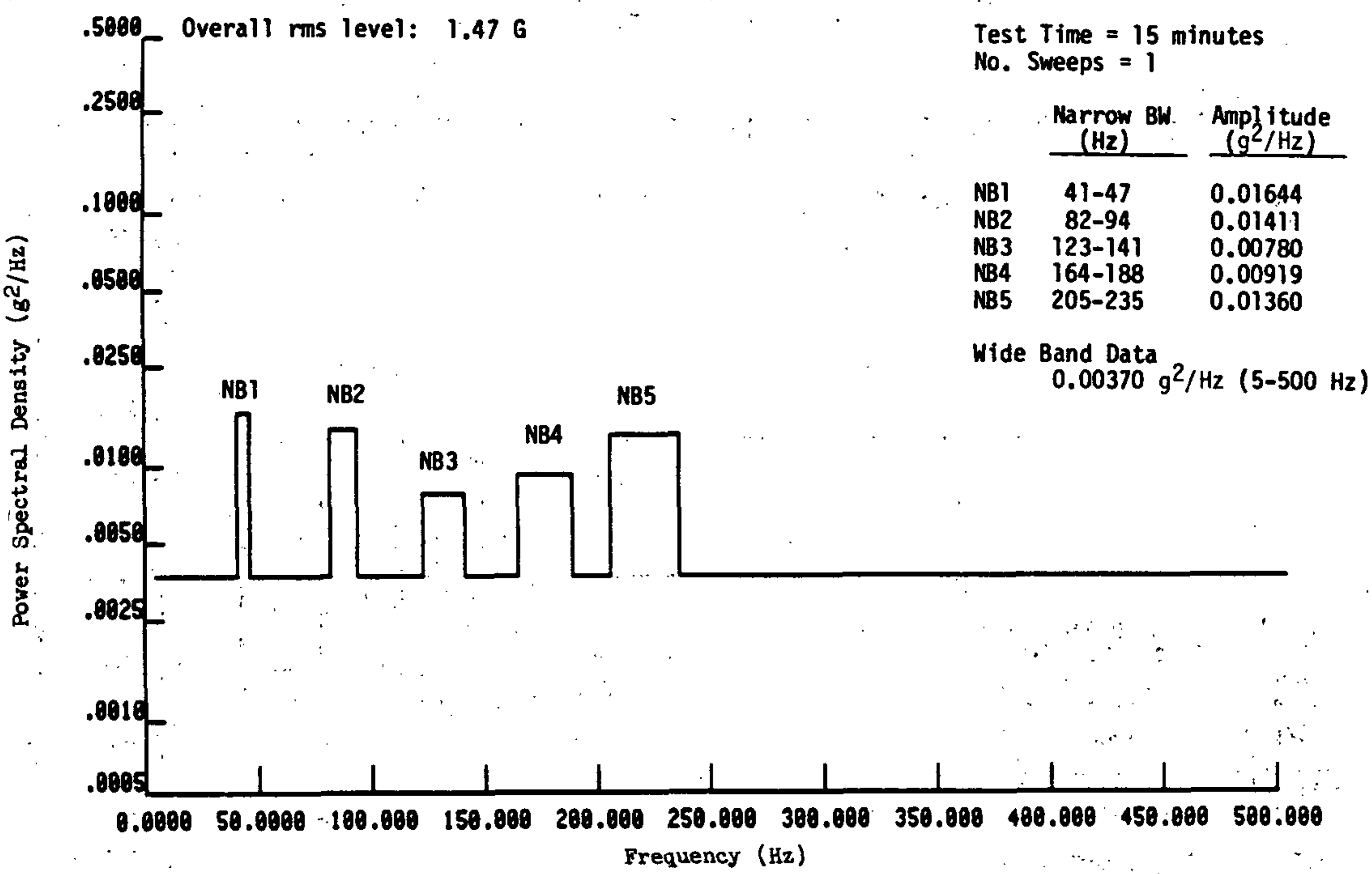

FIGURE 514.3-16. Basic transportation, tracked vehicle (M548) environment, transverse axis, test phase 2.

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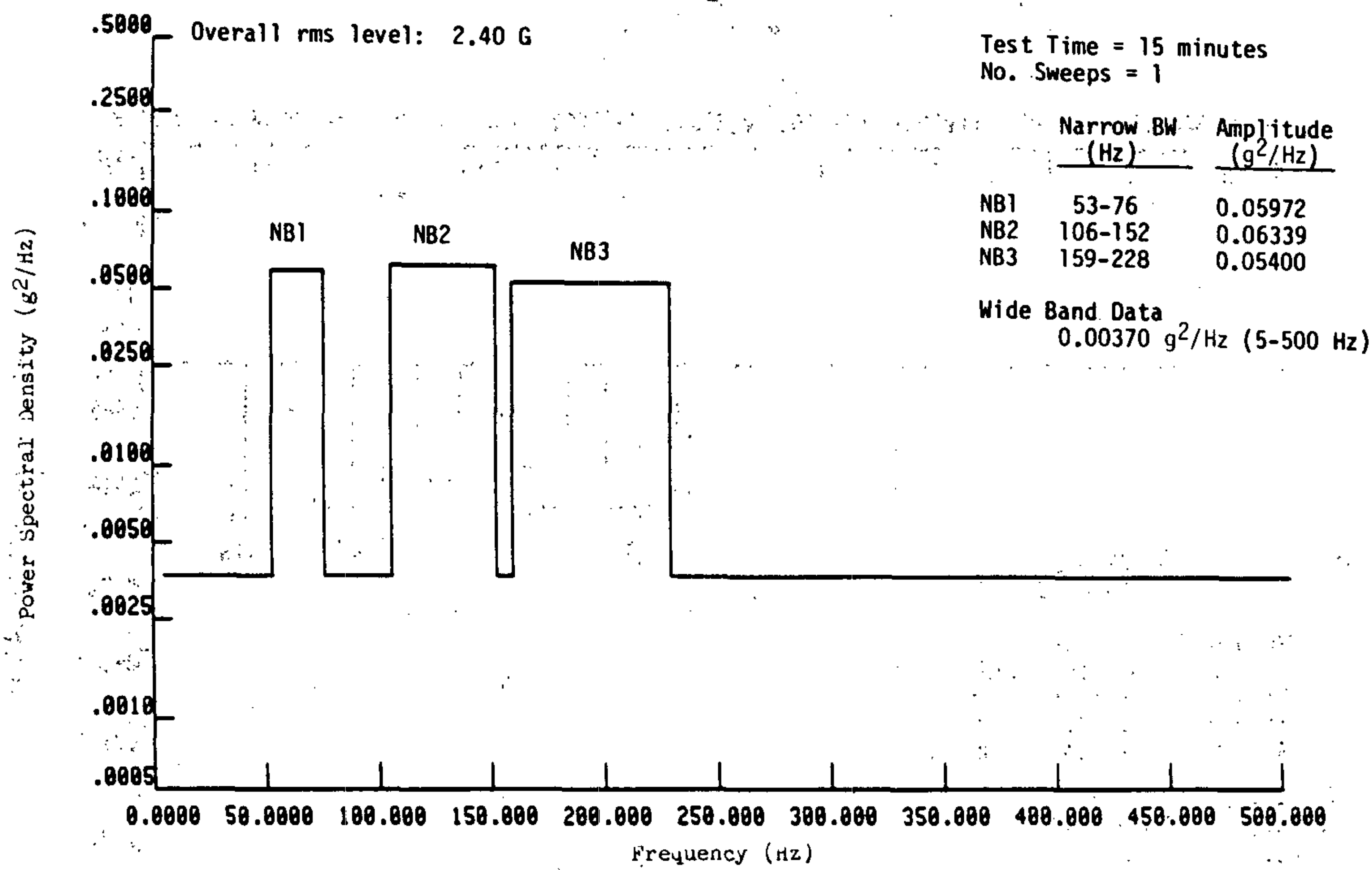

FIGURE 514.3-17. Basic transportation, tracked vehicle (M548) environment, transverse axis, test phase 3.

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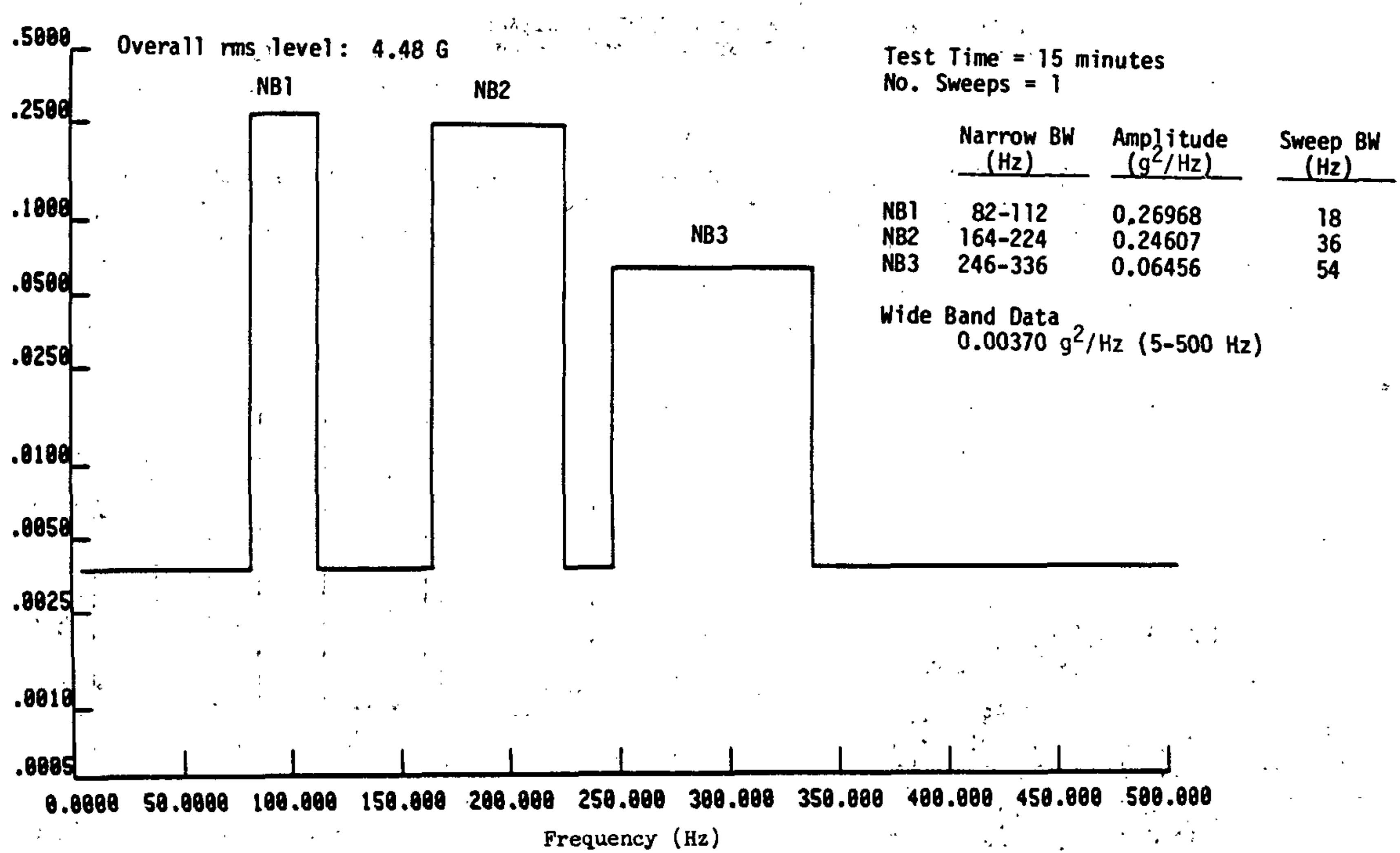

FIGURE 514.3-18. Basic transportation, tracked vehicle (M548) environment, transverse axis, test phase 4.

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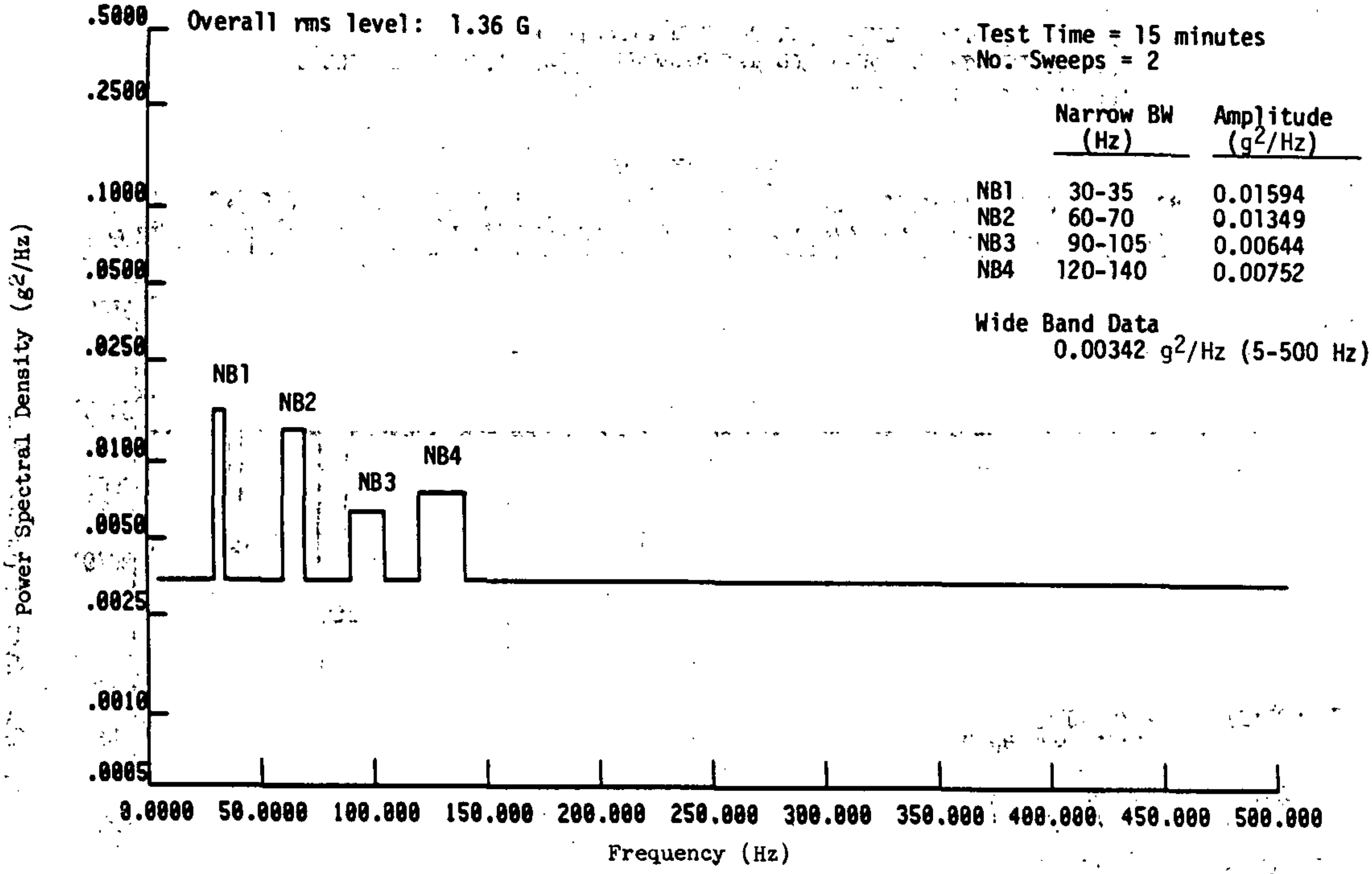

FIGURE 514.3-19. Basic transportation, tracked vehicle (M548) environment, longitudinal axis, test phase 1.

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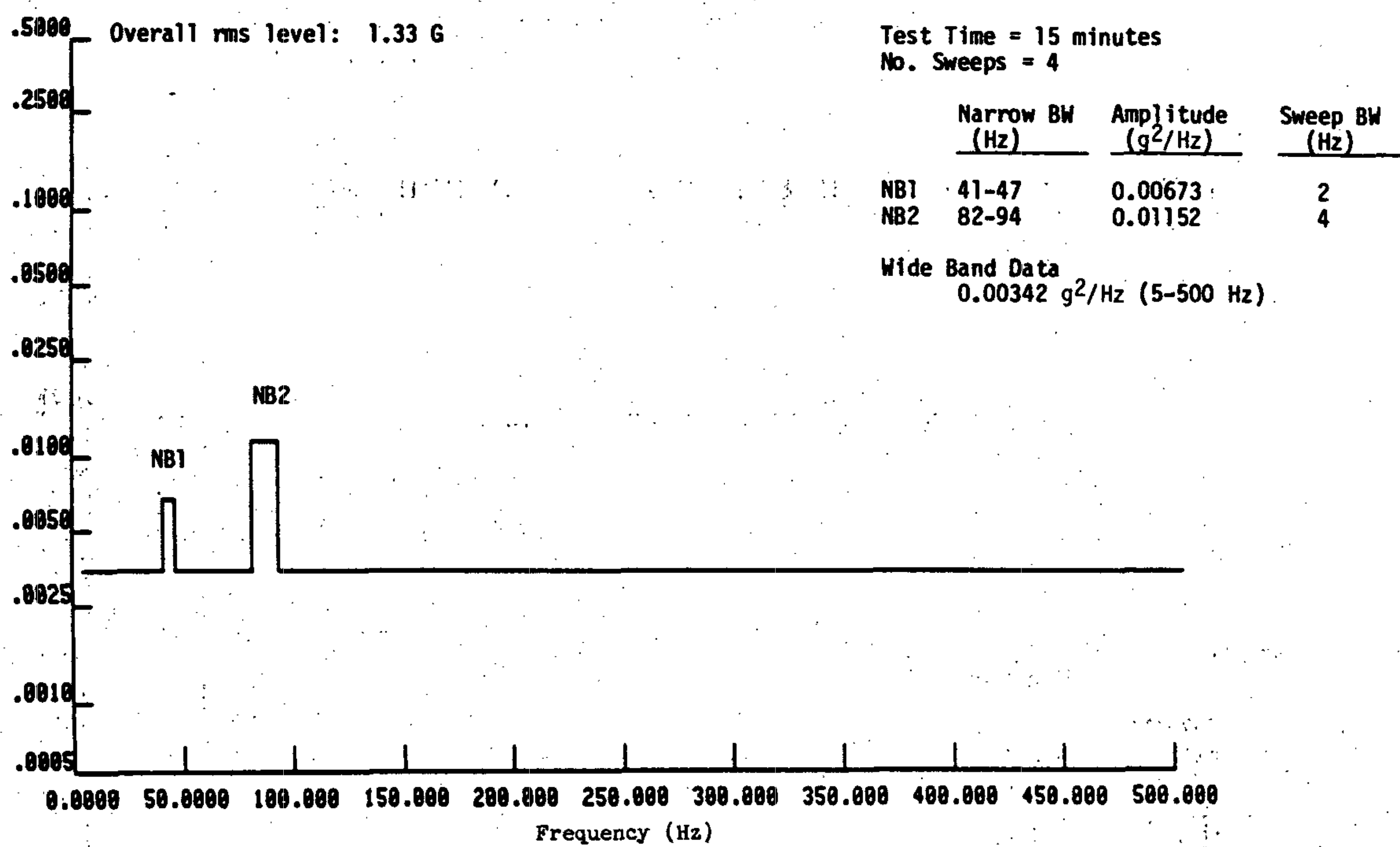
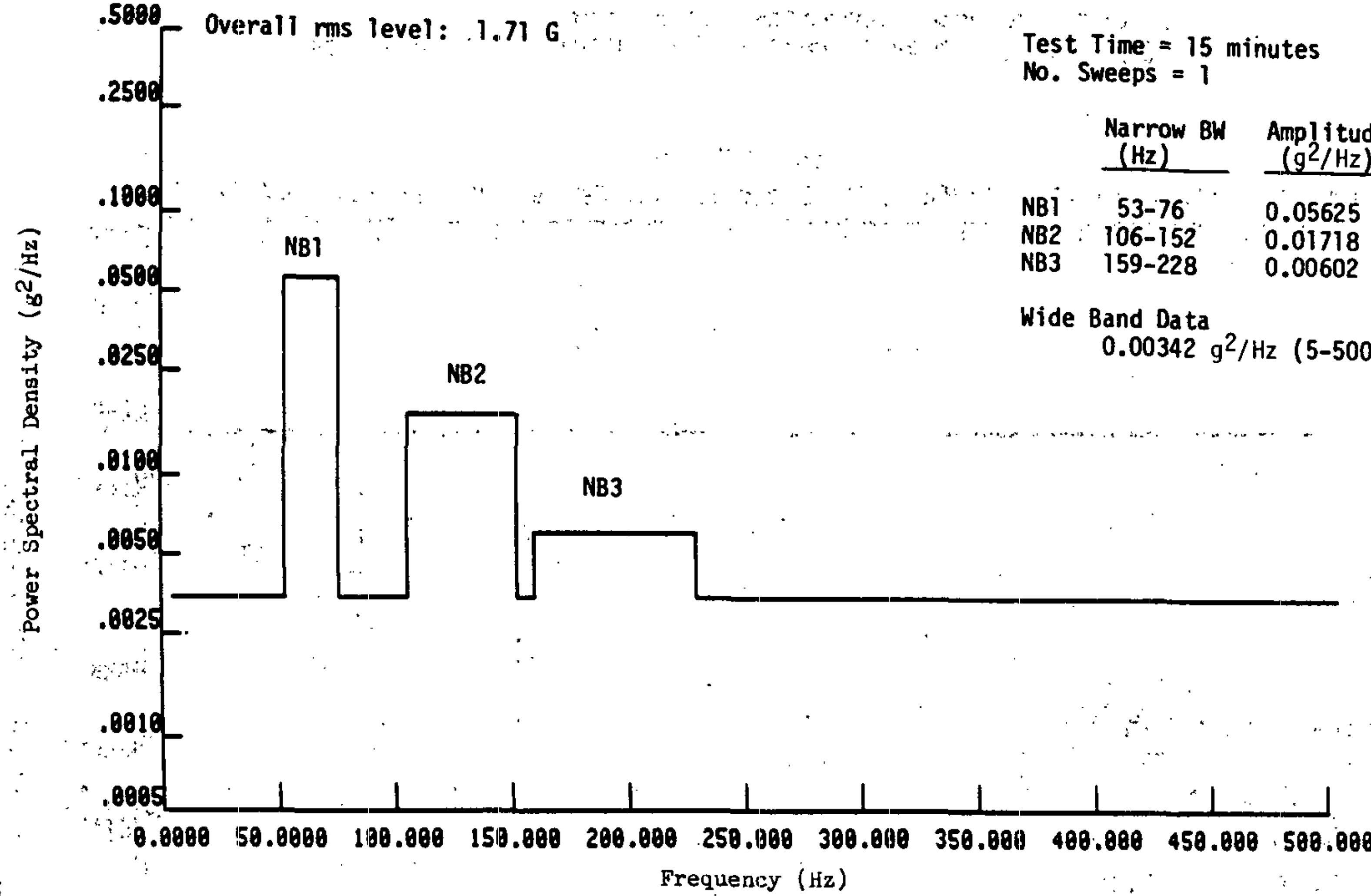


FIGURE 514.3-20. Basic transportation, tracked vehicle (M548) environment, longitudinal axis, test phase 2.



Test Time = 15 minutes
No. Sweeps = 1

	Narrow BW (Hz)	Amplitude (g^2/Hz)	Sweep BW (Hz)
NB1	53-76	0.05625	12
NB2	106-152	0.01718	24
NB3	159-228	0.00602	36

Wide Band Data
0.00342 g^2/Hz (5-500 Hz)

FIGURE 514.3-21. Basic transportation, tracked vehicle (M548) environment, longitudinal axis, test phase 3.

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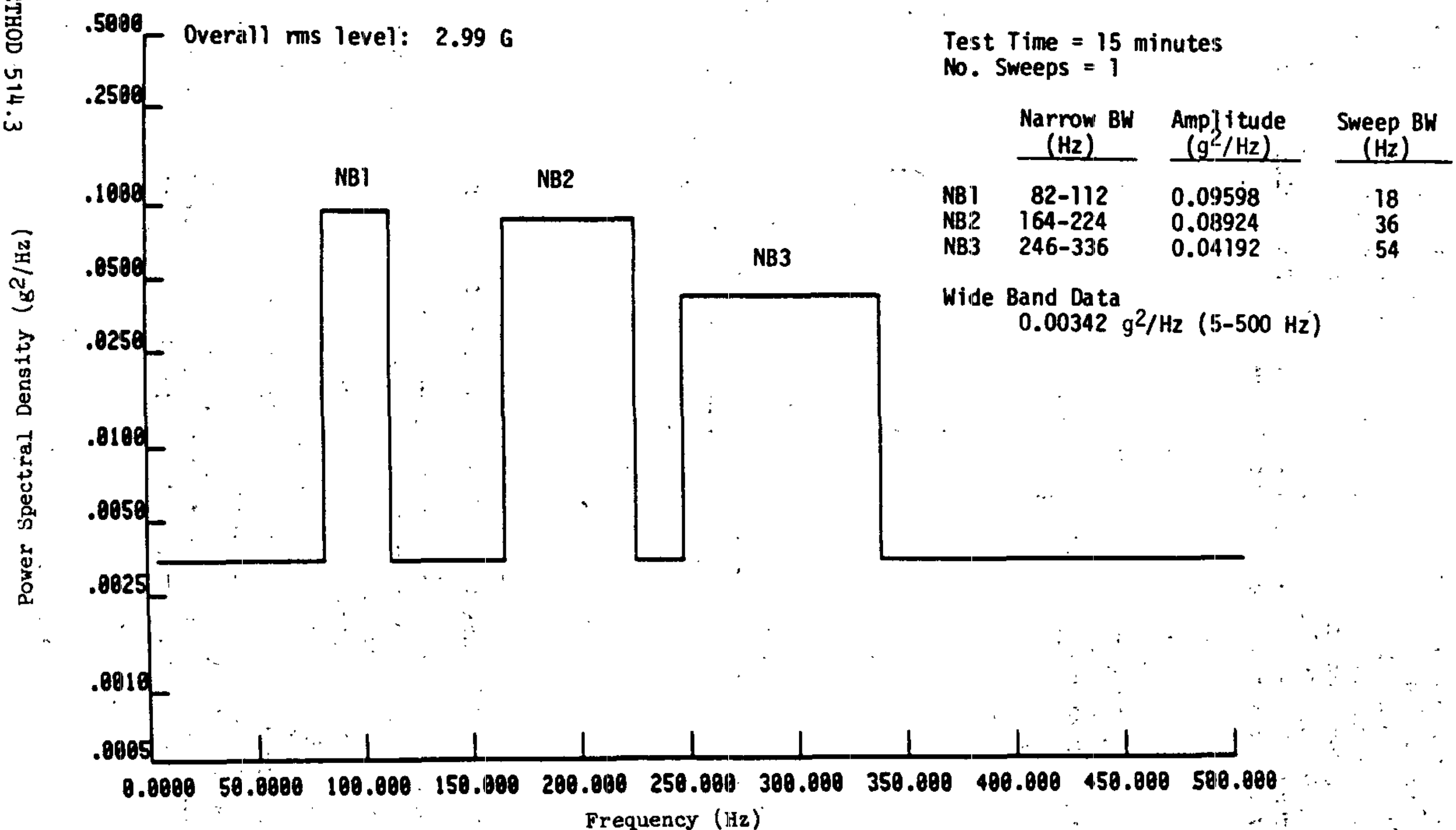

FIGURE 514.3-22. Basic transportation, tracked vehicle (M548) environment, longitudinal axis, test phase 4.

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These durations are derived from the mileage for a typical mission/field transportation scenario which has been established to be 500 miles to the Forward Supply Point (FSP); 15 miles from the FSP to the using unit; and 15 miles at the using unit itself (dependent upon the type of cargo: expendable cargo, e.g. ammunition, may be hauled 15 miles and nonexpendable cargo, e.g. generators, may not be hauled at all once it reaches the using unit). Figure 514.3-23 shows the typical scenario and the types of vehicles utilized most frequently in the various segments of the scenario.

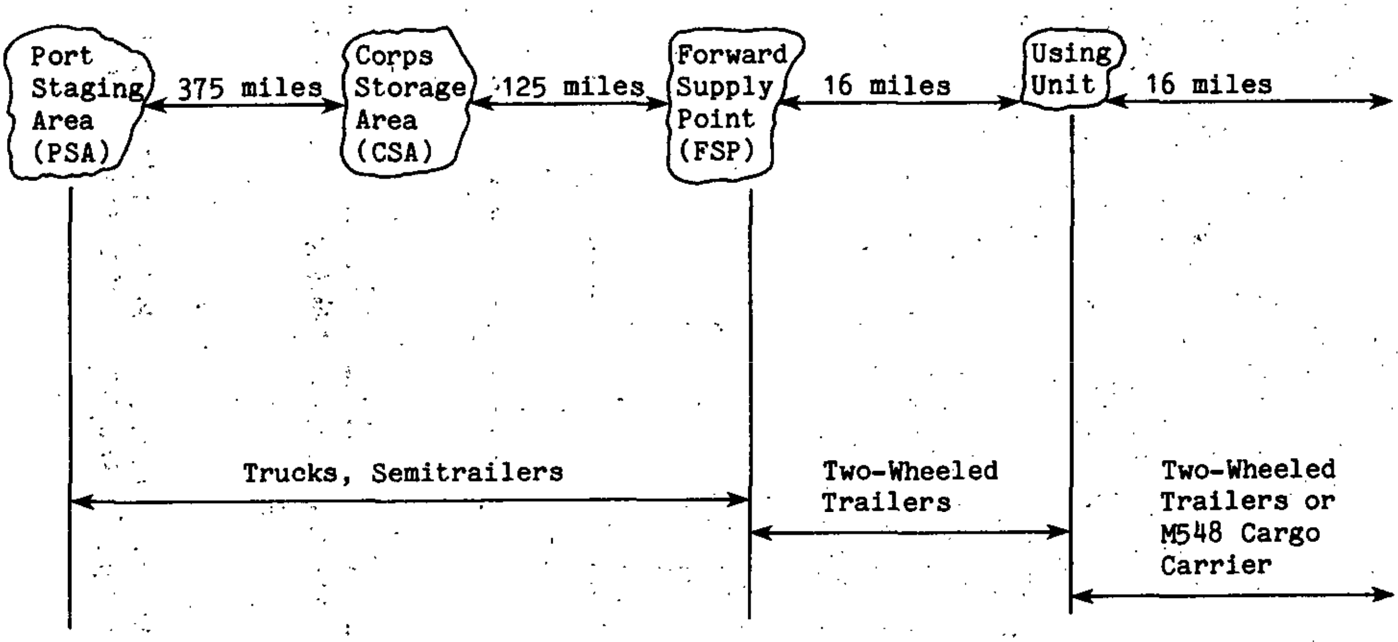

FIGURE 514.3-23. Typical mission/field transportation scenario.

Although both trucks and two-wheeled trailers are utilized between the FSP and the using unit and at the using unit, the vibration levels on the trailers are significantly higher and thus should be used represent the wheeled vehicle environment, unless the test item is too large to fit in the two-wheeled trailer. In that case, the composite wheeled environment should be used.

c. Test setup: Mount the test item in its transport configuration on the vibration fixture/table using restraints and tie-downs typical of those to be used during actual transport. Testing should be conducted using all representative stacking configurations and excitation should be applied through all representative axes. The equipment is not operated during this test.

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I-3.2.2 Category 2 - Large assembly transport. In some cases, it may not be practical or efficient to test large shelters or systems on a shaker. In such cases, transportation conditions may be simulated using the actual transport vehicle as the vibration exciter. The assemblage may consists of equipment mounted in a truck or trailer, or equipment mounted in a shelter which is then mounted on a truck, trailer, or dolly set. The exposure consists of traversing the transport vehicle over a prepared test course until the test item has received exposure representative of anticipated deployment scenarios.

a. Test level. The vibration levels and intensities received by the test item during this test are based upon the course profile and vehicle speeds as specified in procedure III. Various road surfaces are to be used, each traversed at speeds which will produce the desired vibration intensity. Transport vehicle speeds are limited either by the vehicle's safe operating speed over a specific course profile or by the speed limit set for the specific course.

b. Test duration. The test duration shall be as specified in procedure III or until the test item has received the exposure represenative of the anticipated deployment scenarios, whichever is longer.

c. Test setup. The test setup shall be as specified in procedure III. The assemblage shall be mounted into the transport vehicle for which it was designed in its deployment configuration. If the assemblage is to be contained in a shelter, it shall be intalled within the shelter in the deployment configuration.

The shelter should be mounted and secured on the transport vehicle(s) that is normally used for the shelter under actual transport. Instrumentation is provided to measure the vertical axis acceleration time history on the shelter floor and at any other locations of concern.

I-3.2.3 Catgory 3 - Loose cargo transport. The loose cargo environment includes conditions experienced by packaged and unpackaged items transported as unsecured cargo on a vehicle traversing irregular surfaces. The cargo has the freedom to bounce, scuff, or collide with other items of cargo or the sides of the vehicle. This environment is simulated in the laboratory by imparting motion to the test item and allowing it to collide with restraints established within the test setup. The test conditions for this environment are, established to a large extent by the equipment used to impart the motion, and the arrangement of the restraints. This test has few tailoring options and the selection of the test equipment must be based upon the desired end result.

a. Test levels. Two methods are presented. For both methods the basic movement of the bed of the test equipment where the test item is placed is a 2.54-cm (1-inch) double-amplitude orbital path at 5 Hz, such as can be obtained on a standard package tester operating in the synchronous mode. (In this mode any point on the bed of the package tester will move in a circular path in a vertical plane perpendicular to the axes of the shafts.)

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b. Test duration. The test duration for this procedure should be based upon the mechanical setup of the test equipment, the packaging state of the test item, and the desired results of the exposure. A duration of 30 minutes is recommended where several test items are placed on a steel package tester bed and allowed to collide with each other as well as the restraints of the test equipment. A duration of 3 hours is recommended where the test item is placed upon a plywood package tester bed and allowed only to collide with the restraints of the test equipment.

c. Test setup. The differences in the methods for simulating this environment are associated with the test setup. The setup uses a package tester as depicted in figure 514.3-24. The fixturing required is as shown and will not secure the item to the bed of the package tester. A vertical impact wall and sideboards as depicted in figure 514.3-24 shall be implaced to contain the test items on the bed of the package tester. The test is intended to simulate the unrestrained collision of the test item with the bed and sides of the transport vehicle as well as with other cargo.

For the 30-minute test, the bed of the package tester shall be covered with a plate of cold-rolled steel 3/16 to 3/8 inch thick. Several test items shall be placed within the enclosure created by the vertical wall and sideboards. The total free space surrounding each test item placed on the table of the package tester will be at least 5.08 cm (2 inches) between the test item and the opposing sideboards and any other test item. All loading configurations (i.e., test items laid horizontally or stood on end vertically) deemed practical shall be included in the placement of the test items on the package tester to evaluate the item integrity.

For the three-hour test, the constraint fences are constructed of suitable wood and are sized for a single test item. The fences shall be positioned so that the horizontal motion of the test item is limited to not more than two inches. The bed of the package tester shall be covered with a sheet of 1/2 inch plywood suitably secured by nailing.

In both methods, the test item(s) is placed on the bed of the test equipment secured in its transit case combination or as otherwise prepared for loose-cargo field transportation. The test item shall not be operated during vibration.

APPLICATION VIBRATION

I-3.2.4 Category 4 - Propeller aircraft. Service vibration frequency spectra for equipment installed in propeller aircraft consist of a broadband background with superimposed narrowband spikes. The background spectrum results from various random sources (see I-3.2.5) with many periodic (not pure sinusoidal) components due to the rotating elements (engines, gearboxes, shafts, etc.) associated with turboprops. The spikes are produced by passage of pressure fields rotating with the propeller blades. These occur in relatively narrowbands centered on the propeller passage frequency (number of blades multiplied by the propeller rpm) and harmonics.

The spectrum for equipment mounted directly on turbine engines is similar to the propeller aircraft spectrum except the primary spike frequency is the rotational speed of the rotor(s).

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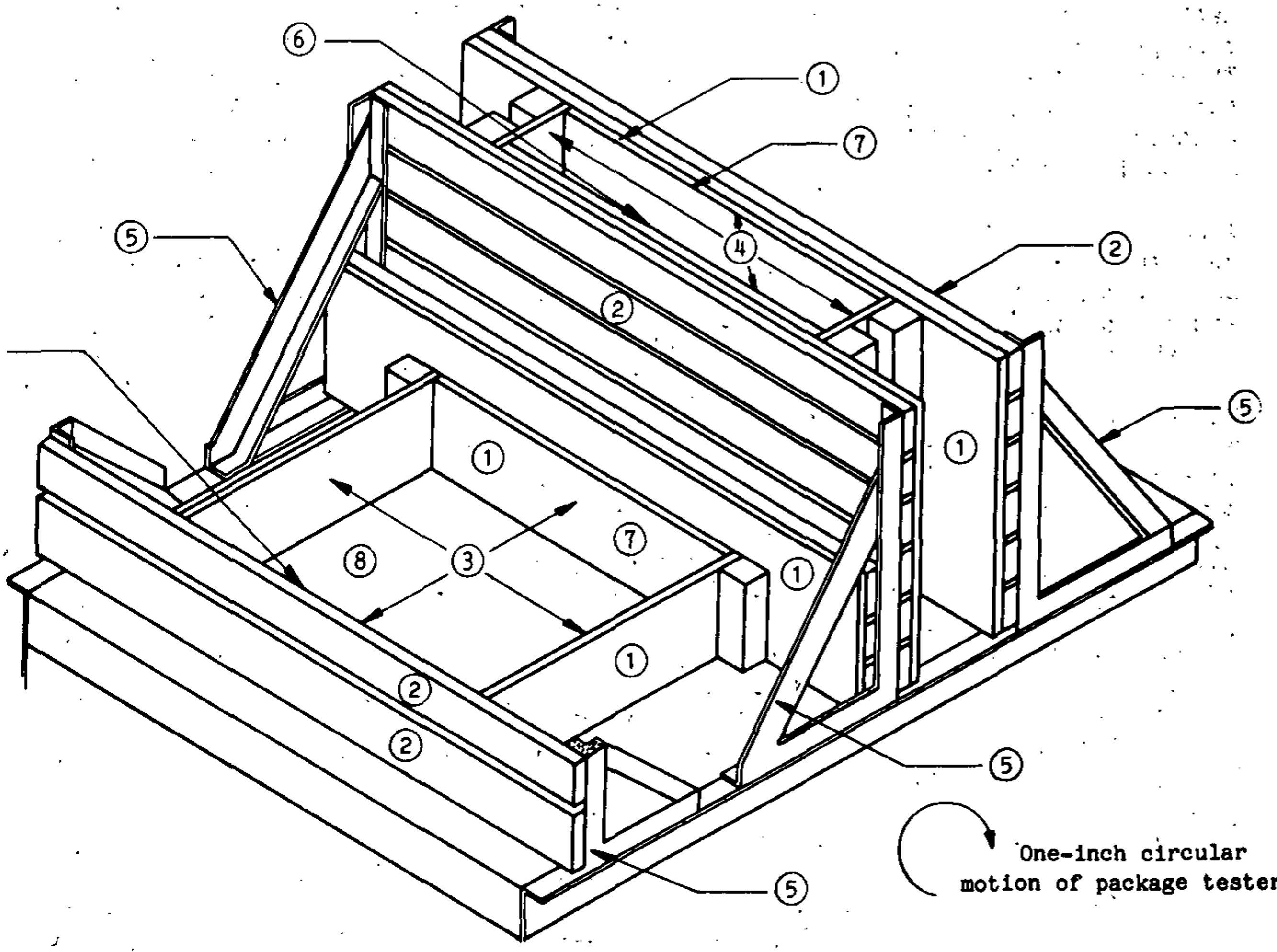

1. One-inch plywood
2. 2" x 6" pine
3. Enclosure where test items could be placed
4. Enclosure where test items could be placed
5. Angle iron structure support
6. Front fence (restraint)
7. Back fence (restraint)
8. Bed of package tester

FIGURE 514.3-24. Typical package tester.

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Most current turboprop aircraft and many turbine engines are constant-speed machines. This means that rpm is held constant and power changes are made through fuel flow changes and variable-pitch blades, vanes, and propellers. These machines produce the fixed frequency spikes of figure 514.3-25. These spikes have an associated bandwidth because there is minor rpm drift and because there is minor rpm drift and because the vibration is not pure sinusodial (I-4.5).

There are indications that future turboprop or propfan engines will not be constant-speed machines. All reciprocating engines and many turbine engines are not constant-speed. Also modern turbofan engines usually have two and sometimes three mechanically independent rotors operating at different speeds. The spectra of figure 514.3-25 must be modified if used for these cases.

These vibration environments can be practically approximated in the laboratory by the source dwell test described in I-4.2.2. Many vibration problems in this type of environment are associated with the conincidence of equipment vibration modes and the excitation spikes. The notches between spikes are used in intelligent design as safe regions for critical vibration modes. Thus source dwell tests minimize the likelihood that equipment will be overstressed at non-representative conditions and that reasonable design provisions will not be subverted.

a. Test level. Whenever possible, flight vibration measurements should be used to develop vibration criteria for laboratory tests. Appendix 1 provides guidance for the development of test criteria from field data. In the absence of flight measurements, the test levels of table 514.3-II can be used with the spectra of figure 514.3-25. The turboprop levels are based on data from various C-130 and P-3 aircraft measurements and are fairly representative of the environments of these aircraft. The decline of spike acceleration spectral density with frequency is based on relatively recent data analyzed in a spectral density format. Engine levels are based on data measured on several current Air Force aircraft engines.

b. Test duration. Test durations should be developed from flight measurements or field data. Refer to appendix 1 for guidance in developing test durations from field data. If field data are not available for development of the test durations, then tests should be conducted for 1 hour per axis at the test levels listed in table 514.3-II, modified according to the guidance in I-4.3, I-4.6, I-4.7, I-4.8 and I-4.9. These levels represent maximum actual operating conditions and are functional test levels.

c. Test setup. The test time shall be installed in a vibration fixture which simulates the actual application configuration. To the extent practical, the vibration test setup should incorporate actual mounting and isolation provisions from the carrying aircraft. Fixture designs which utilize the maximum amount of platform structure possible will allow the test item to respond to the laboratory excitation in a manner more closely duplicating its response in the actual field environment. However, all equipment items protected from vibration by these means should also pass the minimum integrity test requirements of I-3.2.12 with the test item hard-mounted to the fixture.

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I-3.2.5 Category 5 - Jet aircraft and tactical missiles. The vibration environment for equipment installed in jet aircraft and tactical missiles (except engine-mounted) stems from four principal mechanisms. These vibrations are random and, except where the elastic response of primary aircraft structure is the source, broadband. These sources are as follows:

(1) Engine noise impinging on aircraft structures.

(2) Turbulent aerodynamic flow along external aircraft structures.

(3) Pressure pulse impingement due to repetitive firing of guns.

(4) Airframe structural motions due to maneuvers, aerodynamic buffet, landing, taxi, etc.

The guidance provided in this section considers sources (1) and (2). Method 519 covers source (3). General airframe motions (4) cannot be adequately covered by general criteria. They are the result of responses of flexible structures to various transient events. Two examples of such responses are rebound of wings and pylons when heavy stores are ejected, and separate flow or shed vortex excitation of flight surfaces during sustained maneuvers. The vibration spectra are characteristic of the particular airframe involved and must be evaluated through measured data. Airframe structural motions are usually important for the outer regions of flexible structures (i.e. outer 1/2 of wings, empennage, pylons, etc). They are usually not important for fuselage-mounted equipment.

Jet-noise-induced vibration is usually dominant in vehicles which operate at lower dynamic pressures, i.e. limited to subsonic speeds at lower altitudes and transonic speeds at high altitudes. Aerodynamically induced vibration usually predominates in vehicles which operate at transonic speeds at lower altitudes or supersonic speeds at any altitude.

When equipment is used in more than one application, the vibration criteria should be enveloped and test criteria based on a worst-case composite.

Only functional tests are performed for tactical missiles.

a. Test levels. In the absence of satisfactory measurements of field environments, functional test levels approximating jet-noise-induced and flow-induced vibration may be derived from table 514.3-III and figures 514.3-26 and 514.3-27.

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TABLE 514.3-II. Suggested functional test conditions for propeller aircraft equipment (see figure 514.3-25)

Equipment Location 2/, 3/	Vibration Level of L_i, at F_i, (g^2/Hz) 4/
In fuselage or wing forward of propeller	0.1
In fuselage or wing aft of propeller	0.3
In engine compartment or pylons	0.6
Equipment mounted directly on aircraft engines	1.0

1/ F_i = fundamental excitation frequency
$F_2 = 2F_1$, $F_3 = 3F_1$, $F_4 = 4F_1$

2/ When panels and racks are not available for equipment installed on vibration isolated panels or racks, or when the equipment is tested with isolators removed, use "fuselage or wing forward of propeller" category with levels reduced 4dB.

3/ Increase test levels 6dB for equipment mounted on fuselage or wing skin within one propeller blade radius of the plane of the propeller disc. For all other skin mounted equipment, increase levels by 3dB.

4/ Bandwidth of vibration around each F_i will equal ±5% F_i for constant-speed excitation. When excitation is not constant-speed, bandwidth will encompass operating speeds for cruise and high power operation.

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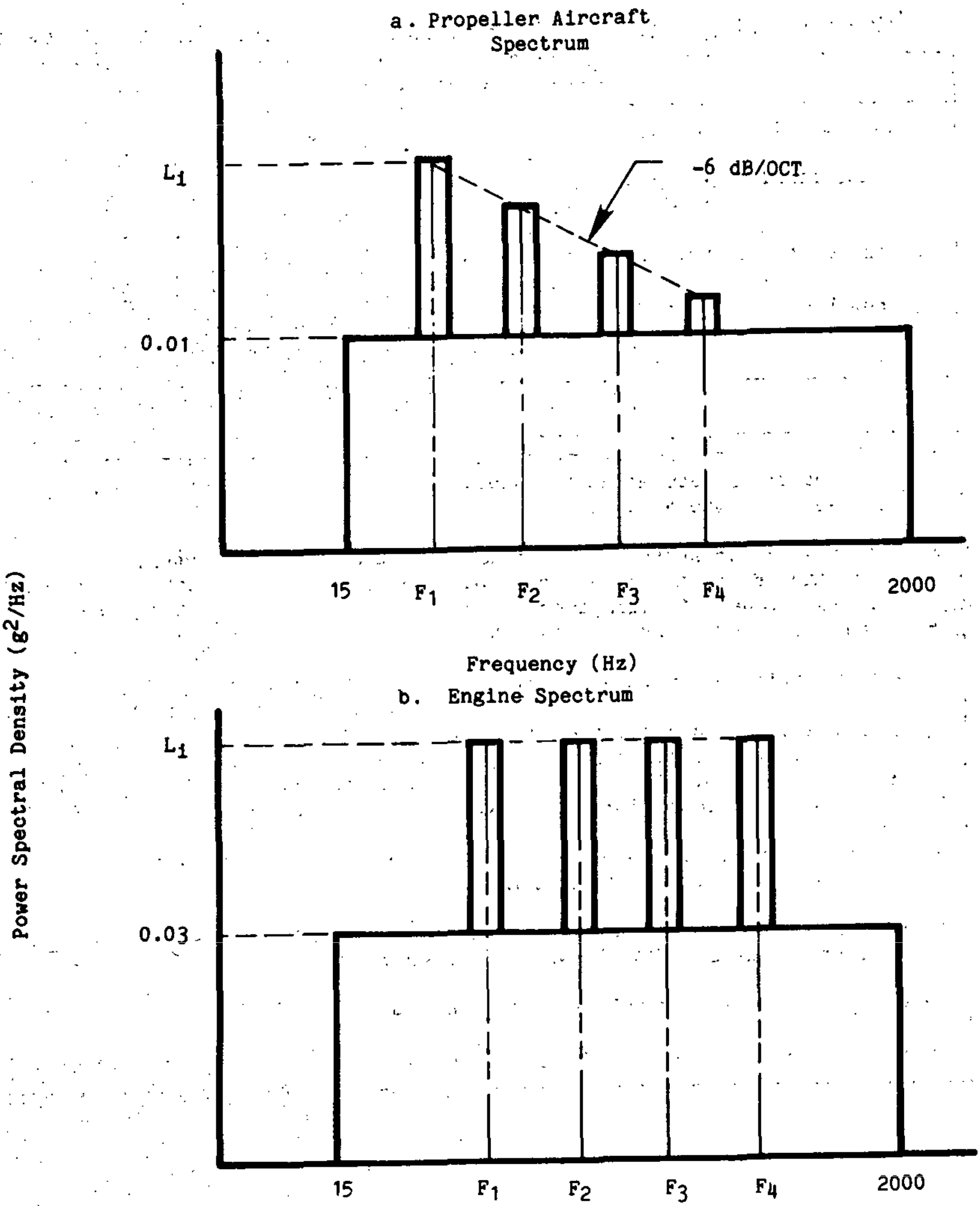

FIGURE 514.3-25. Suggested vibration spectra for propeller aircraft and equipment on engines.

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TABLE 514.3-III. Broadband vibration test values for jet aircraft equipment.

CRITERIA
Aerodynamically induced vibration (figure 514.3-26) 1/ Functional test level 3/, 4/ $W_o = K(q)^2$ Jet engine noise induced vibration (figure 514.3-26) 1/ Functional test level 2/, 3/, 4/, 5/, 6/ $W_o = (0.48 \cos^2 \theta / R)\ [D_c\ (V_c/1850)^3 + D_f/1850)^3]$
DEFINITIONS
K = 2.7×10^{-8} for cockpit panel equipment and equipment attached to structure in compartments adjacent to external surfaces that are smooth, free from discontinuities. K = 14×10^{-8} for equipment attached to structure in compartments adjacent to or immediately aft of external surfaces having discontinuities (cavities, chins, blade antennas, speed brakes, etc.) and equipments in wings, pylons, stabilizers, and fuselage aft of trailing-edge wing root. q = 1200 lb/ft^2 or maximum aircraft q, whichever is less. D_c = engine core exhaust diameter, feet. (For engines without fans, use maximum exhaust diameter.) D_f = engine fan exhaust diameter, feet. R = minimum distance between center of engine aft exhaust plane and the center of gravity of installed equipment, feet. V_c = engine core exhaust velocity, feet per sec. (For engines without fans, use maximum exhaust velocity without afterburner.) V_f = engine fan exhaust velocity, feet per sec. θ = angle between R line and engine exhaust axis, aft-vectored, degrees.

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TABLE 514.3-III. Broadband vibration test values for jet aircraft equipment. - Continued

NOTES

1/ Envelop aerodynamically induced and jet engine induced and use the worst-case composite.

2/ If aircraft has more than one engine, W_o shall be the sum of the individually computed values for each engine.

3/ For equipment weighing more than 80 pounds, the vibration test level may be reduced according to figure 514.3-27.

4/ For $70^\circ < \theta \leq 180^\circ$, use $\theta = 70^\circ$ to compute W_o.

5/ For engines with afterburner, use W_o, which is four times larger than W_o computed using maximum V_c and V_f without afterburner.

6/ For instrument panel equipment, reduce the 0.04 g^2/Hz value of figure 514.3-25 by 3dB and reduce the calculated value W_o by 6dB for functional testing. Endurance is 0.04 g^2/Hz.

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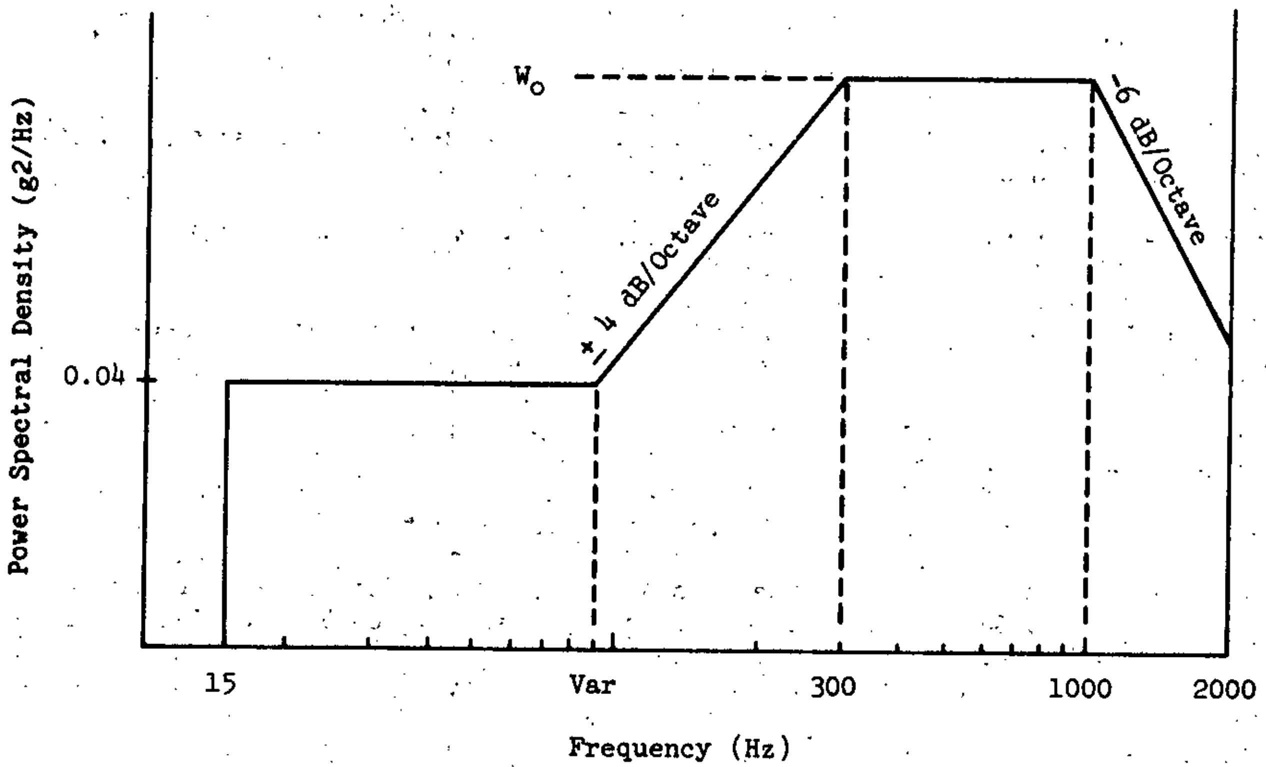

FIGURE 514.3-26. Suggested vibration spectrum for jet aircraft equipment.

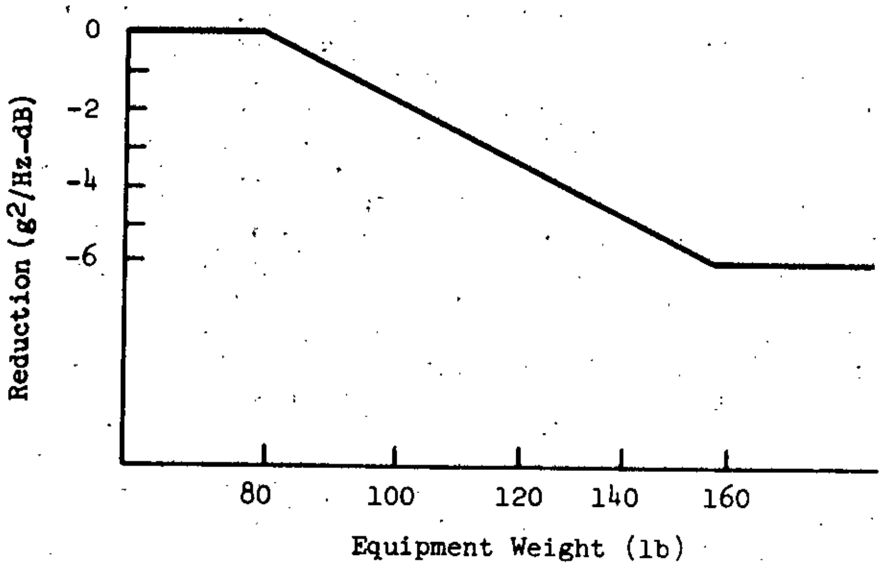

FIGURE 514.3-27. Reduction factor for mass loading.

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b. Test duration. Test durations should be developed from flight measurement or field data. Refer to appendix 1 for guidance in developing test durations from field data. If field data are not available for development of the test durations, then the test levels of table 514.3-III and guidance discussed in I-4.3, I-4.6, I-4.7, I-4.8, and I-4.9 apply. These levels represent maximum actual operating conditions and are functional test levels. The requirements of paragraph I-3.2.12 also apply.

c. Test setup. See test setup criteria, paragraph I-4.11.

I-3.2.6 Category 6 - Helicopter aircraft/installed. Helicopter vibration is characterized by broadband random with superimposed strong vibration peaks, as depicted in figure 514.3-28. These peaks are generated by the rotating components in the helicopter, such as the main and tail rotors, engines and gear meshing. The operating speeds of these components under flight conditions are essentially constant, varying by only about five percent.

The relative levels of these peaks differ thruout the helicopter, depending on the proximity of the sources, geometry of the aircraft, and location of the test item. Thus, the need for measured data is especially acute. An obvious requirement for helicopter equipment design is to avoid a match or near match between an item's resonant frequencies and the excitation frequencies at the installment location. The major peaks in the helicopter vibration spectrum are usually associated with the main rotor. However, each type of helicopter will have different sources within different areas of each aircraft. Since the vibration environment is dominated by discrete frequency peaks, it is logical to use some of these frequencies for exposure in the laboratory test. Normally about four frequencies are chosen for the tests. For equipment mounted on engines, refer to paragraph I-3.2.4. For equipment exposed to gunfire, refer to method 519.

a. Test levels. For the reasons stated above, the test levels for equipment installed in helicopters should be derived from field measurements. When measured data are not available, the test levels can be selected from table 514.3-IV. These levels are an attempt at enveloping potential worst-case environments. They do not represent environments under which vibration-sensitive equipment should be expected to perform to specification. Costs for many devices are a strong function of the performance required in a particular vibration environment. Consequently, performance vibration levels should be tailored to particular applications and are not appropriate for a general standard. For testing purposes, the aircraft can be divided into three zones, shown in figure 514.3-29. All equipment locations included in a vertical projection of the main rotor disc should use the source frequencies of the main rotor for the values of L_1, L_2, L_3, and L_4 at frequencies F_1, F_2, F_3, and F_4. For equipment that will be located in the horizontal projection of the tail rotor disc, use the source frequencies of the tail rotor as the values of L_1, L_2, L_3, and L_4. The fundamental main and tail rotor source frequencies, F_1, for a few helicopters are given in table 514.3-V. All equipment located on drive train components such as gear boxes and drive shafts should use the source frequencies of that drive train component (i.e., gear mesh frequencies, shaft rotational speeds).

b. Test duration. Test durations shall be derived from the field measurements and actual flight characteristics and durations.

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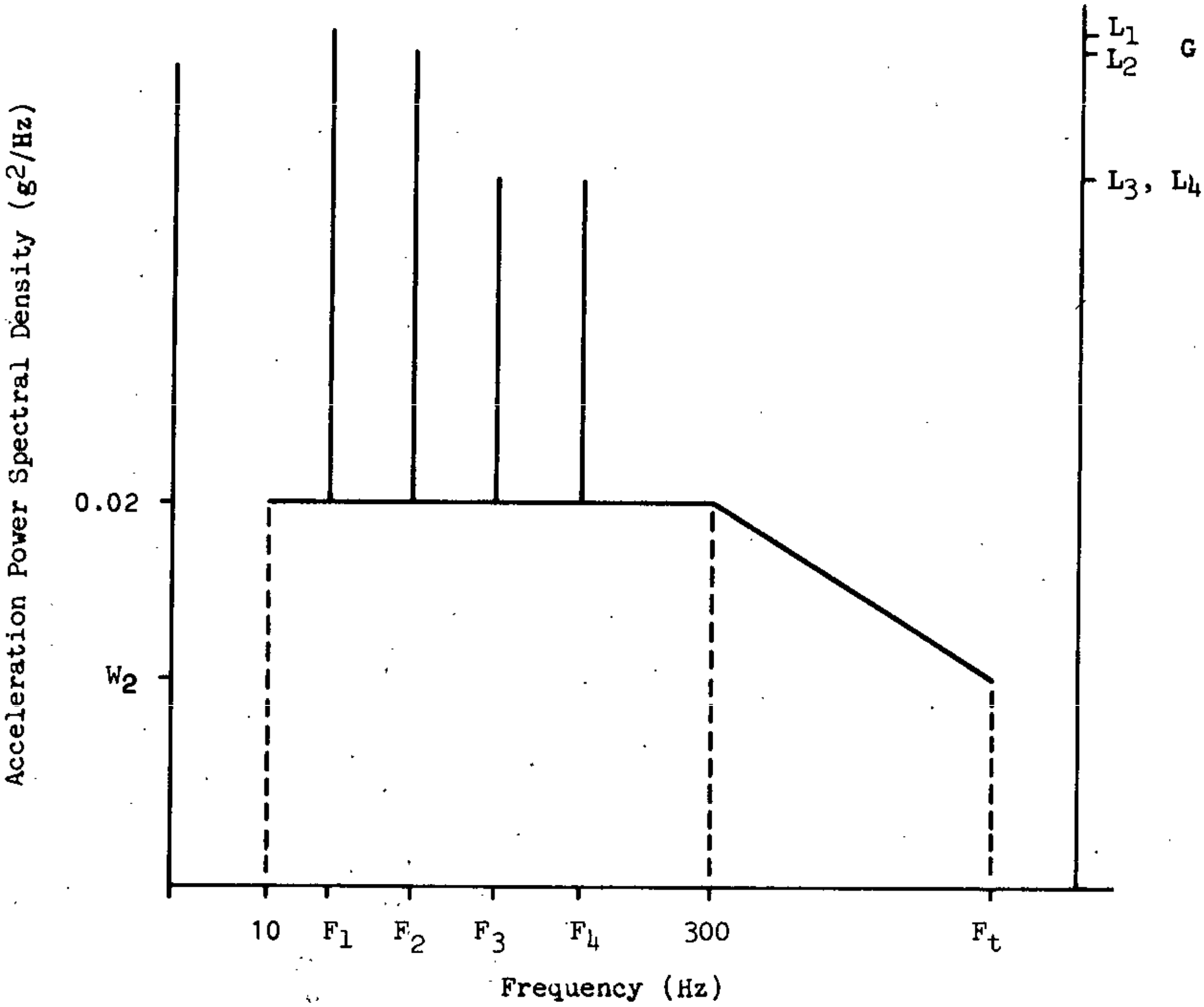

FIGURE 514.3-28. Suggested vibration spectrum for equipment mounted on helicopters.

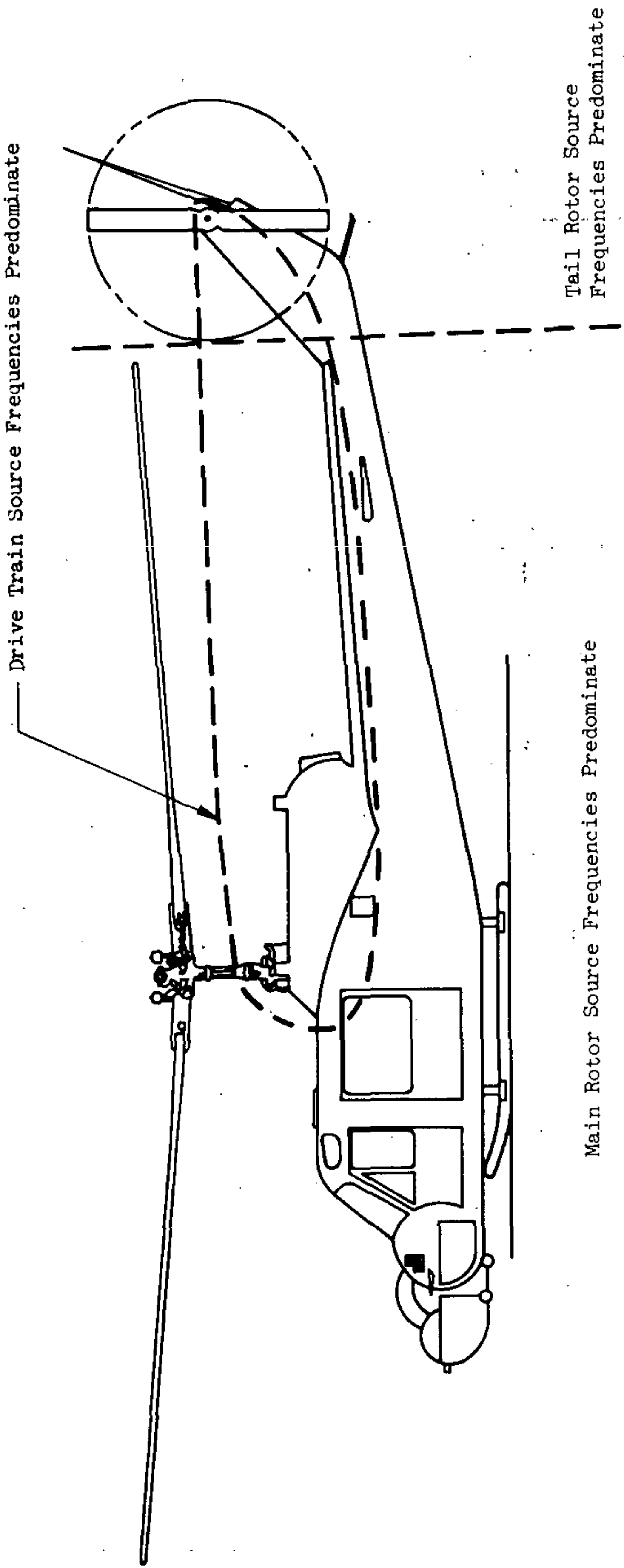

FIGURE 514.3-29. Zones for rotary wing aircraft.

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TABLE 514.3-IV. Suggested function test levels for equipment installed on helicopters.

EQUIPMENT LOCATION	SOURCE FREQUENCY F_i (Hz)	VALUE OF W_2 & F_t	PEAK VIBRATION LEVEL L_i, AT F_i in G
GENERAL 1/	5-25	$W_2 = 0.002$	$0.5 + 0.1 (F_i - 5)$
	25-40	$F_t = 500$	2.5
	40-50		$2.5 - 0.1 (F_i - 40)$
	50-500		1.5
ON INSTRUMENT PANEL 1/			0.7 x GENERAL
EXTERNAL STORES 1/			1.5 x GENERAL
ON OR NEAR DRIVE SYSTEM ELEMENTS 2/	5-50	$W_2 = 0.02$	$0.5 + 0.1 (F_i - 5)$
	50-2000	$F_t = 2000$	$5.0 + 0.01 (F_i)$

1/ $F_2 = 2F_1$, $F_3 = 3F_1$, $F_4 = 4F_1$. Choose F_i from figure 514.3-29 and table 514.3-V.

2/ F_1 - F_4 should be chosen based on drive train source frequencies.

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TABLE 514.3-V. Nominal fundamental rotor source frequency.

ROTARY WING AIRCRAFT	MAIN ROTOR F_1 (Hz) 1/	TAIL ROTOR F_1 (Hz) 2/
CH-3	17	
OH-58A	11.8	40
OH-58D	26.3	40
UH-60	17	20
CH-47D	11.3	11.3
CH-47C	12.3	12.3
AH-1	10.8	27.8
UH-1	10.8	27.8
AH-64	19.3	23.4
OH-6	31.9	51.3
CH-54	18.5	14.1
500MD	41	49
Lynx	21.7	32
BO-105	30	

1/ These frequencies are the number of rotor blades times rotor rotational speed.

2/ Rotor rotational speed.

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c. Test setup. The test item shall be attached to the vibration exciter by means of a fixture capable of transmitting the vibration conditions specified. The fixture shall be designed by utilizing actual racks, panels or platform structures of the helicopter to minimize the introduction of unrepresentative response within the test item. Low-level (0.5-g) 5 to 500 Hz sweeps to identify the resonant and transmissible frequencing the item shal be conducted before and after its exposure to the test vibration environment. Significant changes in resonant properties shall be considered as failures even though the item still functions to specification levels.

I-3.2.7 Category 7A - Assembled external stores, jet aircraft. Assembled jet aircraft stores will encounter three distinct vibration environments: captive flight, buffet maneuver, and free flight.

Captive flight: Extensive measurement programs have shown that the vibration experienced by an externally carried store on a jet aircraft arises from three distinct sources:

(1) Aerodynamic boundary layer turbulence.

(2) Buffet maneuvers.

(3) Aircraft-induced vibration.

In general, store vibration is primarily caused by broadband aerodynamic boundary layer turbulence and is relatively independent of the carrying aircraft and mounting location on the aircraft. Instead, vibratory excitation is mostly influenced by store shape, mounting configuration and dynamic pressure. This source of vibration is distributed along the entire surface of the store and is difficult to simulate by point input of vibration, such as from a vibration shaker, unless the store is relatively stiff. Therefore, an acoustic test (method 515) is recommended for this environment.

The lower-frequency portion of the assembled store vibration spectrum comes from either aircraft-induced vibration or buffet maneuvers. Aircraft-induced vibration generally is present during the entire captive flight phase for a store. Its frequency range is covered by the response threshold spectrum shown in figure 514.3-30.

Buffet maneuver. Recent flight test programs on the F-16 and F-15 with various externally carried stores have shown intense vibrations associated with buffet maneuvers. Other similar aircraft, such as F-14, F-18, or next generation fighters, have the potential to produce intense vibrations during high-performance maneuvers. The buffet maneuver envelope is generally bounded by speeds of 0.8 to 0.9 MACH and altitudes of 3 to 10 kilometers (9,840 to 32,800 ft). Although the vibration levels during high-performance maneuvers are very intense, they generally do not last for more than 10 seconds, reaching their peak in less than a second and rapidly deteriorating in 5 to 10 seconds. For the purpose of establishing test durations, a commonly used assumption is that an aircraft store may experience as much as 30 seconds of maneuver buffet vibration for each hour of captive-carriage flight (figure 514.3-31).

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Buffet maneuver vibration energy is concentrated in the low frequency range, typically between 20 to 100 Hz, dominated by the store's structural characteristics. Depending upon the store location on the aircraft and configuration on the rack, pylon, and aircraft, additional distinct responses may be predominant in the store response. Due to these factors, vibration levels should be derived from in-flight vibration measurement. The maneuver buffet and aerodynamic vibration tests may be combined or performed separately.

Free flight. For stores that are deployed by separation from the aircraft (free flight) such as bombs and missiles, a free-flight functional test is recommended when the free-flight vibration amplitude is greater than the captive-flight levels. In general, if the free-flight dynamic pressure is greater than the captive-flight levels it can be assumed that the associated vibration level will also be higher. In this case if measured free-flight data does not exist, the factors A_1 and A_2 from table 514.3-VI should be set equal to one. The value of q should be the maximum value attainable during free flight. The duration of this functional test, per axis, should equal the maximum free-flight time expected at maximum vibration levels.

a. Test levels: The test levels and spectrum for the three vibration environments, captive flight, free-flight, and buffet, can be selected from table 514.3-VI and fiugres 514.3-30, 31, and 32. The use of these tables and figures is suggested only when there is an absence of satisfactory flight measurements.

b. Test duration. The test duration should be developed from flight measurements, flight characteristics, and flight durations utilizing appendix A. If this data is not available, then test durations can be obtained from the information given in paragraphs I-4.3, I-4.6, I-4.7, I-4.8 and I-4.9.

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

Alternatively, the store may be hard-mounted directly to the shaker, using its normal mounting lugs and a suitable fixture. The stiffness of the mounting fixture shall be such that its induced resonant frequencies are as high as possible but none are below one-third of any f_o frequency. For both methods, launcher rails shall be used as part of the test setup, where applicable.

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

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TABLE 514.3-VI. Vibration criteria for external stores carried on airplanes.

Parametric Equations for Figures 514.3-9 and 514.3-12

Eq (1)1/: $W_1 = (5)(10^{-3}) \quad (A_1)(B_1)(C_1)(D_1)(E_1)g^2/Hz$

Eq (2)1/: $W_2 = (5)(10^{-5})(q/ \quad)^2 \quad (A_2)(B_2)(C_2)(D_2)(E_2)g^2/Hz$

Eq (3)2/,3/: $f_1 = 10^5 \ (t/R^2)$ Hz

Eq (4)2/,3/: $f_2 = f_1 + 1000$ Hz

Eq (5)5/,6/,7/: $f_o = (t/R^2) \times 10^5 + 100$ Hz

Location, Configuration, Special Adjustments

	Factor	
	A_1	A_2
TER (tri-ejection rack, cluster mount)	1	2
MER (multiple ejection rack, cluster mount)	2	4
Single station	1	1
	B_1	B_2
Aft half of air fired missiles	1	4
Aft half of all other stores	1	2
Forward half of all stores	1	1
	C_1	C_2
Blunt nosed stores, single station and TER	2	4
Blunt nosed stores, MER	1	2
All other stores	1	1
	D_1	D_2
Free fall munitions with non-integral finned sheet metal tail cones	8	16
Air fired missiles	1	1
All other stores	4	4
	E_1	E_2
Firebombs (jelly filled)	1/2	1/4
All other conditions	1	1

Representative parameter values to be used for captive flight when specific parameters are not available

Store Type	Max q		N Endurance	T Endurance	f_1(Hz)	f_2(Hz)
Missile, air to ground	1600	100	3	None	500	1500
Missile, air to air	1600	100	100	1	500	1500
Instrument pod	1800	50	500	1	500	1500
Dispenser (reusable)	1200	50	50	1	200	1200
Demolition bomb	1200	120	3	None	125	2000
Fire bomb	1200	40	3	None	100	1100

See next page for Definitions and Notes

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TABLE 514.3-VI. Vibration criteria for external stores carried on airplane. - Continued

DEFINITIONS
q = maximum captive flight dynamic pressure in lbs/ft^2. (See note 1)
ρ = average store weight density in lbs/ft^3 (total weight ÷ total volume)
t = local store average skin thickness where R is measured - inches
R = one-half the average of the major and minor diameters (inches) for a store with an elliptical cross-section (for cylindrical sections use local geometry; for conical sections use smallest f_1 calculated using geometry within one foot of equipment mounting point; for cast irregular shaped cross-section, R shall be one-half the longest inscribed chord; for monocoque irregular cross-section, f_1 = 300 Hz)

NOTES

1. For endurance test, q = 1200 psf or maximum q, whichever is less.
2. Free fall stores with tail fins, use f_1 = 125 Hz; $f_2 = 10^5(t/R^2) + 1000$ Hz.
3. For general-use fuzes which can be used in several stores; use W_1 = $0.04 g^2/Hz$; W_2 = $0.3\ g^2/Hz$; f_1 = 100 Hz; f_2 = 1000 Hz.
4. Acceptance range for parameter values: $40 \leq \rho \leq 150$
   $0.001 \leq t/R^2 \leq 0.02$
   or if calculated values fall outside these limits, use these limit values.
5. For circular and elliptical cross-sections.
6. 500 Hz for all other cross-sections.
7. If $f_o \geq 1200$ Hz is calculated, use 2000 Hz.

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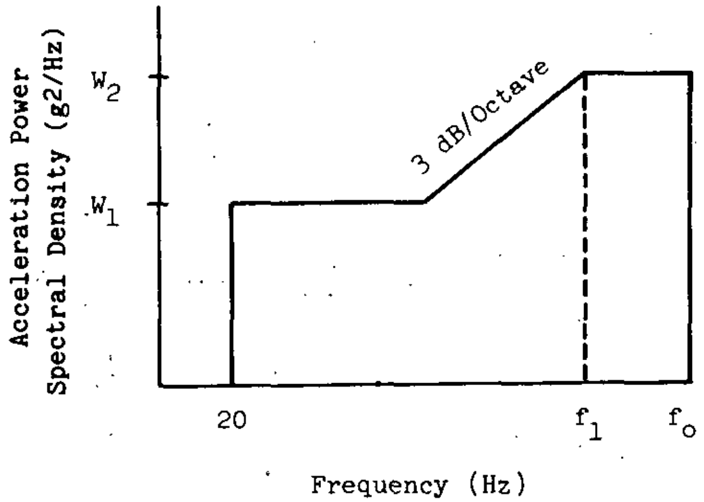
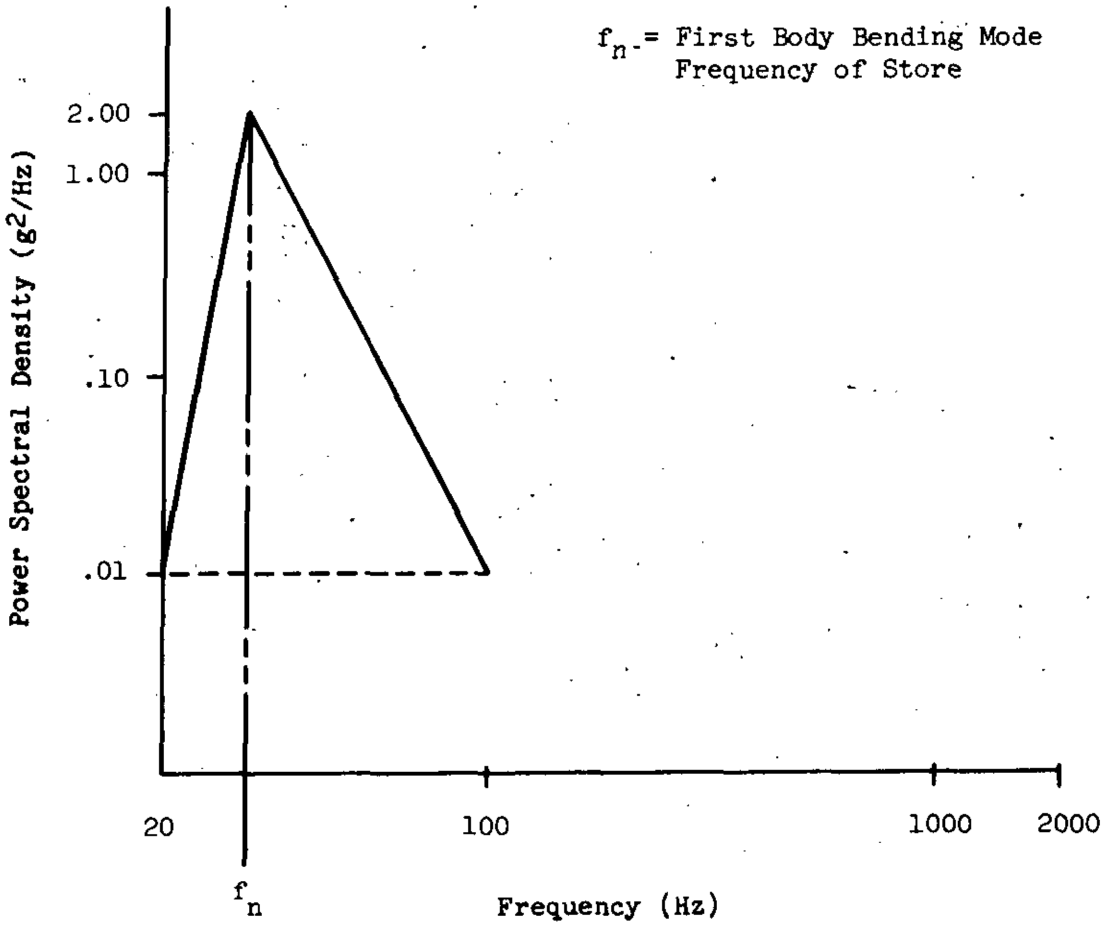


NOTE: Use table 514.3-VI to define W_1 and W_2

FIGURE 514.3-30. Response threshold spectrum for assembled external stores carried on jet aircraft, in the absence of flight measurements.



Test time - 10 minutes based upon following assumptions:

Average maneuver - 6 seconds

Total captive flight life of 150 hours, with a total of 100 buffet maneuvers in the lifetime.

FIGURE 514.3-31. Maneuver vibration response spectrum.

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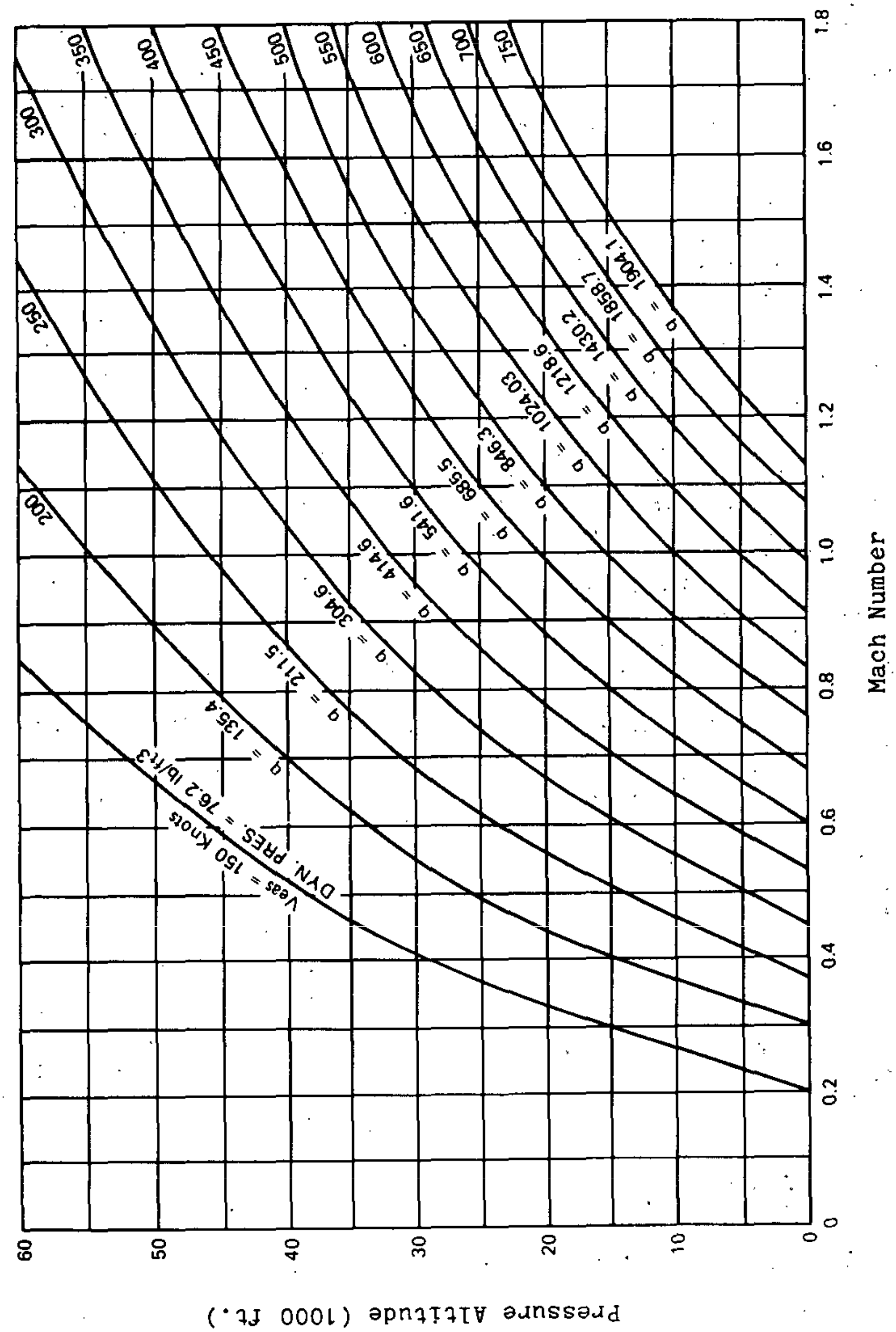

FIGURE 514.3-32. Dynamic pressure (q) as a function of Mach number and altitude.

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Apply broadband vibration to the store using an input spectrum shape of the store-mounted forward accelerometer response spectrum from paragraph I-3.2.7a. The input level shall be 6dB down from the calculated response level of the forward accelerometer.

Identify those frequencies at which the store-mounted accelerometers, in the direction of applied vibration, exceed the applied input vibration by 6dB or greater. There may be different frequencies for the forward and aft accelerometers.

Peak or notch the applied input spectrum until both the forward- and aft-mounted accelerometers in the direction of applied vibration at their respective frequencies identified above equal or exceed the required test levels determined from paragraph I-3.2.7a.

It may be necessary to move the points of attachment between shaker and store until locations are found where both ends of the store are simultaneously excited to their respective test levels.

The off-axis accelerometer response (those accelerometers 90 degrees to the applied vibration) should be examined. For each frequency where the response of an off-axis accelerometer is above in-axis response levels, the following actions are suggested. For each of these frequencies, calculate the ratio of required to observed levels for each accelerometer which was in the direction of vibration (in-axis) and those perpendicular (off-axis) accelerometers which have excessive levels. Average these ratios for each frequency. The input vibration spectrum may then be adjusted so that, at each of these frequencies, their respective average value is equal to unity.

I-3.2.8 <u>Category 7B - Equipment installed in externally carried stores</u>. Equipment installed within an externally carried store will experience a broadband vibration spectrum that depends chiefly on the captive-carry response of the store. Vibration testing, whenever possible should be based on in-flight measurements. If satisfactory flight measurements are not available, functional tests may be derived from figure 514.3-33 and table 514.3-VI. Note that the test levels for equipment installed in stores are the same as the response test levels of assembled stores. The response of the store is the input vibration to an item installed in the store. If buffet-manuever and free-flight conditions can occur for the store into which the equipment will be installed, vibration test spectra need to be developed for each condition.

a. <u>Test levels</u>. If sufficient measured data does not exist, use figure 514.3-33 and refer to I-3.2.7. Vibration testing of equipment to be installed in externally carried jet aircraft stores should be input-controlled testing (see I-4.2.6).

b. <u>Test duration</u>. Refer to I-4.3, I-4.6, I-4.7, I-4.8 and I-4.9 for test duration and endurance test criteria.

c. <u>Test setup</u>. Use I-4.11 for setup.

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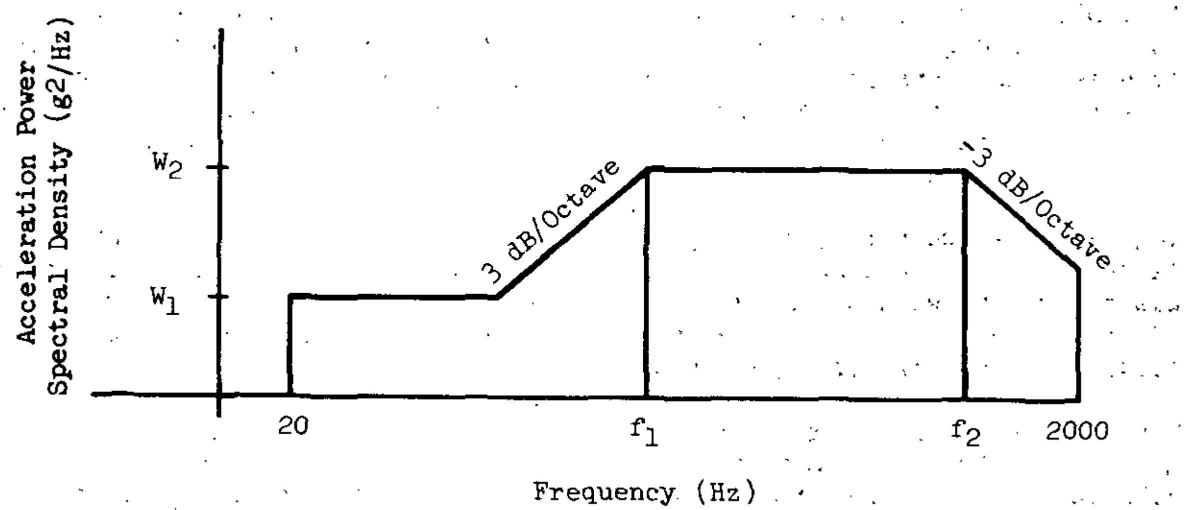

FIGURE 514.3-33. Suggested vibration test levels for equipment installed in external stores carried on jet aircraft.

I-3.2.9 Category 7C - Assembled external stores, helicopters. Complex periodic waveforms characterize the service vibration environment encountered by assembled stores externally carried on helicopters. Unlike stores carried on fixed-wing aircraft, externally mounted helicopter stores receive little aerodynamic excitation, particularly when compared with the rotor-induced vibration. Thus, most of the vibratory energy reaches the equipment through the attachment points between the aircraft and the store. Some excitation, however, is added along the entire store structure due to periodic rotor-induced pressure fluctuations. The result is a complex response, unique to the particular aircraft-store configuration. Therefore, realistic testing depends almost totally upon the use of in-flight vibration measurements. This environment is simulated by exposing the test item to a low-level broadband random spectrum with discrete vibration peaks at the frequencies and first three fundamentals of the aircraft main rotor (source dwell testing - see paragraph I-4.2.2).

a. Test level. As stated above, because of the strong dependency of the vibration level on the aircraft-store combination, the use of measured data taken on the store itself is recommended for setting the levels. The resulting test spectrum shall include exposure based upon the source dwell concepts of I-4.2.2. The suggested vibration conditions from table 514.3-IV and figure 514.3-28 can be used for initial testing prior to acquisition of field data.

b. Test duration. The test duration shall be developed from flight test data. Exposure periods shall be developed by constructing a life cycle based on the measured flight environment, equipment life requirements and aircraft mission profiles. If flight test data are not available, then test durations can be selected from information provided in I-3.2.12.

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c. Test setup. Testing shall be accomplished in three mutually perpendicular axes with the mounting lugs in the up position. The test item should be attached to the fixture by its normal mounting means (e.g., suspension lugs for 2.75 inch FFAR launchers). The vibration fixture shall utilize, if feasible, actual aircraft components for accomplishing this test attachment. Low level 0.05g, 5 to 500 Hz sweeps to identify the store's resonant frequencies and transmissibilities shall be conducted before and after exposure to the test vibration environment. Significant changes in resonant properties shall be considered as failures even though the item still functions to specification levels.

I-3.2.10 Category 8 - Ground mobile. The ground mobile environment consists largely of broadband random vibration resulting from the interaction of vehicle suspension and structures with road and surface discontinuities. The nature of the terrain, vehicle speed, vehicle dynamic characteristics, and suspension loading all affect vibration responses.

There is presently no analytical model of this environment suitable for generalized test application. In general, the vibration spectrum of wheeled vehicles and trailers is predominantly random, with peaks and notches, considerably higher and lower than the mean level, at various discrete frequency bands. This environment can be simulated by a wide-band random vibration test similar to the minimum integrity spectrum for aircraft as given in I-3.2.12. The use of a smooth spectrum similar to figure 514.3-36, generally will produce an overtest at some parts of the frequency spectrum. The spectrums shown in I-3.2.1 and figure 514.3-2 thru 514.3-10 are composites of the cargo beds of typical wheeled vehicles and trailers and again could produce unrealistic test conditions for installed equipment. When these curves are used, consideration must be given to the structure's response at the location where the equipment is installed as it relates to the major structural members supporting the cargo bed.

The track-laying vehicle environment is characterized by the strong influence of the track-laying pattern. The movement of the vehicle, its suspension system, and road discontinuities produce a broadband random excitation which is further extended or excited at frequencies associated with the track pattern. This environment is best simulated by superimposing narrowband random over a broadband random base.

a. Test levels. As discussed above, generalized test levels have not been developed which would be applicable to a specific case. The information, levels and curve presented in I-3.2.1 and I-3.2.12 must be adapted for a specific test item. Whenever possible and justified by the program requirements, the actual vibration environments should be measured before testing the equipment and the results used to formulate a more accurate spectrum shape and level.

b. Test duration. The test duration must be related to the test item's service scenario. Appropriate test durations are given in I-3.2.1 and I-3.2.2; however, their application for this category must be related again to the specific equipment's service scenario. In development of the test duration from measured data, the procedure outlined in appendix A should be reviewed.

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c. Test setup. The test item shall be attached to the vibration generator directly or with a fixture, and securely held by its normal means of attachment. The fixture shall incorporate actual service structures as much as possible to minimize unrealistic response characteristics during test exposure. Any connection to the test item, such as cables pipes, wires, and the like, shall be arranged so that it imposes restraints and mass similar to those present when the equipment is installed in the operational configuration. Excitation shall be applied through the three orthogonal axes of the test item.

I-3.2.11 Category 9 - Shipboard vibration. Equipment installed in ships will receive vibration stresses resulting from natural environmental inputs to the ship's superstructure and local unit transmissibilities (amplifications) within the equipment and its mounting structure. Vibration testing of shipboard equipment should address both the levels of environmental inputs and the susceptibility of equipment/mounting resonances to input frequencies.

Shipboard vibration spectra have a random component induced by the variability of cruising needs, sea states, maneuvers, etc. and a periodic component imposed by propeller shaft rotation and hull resonances. Equipment mounted on masts (such as antennas) can be expected to receive higher input than equipment mounted on the hull or deck.

a. Test levels. Whenever possible, measurements should be used to develop the test criteria. Appendix 1 provides guidance for the development of criteria from measured data. In the absence of shipboard measurements, levels fround in figure 514.3-34 should be used. The random vibration test of shipboard equipment should follow either the Basic Transportation Test (I.3.2.1) or the Bench Handling Shock Test (method 516.3, Procedure VI).

In order to verify structural integrity and the compatibility of equipment/ mounting resonance frequencies with shipboard input frequencies, a sinusoidal vibration test should be conducted in accordance with MIL-STD-167 for Type I (Environment Vibration). In the event that actual shipboard vibration data recorded on candidate vessels show levels or frequency ranges different from those for MIL-STD-167, Type I, the test levels should be tailored to envelope the highest values for each frequency, with appropriate consideration given to the fatigue life of the equipment.

b. Test duration. The test durations for shipboard applications should be based upon the anticipated deployment scenarios. A method for development of test durations is included in appendix 1. For tests which utilize the test levels from figure 514.3-33, the first duration should be two hours along each of three orthogonal axes.

c. Test setup. Equipment should be mounted in its normal configuration with normal shock/vibration isolation mounts used throughout the test.

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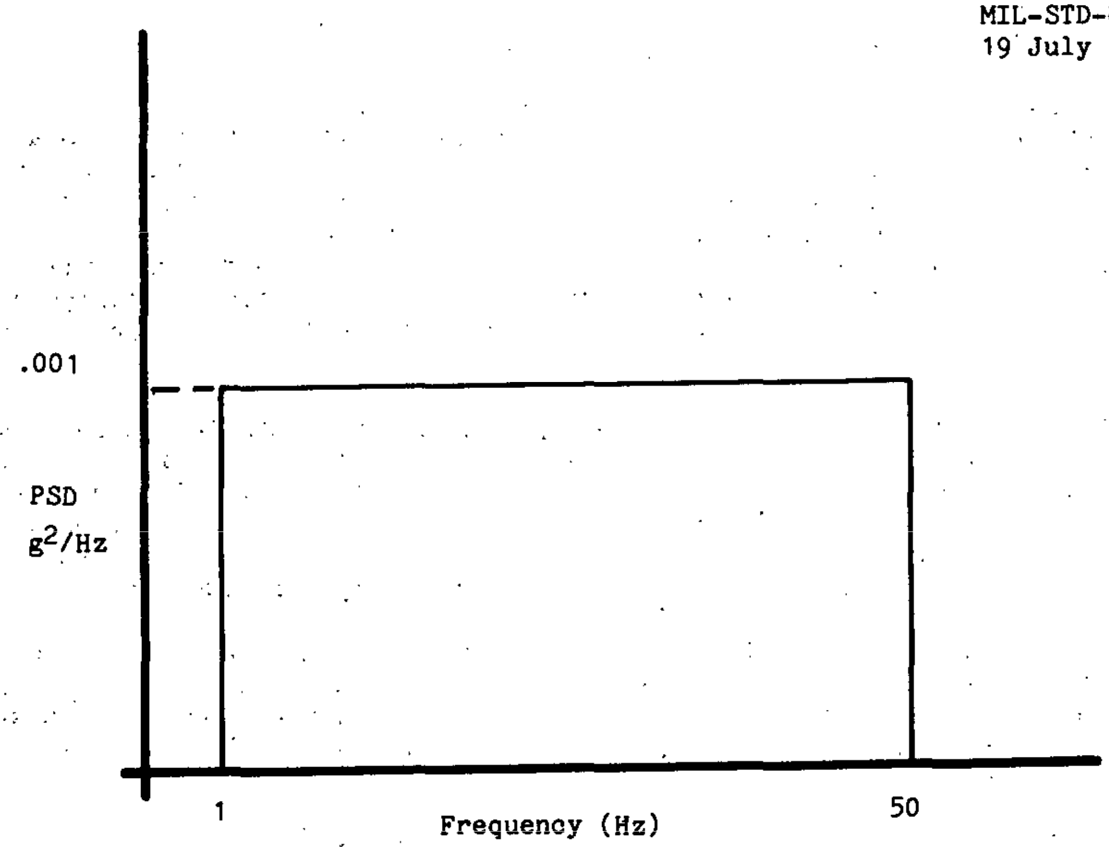

FIGURE 514.3-34. Threshold performance random vibration spectrum for equipment installed in ships (non-combat).

I-3.2.12 Category 10 - Mininum integrity test. The following information is provided for developing a test program for items which will not encounter any of the other vibration environments listed in table 514.3-I and for items mounted on vibration isolation devices (I-4.10). The test program may include a secured-cargo test from paragraph I-3.2.1, since all material is subject to transportation from the point of manufacture to point of use. Additional testing will be needed if the stresses experienced in the secured cargo test will not assure adequate performance during application. The additional vibration tests are for helicopter and aircraft/external store equipment applications. These vibration levels are found in figures 514.3-35 and 514.3-36 and have no relationship whatsoever to the application environment. However, historical experience has shown that equipment which can withstand these test conditions can function satisfactorily in the field. These exposures are sometimes called "junk level" tests and provide some assurance that the equipment can withstand operations and handling during removal and repair, but certain risks must also be assumed without further comprehensive testing. For helicopter applications, this test should only be applied to electronic boxes which have first natural frequencies, as installed in the helicopter, greater than 100 Hz, and which weigh less than 75 pounds. The weight penalty associated with this unrealistic test begins to become significant for electronic boxes that weigh more than 75 pounds.

a. Test level. The test levels shown in figures 514.3-35 and 514.3-36 are based upon a variety of platforms.

b. Test duration. The suggested test durations are provided in table 514.3-VII. The time of exposure can be varied to meet the test requirements.

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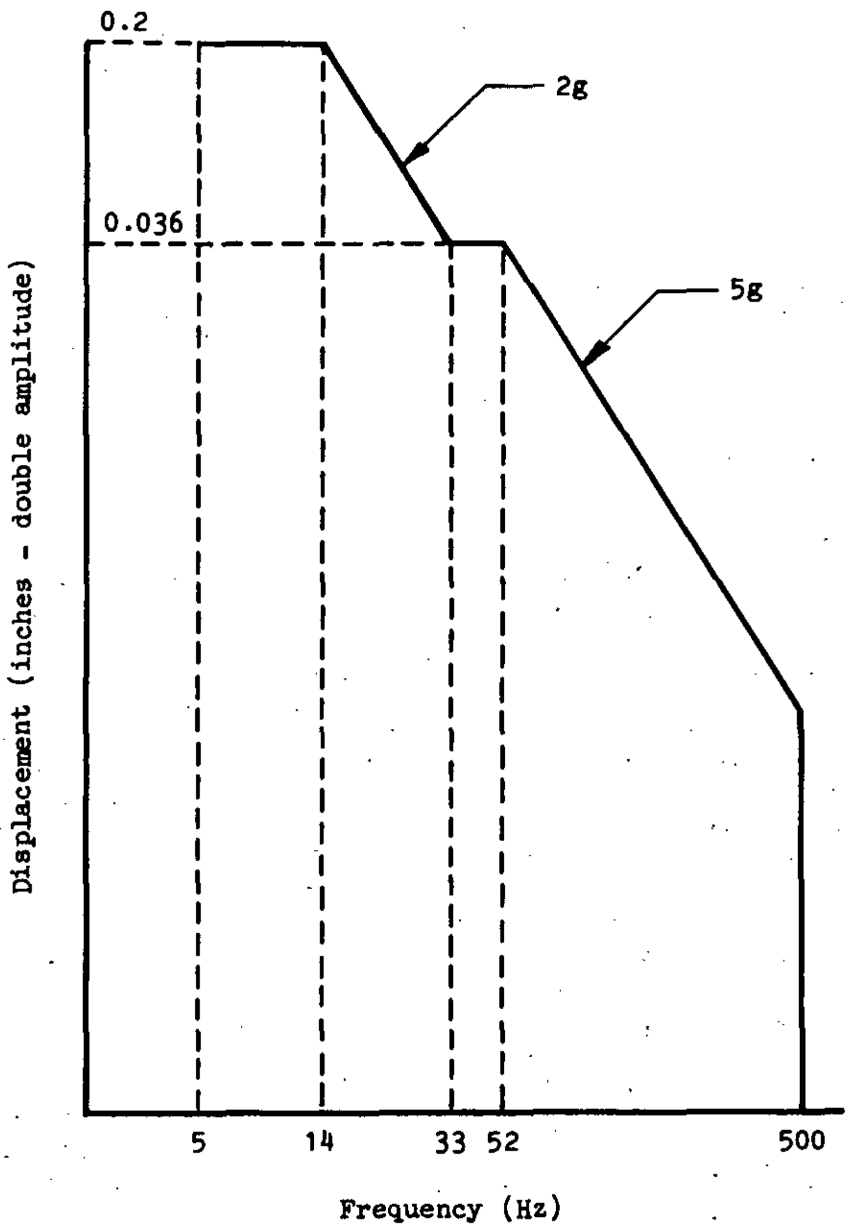

FIGURE 514.3-35. Minimal integrity test-helicopters.

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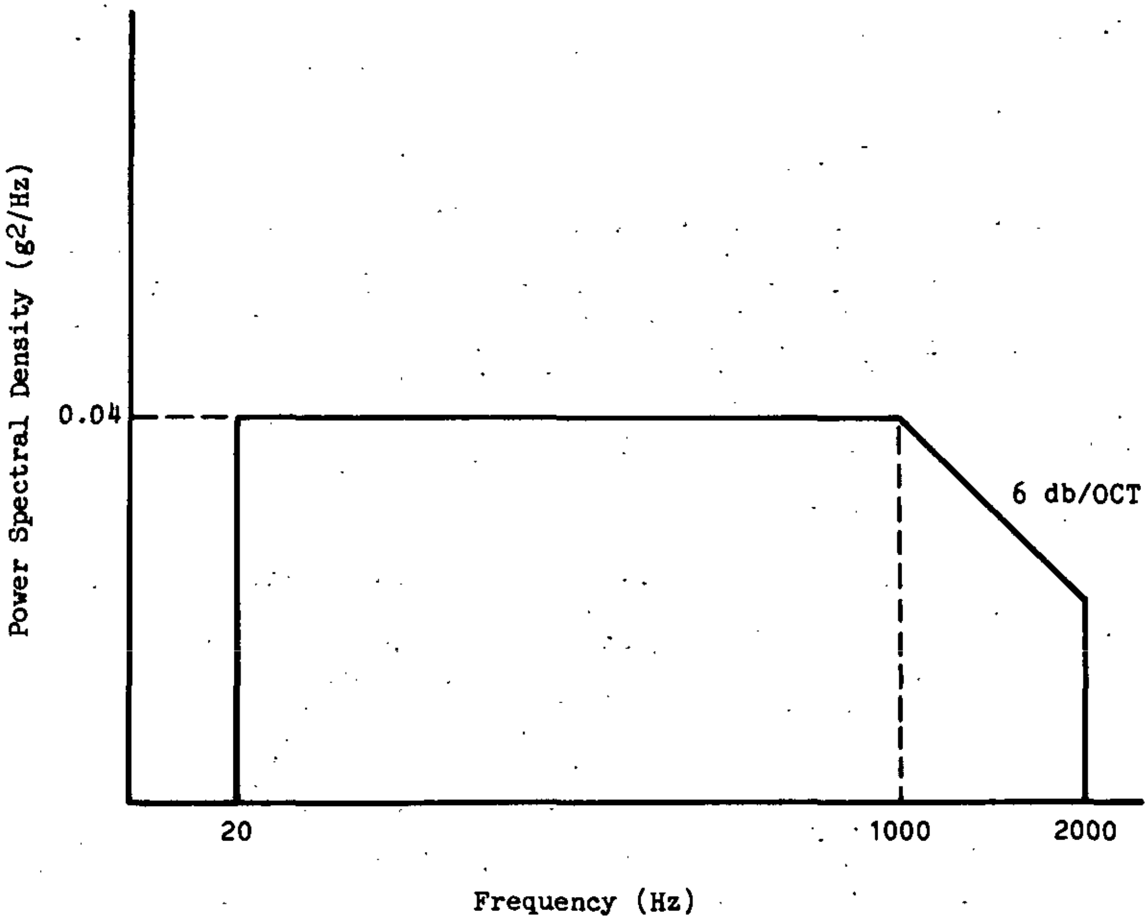

FIGURE 514.3-36. Minimum integrity test-aircraft/ external store equipment.

TABLE 514.3-VII. Suggested test durations for equipment installed in aircraft.

SOURCE	TEST DURATION
Figure 514.3-35	Maximum three hours per axis 30 minute logarithmic sweep 5 to 500 hz
Figure 514.3-36	One hour per axis

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c. Test setup. The secured cargo transportation test phase shall be accomplished as indicated in paragraph I-3.2.1. The additional vibration exposure shall be accomplished with the test item secured to the fixture/exciter. Items which are mounted on vibration isolation equipment should be tested with the isolation removed. The items shall be tested in each of three orthogonal axes.

I-4 SPECIAL CONSIDERATIONS

I-4.1 Combined temperature, vibration test. To expose materiel to realistic service stresses, a combined temperature-vibration test may be necessary. The high and low temperatures that materiel is expected to endure while being transported are usually specified in the requirements documents in terms of the climatic categories described in MIL-STD-210 or AR 70-38. These same criteria are presented for use in methods 501.2 (High Temperature) and 502.2 (Low Temperature). The temperature values selected for those tests can be used for combined temperature-vibrational testing.

I-4.2 Common test techniques

I-4.2.1 Random vibration. The majority of vibration experienced by equipment in operational service has been determined by analysis to be broadband in spectral content. That is, all frequencies are present at all times in various combinations of intensity. Controlled experiments have demonstrated that random vibration effectively simulates broadband in a test situation. Therefore most of the tests in this method use random vibration.

Random vibration spectra are defined in terms of acceleration spectral density (also referred to as power spectral density, or PSD) profiles, which relate energy density levels to specific frequency bands. The vibration is defined over a relevant frequency range.

The use of g-rms values alone to describe vibration tests is not valid, since a a g-rms value does not characterize a specific vibration profile. An infinite combination of frequency bandwidths and spectral shapes can satisfy one g-rms value. Therefore, vibration measurements and test spectra should always relate energy content to specific frequency bands.

As traditionally applied in the test laboratory, random vibration is characterized by a gaussian energy distribution, but other forms of broadband excitation (mechanical or electro-hydraulic) may be employed if the desired spectral control can be achieved.

I-4.2.2 Source dwells. In some cases, the vibration environment is characterized by periodic excitation from reciprocating or rotating structures and mechanisms (e.g., rotor blades, propellers, pistons, gunfire). This excitation may be transmitted through fluids (air or liquid) or structures. When this form of excitation predominates in a critical frequency band, source dwell vibration is appropriate. A source dwell excitation is characterized by broadband random, narrowband random, or one or more sine waves.

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This technique differs from the traditional sinusoidal resonance dwell test. A resonance dwell emphasizes those frequencies at which the test item resonates. A source dwell emphasizes those frequencies which predominate in the platform environment. Obviously the source dwell spectrum provides a more realistic test. Source dwell testing should be performed using one of the following techniques:

(1) Broadband random excitation with vibration peaks centered at the fundamental and harmonic frequencies of the platform.

(2) Narrowband random superimposed over a low-level background broadband random signal with the narrowband portion centered at the fundamental and harmonic frequencies. (NOTE: The narrowband signals may also be cycled through a frequency band representative of the platform conditions).

(3) Sinusoidal inputs at the fundamental frequencies and harmonic frequencies either singularly or simultaneously. A low-level random background may also be added to the sinusoids. (NOTE: The sinusoidal inputs may be cycled through a frequency band representative of the platform conditions).

I-4.2.3 Sinusoidal vibration. The service vibration environment in some propeller aircraft and helicopters contains excitation which is basically sinusoidal in nature. The excitation derives from engine rotational speeds, propeller and turbine blade passage frequencies, rotor blade passage and velocity, and their harmonics. Environments such as this may be best simulated by a sinusoidal test. Caution must be exercised to assure that the frequency range of the sinusoidal exposure is representative of the platform environment.

Most vibration problems are associated with a resonant response of the equipment item or component to the platform source excitation. Thus, the traditional sweep sinusoidal vibration test technique is not used in this method for representation of the actual service condition. Swept sinusoidal testing is a useful engineering development technique.

I-4.2.4 Response characterization. Response characterization is a technique for measuring the structural response of equipment or test fixtures to applied vibration. Response characterizations may either use broadband or swept-sine excitation. They are performed for reasons which include, but are not limited to:

(1) Identifying the frequencies at which an item resonates, especially when those frequencies might be present in the service vibration environment.

(2) Evaluating fixture/test item interactions to ensure reasonable duplication of known or expected service-induced responses.

(3) Determining appropriate locations for test control instrumentation.

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Response characterizations should ultimately be performed at realistic vibration levels since nonlinearities in equipment response render characterizations at other levels inconclusive.

I-4.2.5 Test axes. Unless otherwise stated in specific procedures, test items shall be excited along three orthogonal axes. Excitation shall either be directed along each axis, one axis at a time or applied along two or three of the axes simultaneously.

I-4.2.6 Input control versus response-defined control. Input control is the traditional approach to vibration testing. Ideally, this form of testing should represent the input from a carrying platform into equipment on the platform. It should not be used when the equipment mass-loading could significantly alter the platform behavior or when the actual service excitation is applied to all parts of the structure simultaneously (i.e., aerodynamic turbulence) rather than through a few distinct attachment points.

Response-defined testing uses an essentially undefined input and instead tries to achieve an equipment structural response representative of that anticipated or measured in service. This approach is especially appropriate when service vibration measurements exist and close correlation between laboratory and service conditions is readily achieved.

I-4.2.7 Test durations. Test durations should be chosen along with test levels to accomplish the test purpose. Guidance is included in the individual test technique discussions of I-3, in I-4.6, I-4.7, I-4.8, and in appendix A.

Usually vibration criteria are written in terms of total time at a given level and are implemented as a continuous exposure. However, service exposure is usually made up of a series of discrete or short-term events. Thus, continuous application of vibration could result in unrealistic structural, isolator, or other heat buildup effects. Vibration should be applied for short periods representative of service conditions. Vibration-on periods should be alternated with vibration-off periods of sufficient length to allow heat to dissipate. Examples of intermittent vibration events requiring such treatment are gunfire and aircraft maneuver buffet.

I-4.3 Endurance versus functional testing. Functional tests are intended to demonstrate that the equipment will function satisfactorily in the service environment. Thus, functional test levels normally are the maximum levels expected in normal use at which full function of the equipment is required. Where partial or degraded functioning is permitted or under particular environmental extremes, an additional functional test should be accomplished accordingly. In cases where the relationship between vibration stress level and equipment's degree of performance is uncertain, functional testing at lower levels should be considered.

Endurance testing is conducted to demonstrate that the equipment has a structural and functional life which is compatible with the system/subsystem life requirements. An endurance environment is one in which the equipment is not required to meet all performance specifications. No damage is allowed while it is operating and the system must exhibit unimpaired performance when the endurance environment is removed.

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Endurance testing does not establish fatigue life. This is because:

(a) the test item is tested for the amount of stress anticipated for one lifetime but not necessarily to destruction, and

(b) because the sample size is too small.

Rather endurance testing assures that the required life can be achieved with reasonable maintenance. The determination of the item's useful life would require a combined environments test (method 520) where all relevant environments were varied realistically and a sufficient number of samples were tested to failure. A test item which has survived an endurance test is not necessarily used up; however, the risk of failure in further use is higher than that of a new unit. So the test unit should not be used for a true life test, a reliability demonstration, or a safety-critical application. Other uses are acceptable if the increased risk of failure is compatible with the use.

I-4.4 Mechanical impedance effects. Allowance should be made for mechanical impedance effects whenever the benefits of increased realism are worth the time, effort, and cost required for implementation.

Equipment structures dynamically influence their own response to an external forcing function. At structural natural frequencies where the response stresses are high, the structure will load the adjacent supporting structures (i.e., notch the acceleration spectral density at these frequencies). The magnitude of loading effects is related to the relative impedance of the equipment structure and support structures. As a rule of thumb, the resonant element exhibits a loading force in proportion to its dynamic weight multiplied by the corresponding amplification factor.

Mechanical impedance effects can be accounted for in establishing vibration test spectra. The depths of notches are determined by measurement or by calculation. Ref 54 gives guidance in this matter.

I-4.5 Determination of bandwidth for source dwell testing. A test spectrum representative of this type of testing is presented in figure 514.3-14. Test bandwidths should be based on measured data if possible. When data are not available, the bandwidth can be defined as:

$$BW_{3dB} = \frac{\pi(F)}{4}^{1/2}$$

Where: BW_{3dB} = the bandwidth at a level 3 db below the peak PSD level

F = the fundamental frequency, f_n or one of the harmonics:

f_1, f_2, f_3, f_4.

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This peak bandwidth should be readily achieved by even the least sophisticated digital random vibration control system. The bands between the vibration peaks are filled with broadband random vibration at a level representative of the platform being simulated. When variable RPM cases (see I-3.2.4) are being simulated, wider bandwidths will be required.

I-4.6 Engineering development testing. Engineering development testing is used to uncover design and construction deficiencies as quickly as possible and to evaluate subsequent corrective actions. It should begin as early as practical in the development phase and continue as the design matures. The ultimate purpose is to assure that developed equipment is compatible with the platform environment and that qualification testing does not reveal that more development work needs to be done.

The tests have a variety of objectives. Therefore, considerable freedom can be taken in selecting test vibration levels, excitation, frequency ranges and durations. Typical programs may include resonant search accomplished by exposing the item to low-level sweep sine input over the frequency range of concern. Sine dwells are then used to obtain mode shapes. Fast Fourier transform analyses of random inputs can also be used to accomplish this. Mode shape and frequency determinations are necessary for verifying structural dynamic models and for discovering platform/equipment compatibility problems. Once mode shapes as well as module frequencies have been identified, the test item may be exposed to dwell, swept-sinusoidal or random excitation testing. The vibration intensity of this testing is selected to accomplish specific test objectives. The level may be lower than the field environment to avoid excessive damage to a prototype, higher to verify the test items' structural integrity, or raised in steps to evaluate performance variations and obtain failure data.

I-4.7 Environmental worthiness. Worthiness testing is performed to verify that prototype or test versions of equipment are adequate for use in a system or subsystem test. Levels and durations should be selected to provide confidence that the equipment will perform well enough to support the test program with an acceptable level of maintenance. In cases where safety is a factor, the test must be adequate to assure safe operation or possible fail-safe operation. Levels are usually typical operating levels unless safety is involved; then maximum operating levels are necessary. Durations are either long enough to check equipment function or an arbitrary short time (5-10 minutes), whichever is greater.

I-4.8 Qualification. Qualification tests are used to verify that production equipment is capable of operating to specified performance criteria throughout the range of environments of its service application and to provide reasonable assurance that life requirements will be met (see I-4.3). This normally requires funtional tests to accomplish the first goal and endurance tests for the second.

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Functional test levels are normally the maximum service levels. When there is significant non-linearity, testing at lower levels should be considered. When separate functional and endurance tests are required, the functional test duration should be split, with one half accomplished before the endurance test and one half after the endurance test (in each axis). The duration of each half should be sufficient to fully verify equipment functional or one half hour (1 hour per axis), whichever is greater. This arrangement has proven to be a good way of adequately verifying that equipment survives endurance testing in all respects.

In the past, endurance test duration was normally set at one hour per axis. Test levels were esablished by raising functional levels to accoount for equivalent fatigue damage. Another approach is to establish levels and durations to test to maximum service levels for a duration sufficient to reach the material endurance limit (approximately 10^6 cycles at each resonant frequency). These techniques are basically valid; however, both have shortcomings. The first technique results in test levels higher than field levels -- in some cases, much higher.

The fatigue relationships (I-4.9) used to generate these criteria are simplified representations at best and when structural nonlinearity at high vibration levels becomes a factor, the validity of the relationships is questionable. The second technique depends on the definition of endurance limits. This is a further simplification of the already simplied fatigue relationship. Further, it is shown that some materials do not exhibit endurance limits.

Based on the above, the following approach is recommended. Use the simplified fatigue relationship to determine the time at maximum service levels (functional levels) which is equivalent to a vibration lifetime (levels are different for different mission profiles). Appendix A contains an example of this process. Use the equivalent time as the functional test duration, thereby combining functional and endurance tests. There may be cases when this test duration is too long to be compatible with program restraints. In this case use as long a test duration as is practical and use the fatigue relationship to define the test level. However, in no case should endurance test levels and durations be less than those specified in I-3.2.12.

I-4.9 Fatigue relationship. The following relationship may be used to determine the required test times at functional levels to satisfy endurance requirements or when necessary to develop the ratio between functional and endurance levels:

$$\left(W_o/W_1\right) = \left(T_1/T_o\right)^{1/M}$$

where

W = Vibration levels (acceleration spectral density)

T = Time (hours)

M = Material constant (slope of log/log random s/N curve)

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This relationship is a simplified expression of linear fatigue damage accumulation for typical materials used in electronic equipment. More sophisticated analysis techniques can be used when warranted. The recommended value of M is 4.0. (Note: if this equation is used for sine calculation, W represents peak g and M = 6.)

I-4.10 Vibration isolation devices. Vibration isolators (shock mounts), isolated equipment shelves, and other devices designed to protect equipment from platform or shipping environments use low-frequency resonance to attenuate high-frequency vibration inputs. Effective performance of these devices depends on adequate frequency separation between isolation resonant frequencies and equipment resonant frequencies, and sway space (clearance around isolated elements) to avoid impacts of the isolated elements with surrounding equipment and structure. In addition, all military equipment should have a minimum level of ruggedness even if it will be protected by isolation in its application environment. To assure that these requirements are met, sway amplitude and isolation characteristics (transmissibility versus frequency) should be measured during all vibration tests. This is also true when sub-elements are isolated within equipment items. Further, all isolated equipment should pass the Minimum Integrity Test requirements (I-3.2.12). These parameters should be measured at each test level. This is necessary because isolation devices are nonlinear.

I-4.11 Test setup. Unless otherwise specified in the individual test description (section I-3), the test item shall be attached to the vibration exciter by means of a rigid fixture capable of transmitting the vibration conditions specified. The fixture should input vibration to racks, panels, and/or vibration isolators to simulate as accurately as possible the vibration transmitted to the test item in service. However, all equipment items protected from vibration by these means should also pass the minimum test requirements of I-3.2.12 with the test item hard-mounted to the fixture.

I-4.12 Equipment operation. During all platform-induced vibration simulations, the test item should be functioning and its performance should be measured and recorded. Performance to full specification requirements should be required during all functional tests. Measurement of performance level attained should be required when endurance levels are higher than functional levels (I-4.8).

I-4.13 Summary of test information required. The following information is required in the test plan to adequately conduct the tests of section II:

a. Test procedure

b. Test item configuration

c. Operational requirements

d. Test levels and durations

e. Test set-up description

f. Accelerometer location and calibration

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SECTION II

II-1. APPARATUS. Any vibration-inducing machinery capable of satisfying the test conditions is acceptable. Specific requirements for test apparatus are provided in subparagraph c of each subdivision of I-3.2.

II-1.1 Tolerances. The acceleration power spectral density of the test control signal shall not deviate from the specified requirements by more than ±3dB over the entire test frequency range. However, deviations of -6dB in the test control signal may be granted for frequencies greater than 500 Hz due to fixture resonance, test item resonance, or facility limitations. The cumulative bandwidth over which this reduction shall be allowed cannot be greater than 5% of the test frequency range (see figure 514.3-37). In no case shall the acceleration power spectral density be more than -6dB below the specified requirements. No deviation shall be grated for frequencies below 500 Hz. When the test cannot be controlled within +3dB from the specified requirement, at the risk of the tester, the test may continue. The risk shall be to assume no overtesting is occurring, test results are valid, and appropriate corrective action will be taken in accordance with the nature of the test. Tolerance levels in terms of dB are defined as:

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

where

W_2 = measured acceleration power spectral density in g^2/Hz units

W_o = specified level in g^2/Hz units.

Confirmation of these tolerances shall be made by the use of an analysis system providing at least 100 statistical degrees of freedom. For all procedures using broadband random vibration with random peaks, sinusoidal peaks, or source dwell, analysis systems shall be less than or equal to 10 Hz in bandwidth up to and including the frequency of the highest peak in the test spectrum.

A digital analysis system is the preferred method for performing a power spectral density control and analysis. Digital systems used shall have accuracies in excess of standard analog analysis and control systems with the following capabilities:

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

B = 25 Hz, maximum between 20 and 200 Hz

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

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

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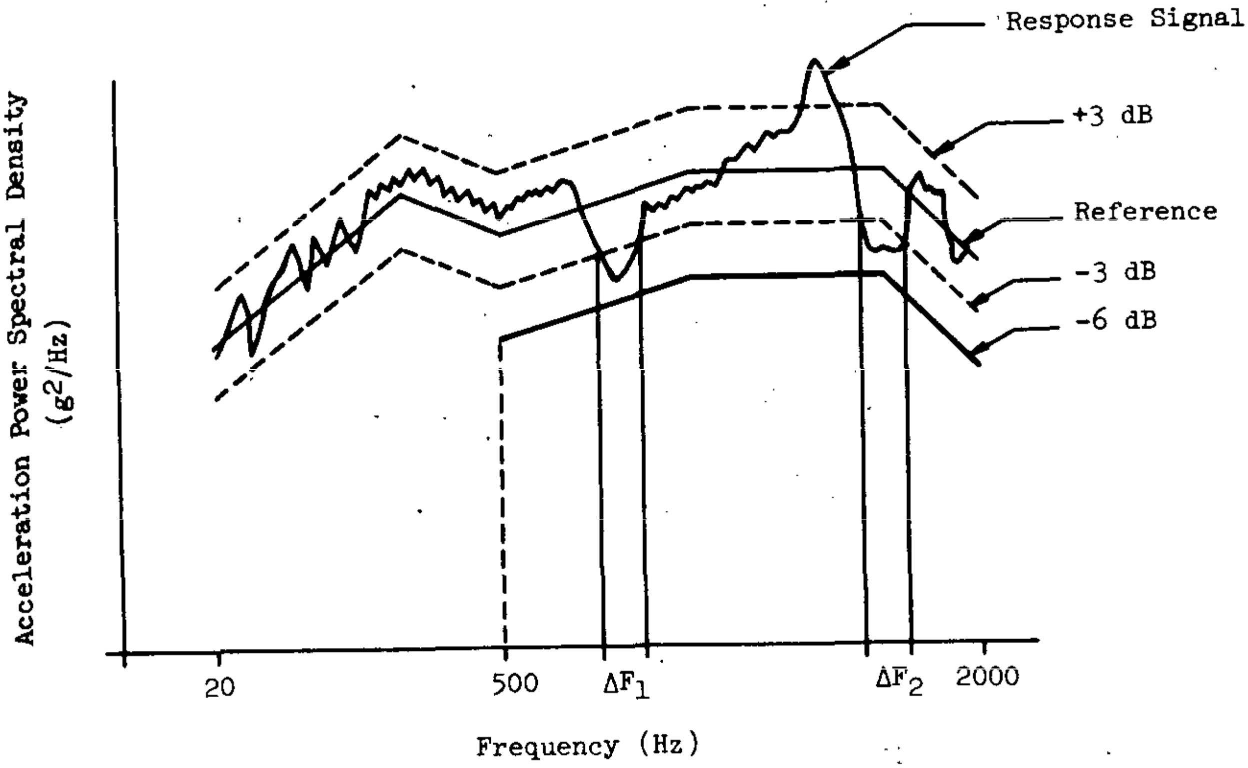

$\Sigma \Delta F_i \leq 5\%$ of Test BW

FIGURE 514.3-37. Example of acceptable performance within tolerance.

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b. Swept frequency analysis systems characterized as follows:

(1) Constant bandwidth as follows:

(a) Filter bandwidth as follows:

B = 25 Hz, maximum between 20 and 200 Hz

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

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

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

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

(2) Constant percentage bandwidth analyzer.

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

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

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

II-2 PREPARATION FOR TEST

II-2.1 General preparation

Step 1. Perform life cycle analysis described in section 4 of this standard.

Step 2. Identify test categories which are applicable and pertinent from the life cycle analysis.

Step 3. Determine test conditions for each applicable and pertinent category.

Step 4. Select appropriate test apparatus, data collection and analysis equipment.

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Step 5. Prepare the test item in accordance with General Requirements, paragraph 4 and as specified for the test category.

Step 6. Examine the test item for physical defects, etc, and document the results.

Step 7. Conduct an operational check and document the results.

Step 8. Proceed to the required test procedure if no problems are found; otherwise, correct the problems and restart with step 6 above.

II-3. PROCEDURES

II-3.1 Procedure I

Step 1. Complete step 1 through 8, paragraph II-2.1.

Step 2. Inspect test item to establish pre-test criteria and physical condition.

Step 3. Verify the test items' functionality.

Step 4. Mount the test item on the vibration equipment in accordance with the provisions stated in the appropriate category from section I-3.2.

Step 5. Expose the test item to the test level and duration as determined from section I-3.2.

Step 6. During step 5 the test item shall be operated as if it were in operational usage. This step only applies for categories and equipment for which operations during exposure to vibration are appropriate.

Step 7. Inspect the test item and compare it to pre-test data and physical condition. If applicable, verify the test item functionality and record the results.

Step 8. Repeat steps 2 through 7 for each axis (see paragraph I-4.2.5).

Step 9. Document the test results in accordance with paragraph II-4.

II-3.2 Procedure II:

Step 1. Complete steps 1 through 5, paragraph II-2.1.

Step 2. Inspect test item to establish pre-test criteria and physical condition.

Step 3. Verify the test items' functionality.

Step 4. Prepare the package tester/test equipment in accordance with provisions of paragraph II-2.1.

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Step 5. Place the test item which has been prepared for field transportation on the bed of the package tester/test equipment.

Step 6. The package tester/test equipment shall be operated to provide the test level and duration as specified for category 3, I-3.2.3.

The test duration shall be divided into six periods. At the end of each period the test item shall be rotated onto a different face so that at the end of the total duration, the test item will have rested on each of its six faces.

NOTE: The item shall not be rotated or tested on a face which, in the judgment of the test engineer, would be an unrealistic test condition. In this instance, the total test time of three hours would be divided equally between the number of faces on which the test item is to be positioned.

Step 7. Inspect the test item and compare to pre-test criteria and physical condition. If applicable, verify the test items' functionality.

Step 8. Document the test in accordance with paragraph II-4.

II-3.3 Procedure III

Step 1. Complete steps 1 through 5, paragraph II-2.1.

Step 2. Inspect test item to establish pre-test criteria and physical condition.

Step 3. Verify the test items' functionality.

Step 4. Place the shelter on the transport vehicle(s) that is normally used to transport the shelter.

Step 5. The shelter shall be secured in its normal manner to the transport vehicle.

Step 6. Install instrumentation in the shelter to measure the vertical axis acceleration time history on the shelter floor.

Step 7. Drive the trailer/shelter combination on the Munson Test Course at Aberdeen Proving Ground, Aberdeen, Maryland or an equivalent course.

Step 8. The trailer/shelter combination shall be driven five times over the following sections of the course at specified speeds:

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NOTE: The speeds will be utilized as specified unless the speed poses an unsafe driving condition, in which case the maximum safe operating speed will be utilized.

(a) Coarse washboard (6-inch waves spaced 72 inches apart) - 5 MPH

(b) Belgian block - 20 MPH

(c) Radial washboard (2-inch to 4-inch waves) - 15 MPH

(d) 2-inch washboard - 10 MPH

(e) 3-inch spaced bump - 20 MPH

Step 9. Inspect the shelter/test item and compare to pre-test criteria and physical condition.

Step 10. Verify the test items' functionality.

Step 11. Document the test in accordance with paragraph II-4.

II-3.4 <u>Procedure IV - Qualification (externally carried jet aircraft stores)</u>.

Step 1. Check test item for performance in accordance with requirements.

Step 2. Expose test item to functional test levels. Function the test item as if it were in operational usage. Duration of step 3 shall be one-half of the required duration of functional test. See I-3.2.7b for durations.

Step 3. Expose test item to endurance test levels. The test item need not be functioning during endurance testing. See I-3.1.7b for durations.

Step 4. Expose test item to second half of functional test. Follow step 3 procedure.

Step 5. If test item does not have a free-flight phase, go to step 9.

Step 6. If free-flight test is required, expose test item to test levels and duration as defined in paragraph I-3.2.7 (Free Flight).

Step 7. Function stores thru free-flight performance requirements during step 7.

Step 8. If life analysis shows that store shall not be exposed to buffet vibration, go to step 12.

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Step 9. Expose the store to 10 minutes of vibration levels and spectrum of buffet-induced vibration as described in paragraph I-3.2.7 (Buffet).

Step 10. Verify performance of store after performance of step 10.

Step 11. Repeat steps 1 through 11 for each test axis.

Step 12. Document test as outlined in paragraph II-4.

II-4 INFORMATION TO BE RECORDED

a. Prior test history of the specified test item.

b. Inspectionand test procedures, including inspection requirements, test criteria, instrumentation, data requirements, and failure criteria.

c. List of all test equipment, including vibration generating and analysis equipment, mounting arrangements, and fixtures.

d. Orientation of test item, including axes of applied vibration.

e. Location of accelerometers used to control and measure vibration.

f. Resonant frequencies, including those selected for test, as applicable.

g. Isolation characteristics, including sway amplitudes and transmissibility versus frequency.

h. Applied test levels, durations, and frequency ranges.

i. Results of all performance measurements, including overall test results.

j. Analysis of each failure and corrective action proposed.

k. Analysis bandwidth.

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APPENDIX A

GUIDANCE FOR DEVELOPMENT OF
LABORATORY DYNAMIC TEST SPECIFICATION

A-1. INTRODUCTION

Laboratory test specifications developed from test item stresses measured during actual service conditions are or may be significantly more realistic than the standard laboratory specifications contained in the dynamic test procedures of this standard. This is generally true even when compromise is made due to unavailability of prototypes, lack of definition of service scenarios, or limited measured service stress data. All possible effort should be made to develop realistic laboratory test specifications. Service scenarios should be estimated and ballast loads used to obtain field data for interim criteria. It is imperative that the interim criteria be updated as prototypes and additional data and information become available.

In the development of laboratory test specifications, the effort must be planned since each step in the process affects all other steps. Factors such as cost, sample sizes, test facilities, conduct of test, and pass-fail criteria must be considered. Detailed procedures, including assumptions, approximations, and supporting rationale, should be fully documented. The degree of accuracy should be consistent throughout the specification development, test program, and evaluation of results. While technical analysis is a valuable tool, sound judgment is the basis of quality in testing.

A-2. GENERAL PROCEDURES

The procedures for development of a laboratory dynamic test specification can be generalized as follows:

a. Define service scenarios in accordance with section 4 of this standard.

b. Obtain representative field stress data.

c. Estimate the fragility of the item relative to the service conditions. This information is used to:

(1) Reevaluate the decision to conduct the test.

(2) Determine the degree of accuracy required for the specification development.

(3) Predict critical frequencies and establish a hierarchy with respect to frequency.

d. Develop a failure model for potential use in the time scaling of the laboratory test.

e. Separate types of data (periodic, random, transient) for processing by individual techniques.

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f. Develop an equivalent scenario and an equivalent duration by deleting negligible stress levels, combining similar data and using maximum measured field levels.

g. Apply conservation (additional severity) to cover unknown conditions. A factor of 1.2 may be used as a base. However, the conservative factor is determined by:

(1) The tester's confidence in definitions of service conditions.

(2) The accuracy required (the consequences of passing a bad item versus the consequences of failing a good item).

h. Conduct the laboratory test.

i. Evaluate the results with consideration to overall specification development.

A-3. TYPICAL VIBRATION TEST SPECIFICATION DEVELOPMENT

This section describes the development of a laboratory spécification for a tracked vehicle. This example is to be used as a guide and may be modified as appropriate for other types of platforms and forcing functions.

A-3.1 Required scenario. The materiel user's requirements and service scenarios are identified. The required scenario defines the road, speed, and mileage distributions as well as the frequency of missions and the test item configuration. The test specification is based on these required scenarios.

A-3.2 Field data requirements. The dynamic stresses occurring duringn service conditions are measured during instrumented road tests. Road test data requirements are specified to obtain representative data for service conditions which are to be accounted for. Requirements include instrumentation, locations, frequency response, roads, speeds, and provisions for validation of field data.

A-3.3 Data reduction and specification development

A-3.3.1 Data reduction. The overall data reduction and specification document is summarized in flow chart format in figure A1. In the following discussion, it is assumed that the reader is familiar with basic vibration data reduction techniques and laboratory test conduct. Detailed data reduction procedures may be found in reference A1.

The final vibration criteria will be in the form of a shaped random spectrum with a periodic component mixed in to account for the tracklaying response. Certain key features of the specification development are discussed below.

A-3.3.2 Equivalent damage theory. This provides a model for the failure mechanism. It is assumed that the failure mechanism is fatigue. (Other possible failure modes: fracture, wear, loosening, operational, and heat-related failures.) As detailed in reference A2, fatigue damage can be accelerated by increasing the stress levels along a test exaggeration curve. The specification development will use the composite test exaggeration curve developed in reference A2. The curve is presented in figure A2.

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A-3.3.3 Equivalent scenario. The random and periodic levels are separated by means of the autocorrelation and acceleration spectral density (ASD) functions, and the required scenario of 3.1 is reduced to an equivalent scenario as indicated by the data. This operation consists of combining road conditions which produce similar data and eliminating conditions which produce levels that are 6dB below the maximum level. From a fatigue standpoint, these levels are considered insignificant. The equivalent scenario replaces the required scenario.

A-3.3.4 Equivalent duration. To reduce the time required by the equivalent scenario without actually testing beyond the field levels, the ASD's are collapsed (normalized) to the highest measured field level as indicated by the individual random and periodic g_{rms} vs speed information. An example of this operation is presented in table A-I. As table A-I illustrates, a service time of approximately 50 hours can be reduced to an equivalent duration of approximately 6 hours by using the test exaggeration curve and testing at maximum measured field level. If necessary, the equivalent test duration can be reduced further by again using the test exaggeration curve, but this must be done with caution to avoid testing beyond peak, short duration levels.

A-3.3.5 Conservatism. Conservatism (additional severity) is added to the random spectrum and periodic component. The conservatism for the periodic component is a factor of 1.2. For the random spectrum, a factor of 1.2 standard deviations (σ) as a function of frequency is added at frequencies where the field levels are better defined (i.e., lower σ). Conversely, more conservatism is added where the variance of the field levels is greater (which indicates a poorer definition of field levels). The conservatism is also used to account for items such as:

a. Other terrains and vehicles for which no data was obtained.

b. Effects of vehicle wear, track tension, temperature, etc.

c. Available maximum field data that may not be true maximum.

d. Greater variance of field levels than laboratory levels.

e. Test item differences within normal quality control requirements.

A-3.3.6 Test tolerances. To obtain realistic test tolerances for the random spectrum, the maximum and minimum envelopes of the collapsed ASD's or ±3dB (whichever is greater) is used. This results in a test tolerance which varies with frequency but allows the response to vary as it does during service conditions.

A-3.3.7 Laboratory test performance. Using the developed specification, a laboratory vibration test is performed. The physical setup duplicates, as much as possible, the actual field configuration. As much of the actual platform structure as practical is included in the test setup.

The required overall g-rms is maintained to preclude testing at extremes (over wide bandwidths) within the tolerance range. Control data sampling bandwidths and sample averages are consistent with that used in the specification development.

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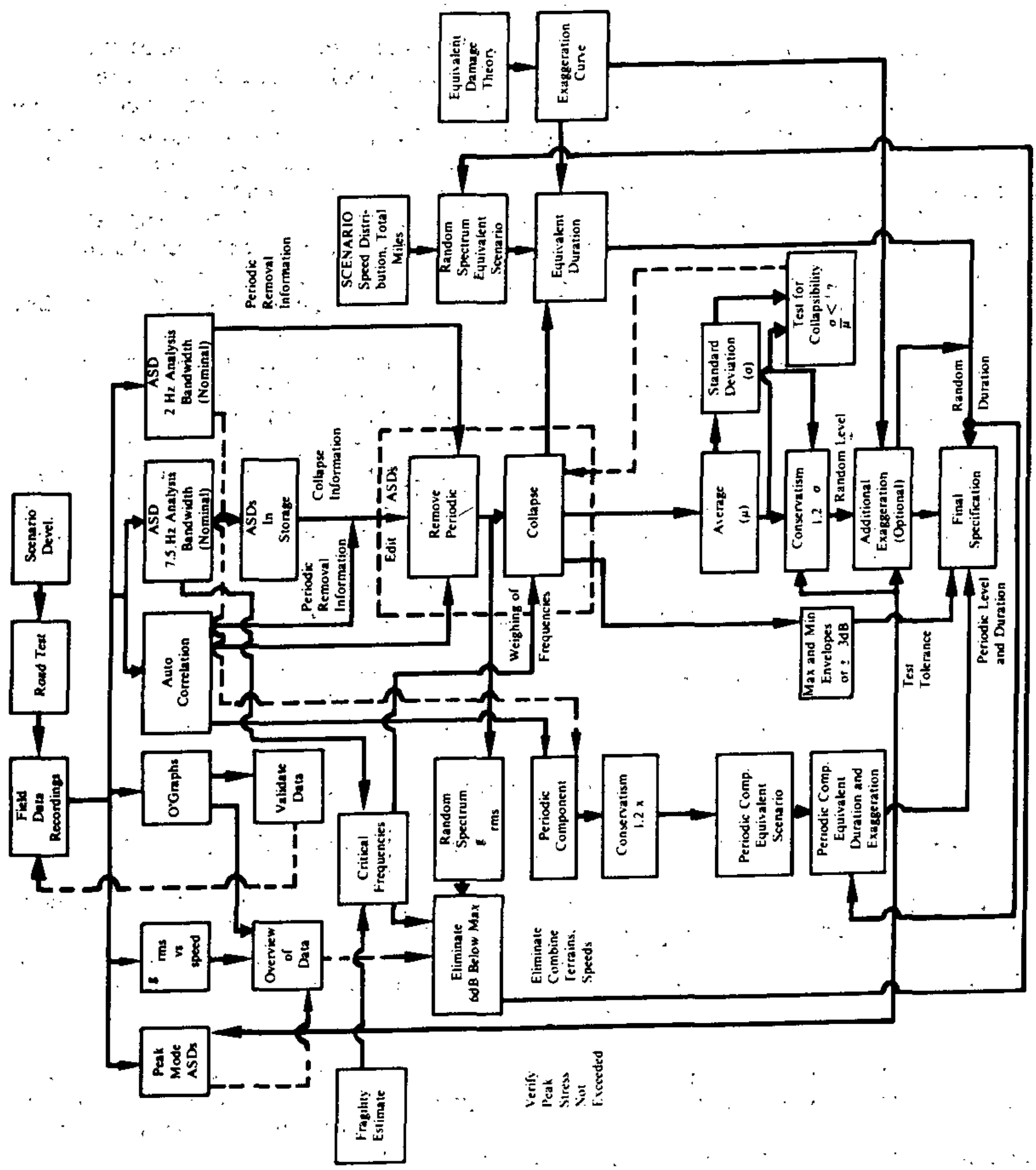

FIGURE A1. Vibration test specification development.

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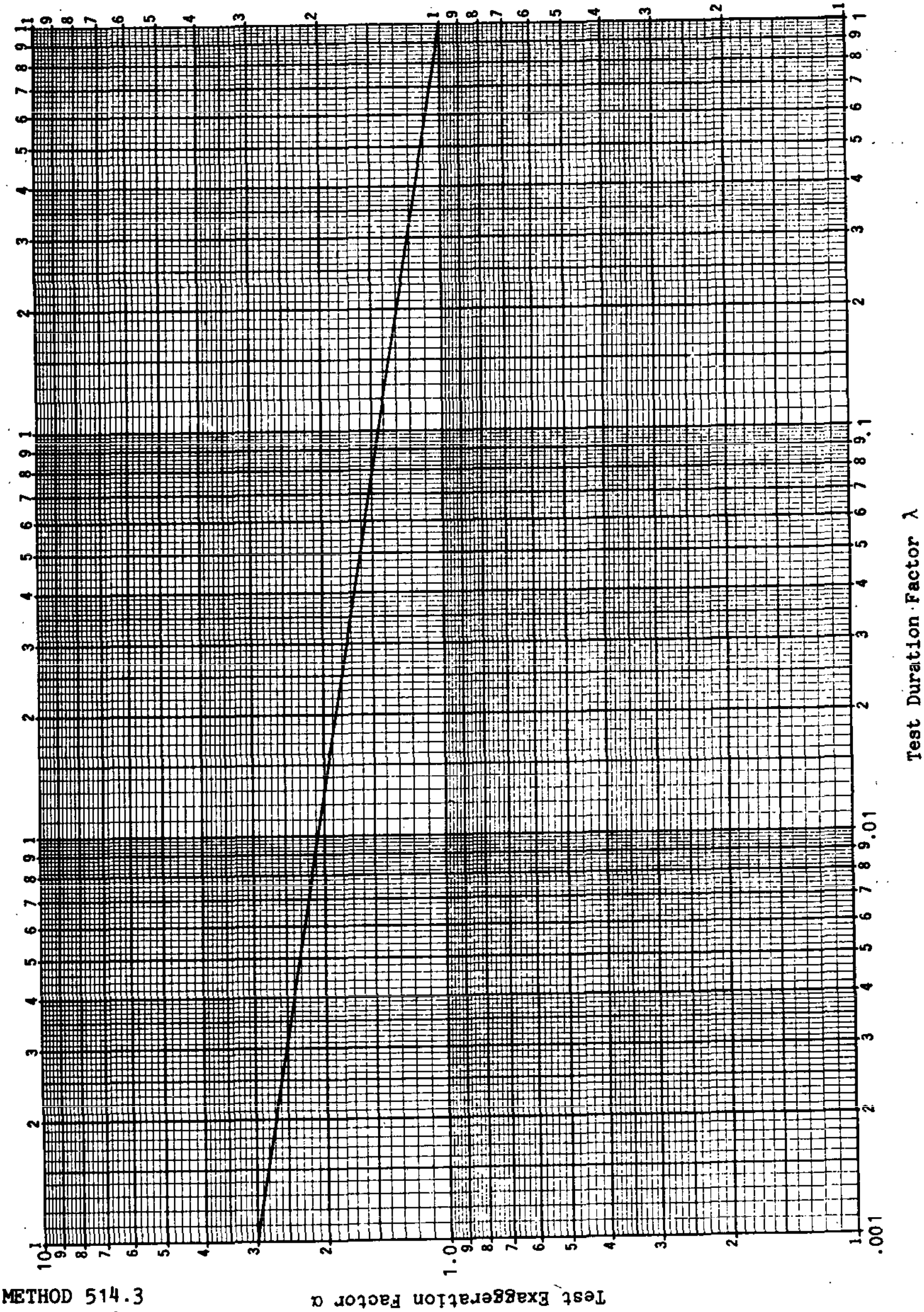

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TABLE A-I. Equivalent duration (example).

SPEED (MPH)	DISTANCE (MILES)	TIME (HRS)	TEST EXAGGERATED FACTOR α	TEST DURATION FACTOR λ	EQUIVALENT DURATION (HRS)
8	148	18.5	2.0	0.012	0.22
12	148	12.3	2.0	0.012	0.15
16	97	6.1	1.5	0.073	0.45
20	102	6.1	1.5	0.073	0.37
24	97	4.0	1.0	1.0	4.0
28	50	1.8	1.2	0.31	0.56
32	50	1.6	1.2	0.31	0.5
36	4	0.1	1.2	0.31	0.03
40	4	0.1	1.2	0.31	0.03
	700	49.6			6.31

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A-3.3.8 In the test specification development, the following assumptions are made:

a. Test item response along off-axes is negligible. This may not be an acceptable assumption and is evaluated during testing. Test durations are reduced accordingly, with particular consideration given to critical frequencies.

b. A difference between the mechanical impedances of field and laboratory test item mountings is acceptable. Field and laboratory frequency response functions are compared to evaluate this. If it is determined that this is not a valid assumption, average, extremal and/or response control are considered to minimize any mismatch of mechanical impedance. This is particularly significant for massive test items.

c. Test item response is constant with temperature. That is, the test may be conducted at temperatures other than those for which field data was obtained.

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METHOD 515.3

ACOUSTIC NOISE

SECTION I

I-1. PURPOSE. The acoustic noise test is conducted to measure how well a piece of equipment will withstand or operate in intense acoustic noise fields. The acoustic noise test complements tests for structure-borne vibrations (method 514).

I-2. ENVIRONMENTAL EFFECTS. Acoustic noise can produce vibration in equipment similar to that produced by mechanically transmitted vibration. In an acoustic noise field, pressure fluctuations impinge directly on the equipment. The attenuation effects of mechanical transmission are missing and the response of the equipment can be significantly greater. Further, components which are effectively isolated from mechanical transmission will be excited directly. Examples of acoustically induced problems:

a. Failure of microelectronic component lead wires.

b. Chafing of wires.

c. Cracking of printed circuit boards.

d. Malfunction/failure of waveguides, Klystron tubes.

e. Vibration of optical elements.

I-3. GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS. This test method should be applied at the end of the tailoring process described in section 4 of this standard.

a. Application. The acoustic noise test applies to any equipment operated or stored in the intense acoustic noise fields that occur in or near aircraft, missiles, and large machinery such as pumps and generators. In particular, it applies to:

(1) Internally-carried airborne equipment

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(2) Assembled externally-carried stores

(3) Ground support equipment on the flightline

Acoustic testing is performed if the operational acoustic level exceeds 135 dB or vibration testing is impractical.

b. Restrictions. This method is not applicable to space and water vehicles and is not for hearing safety. Nor is it applicable to items which, because of their construction, are insensitive to acoustic noise. Examples of such equipment are items that have small surfaces, high ratios of mass-to-area, and high internal damping. Examples are (1) high density modules, particularly if they are encapsulated and (2) equipment that is surrounded by a heavy metal case, particularly if the equipment is potted. A practical guideline is that acoustic tests are not required if equipment is exposed to broadband random noise at a sound pressure level less than 130 decibels (ref 20 μPa) overall, and if its exposure in every one-Hertz band is less than 100 decibels (ref 20 μPa).

c. Sequence. Acoustic testing may be performed anywhere in the test process. The accumulated effects of acoustic stress may affect equipment performance under other environmental conditions, such as temperature, altitude, humidity, or EMI/EMC. When it is desired to evaluate the cumulative environmental effects of acoustic noise (paragraph I-2) and other environments, a single test item should be exposed to all environmental conditions, with acoustic noise testing performed first.

d. Test variations

(1) Test procedures. This method is composed of four procedures -- the environmental worthiness test, the qualification test, the mission profile test, and the cavity resonance test.

(2) Test conditions. Within each procedure, values must be assigned to the following variables:

(a) Sound spectrum

(b) Dynamic pressure level

(c) Duration

(d) Tolerances

(e) Acoustic excitation field -- reverberent, progressive wave, or jet engine.

I-3.1 Choice of test procedures. The choice of test procedure(s) depends on:

a. The stage of the item in the design process.

b. Whether or not accelerated testing is desired.

c. Whether an open cavity on an aircraft or aircraft store is involved.

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d. Test item configuration: externally-carried aircraft stores may have to be tested in both the assembled and free-flight configurations.

e. Whether one test obviates another: if one test is more stressful in all variables than another, the easier test need not be performed (e.g., functional test vs endurance test, captive flight vs. free flight).

I-3.1.1 Procedure I - Environmental worthiness test. The environmental worthiness test is a relatively short test used during engineering development to identify defects in a prototype or flight test item before attempting service or flight testing with the same unit. It helps to eliminate simple, rapidly occuring problems that can delay or prevent service or flight testing. The test simulates the most severe environmental conditions expected during service or flight testing.

I-3.1.2 Procedure II - Qualification test. The qualification test is used to demonstrate the test item's compliance with contract requirements. Only the most severe anticipated service environments are used as the basis for testing.

It is divided into functional and endurance tests. The functional test must be tailored to show whether the item can perform to specifiction in the most severe environment of its service life. The endurance test is an accelerated test and must be tailored to simulate the item's lifetime damage accumlation. Test sequence is one-half hour functional test, endurance test, and another one-half hour functional test.

I-3.1.3 Procedure III - Mission profile. A mission profile test can be used when a close correlation is desired between test time and acoustic stress exposure time in service. This is not an accelerated test since testing is performed at realistic stress levels.

I-3.1.4 Procedure IV - Cavity resonance test. Aircraft compartments or stores that open during flight can expose cavities to the airstream. Standing waves often become established in such cavities at the resonant frequencies of the cavity. The resulting acoustic noise is very intense.

I-3.2 Choice of test conditions. The choice of test conditions depends on

(1) The procedure chosen.

(2) The availability of measured data on the test item's operational acoustic environment.

(3) The location of the test item with respect to the noise source.

(4) Whether the noise source in the operational environment is localized or distributed.

(5) The mission profile(s).

(6) The predicted life-cycle history of the item.

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I-3.2.1 Spectrum shape. The spectrum shape shall be determined from measured data, if available (see I-4.1). If data are not available, use the spectrum given in figure 515.3-1, with two exceptions: For assembled, externally carried aircraft stores, use the spectrum given in figure 515.3-2. For cavity resonance testing, use the spectrum given in figure 515.3-4.

I-3.2.2 Acoustic test level. The acoustic test level should be determined from measured data, if available (see I-4.1). Otherwise, use the values suggested by table 515.3-I.

a. Procedures I, II, and IV - The most severe acoustic stress conditions shall be used as test conditions.

b. Procedure III - The measurements shall be taken for the entire mission, including periods of low stress. For this procedure, the test level is varied over time, but the test does not exactly duplicate a mission in this respect. Test levels should be determined using the technique described in paragraph I-3.2.3.1.

I-3.2.3 Test duration. For procedure III, test duration should be determined as described in paragraph I-3.2.3.1. For all other procedures, determine the test duration by referring to table 515.3-I.

I-3.2.3.1 Dynamic pressure histogram. For airborne equipment, the test mission profile should be based on the dynamic pressure histogram. Test cycle duration should equal the average duration of the missions used to develop the histogram. The percentage of time spent at each dynamic pressure band level in the test cycle should be in proportion to the relative contribution of the same level to the histogram. The test cycle, therefore, resembles a service mission with varying test levels as a function of time. The test cycle is then repeated until the desired number of "missions" has been accumulated.

Each mission profile should be expressed in a dynamic pressure versus time profile rather than Mach number and altitude profiles. The dynamic pressure profile for each mission is analyzed to develop a histogram of mission time spent at various ranges of dynamic pressure. This is accomplished as follows.

Using the highest measured value of dynamic pressure (regardless of mission) as Q_{max}, sum all of the mission time for which dynamic pressures were within 5 percent of Q_{max}. Then, sum all of the mission time for which dynamic pressures were between 0.95 Q_{max} and 0.90 Q_{max}. Continue this process of summing mission time for 5 percent increments of dynamic pressure until all values of measured dynamic pressure are included.

For test purposes, the pressure levels can be determined using the midpoint dynamic pressure value of the appropriate 5 percent dynamic pressure band. This value will be assumed to be constant for the amount of flight time within this band.

I-3.2.4 Test tolerances. The tolerance can be adjusted to reflect the purpose of the test and the available acoustic noise source. For environmental worthiness tests the upper limit on figure 515.3-1 can be ignored and the tolerances on figure 515.3-2 can be -3dB to plus infinity. For qualification testing the tolerances should be as shown on figure 515.3-1 and for figure 515.3-2 they can be -3dB for each one-third octave band.

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I-3.2.5. Acoustic source. The fluctuating pressure environment experienced in service is a complex combination of progressive wave and reverberant acoustic fields. Because of practical limitations, equipment testing is generally accomplished in reverberant laboratory facilities. If an appropriate laboratory facility is not available, a jet engine may be able to provide the required acoustic field.

I-3.2.5.1 Reverberant testing. This technique is used when the pressure fluctuation source is distributed. Such a source is turbulent boundary layer flow along a vehicle's skin. Reverberant testing is also used for equipment located in closed spaces inside a vehicle exposed to strong localized acoustic sources.

I-3.2.5.2 Progressive wave testing. This technique is used to simulate a strong localized acoustic source. The accoustic energy sweeps over the test item like ripples spreading on water. This test environment is appropriate for externally-carried components on all types of vehicles which are directly exposed to localized acoustic sources such as rocket or jet engines. A reverberant test environment can be used to approximate a progressive wave environment but the level should be adjusted to account for the difference in vibration efficiency of the two types of fields.

I-3.2.5.3 Cavity resonance testing. It is recommended that sinusoidal acoustic energy be used in the cavity resonance test.

I-4. SPECIAL CONSIDERATIONS

I-4.1 Acceptable measured data. Measured operational or flight test data can be in either of two forms: (1) acoustic pressure levels, or (2) vibration response of the test item in the field environment. For either form of the data, the data shall be analyzed using a constant percentage bandwidth no greater than one-third octave with a minimum of 50 statistical degrees of freedom. The data shall be over a frequency range of at least 20 to 2,000 -- and preferably to 10,000 -- Hertz.

I-4.1.1 Acoustic operational or flight test data. The levels and spectra measured in flight cannot be used directly as the test conditions for the flight conditions under which they were measured. They must be adjusted (recognizing that aerodynamic noise is less efficient than reverberent acoustic noise at frequencies before the first structural resonance and more efficient above that frequency) to compensate for the differences between flight turbulent boundary layer pressure fluctuations and a reverberant acoustic test environment. The parametric relationships specified in tables 515.3-II and 515.3-III can be used to extrapolate to other operational or flight conditions.

I-4.1.2 Vibration operational or flight test data. Vibration can be used indirectly to establish acoustic test levels. The test item is instrumented with accelerometers mounted identically as those used in operational or flight testing. The acoustic test levels and spectra are varied until the reproduced vibration matches the previously measured operational or flight test data within MIL-STD-810D method 514.3 tolerances for random vibration. This acoustic test environment can be considered as the operational or flight environment. The parametric relationships specified in tables 515.3-II and 515.3-III can be used to extrapolate to other conditions.

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I-4.2 Test interruption. In the event of an unprogrammed test interruption, the cause of the interruption should be analyzed to determine the likelihood that environmental stress conditions present at the interruption could occur in service. The test should be resumed at the point of interruption using the same specific test item. If the test item has been damaged, it may be necessary to start the test over using a new test item.

I-4.3 Retest requirements. When failures occur during qualification, the failure will be fixed as appropriate. The test will be restarted and run through the complete qualification cycle to verify the fix. Parts which survive a complete qualification cycle are considered to have passed and are repaired only if required to finish the retest.

I-4.4 Overtest. An interruption in the test that results in a more extreme exposure of the test item than required by the equipment specification should be followed by a complete physical inspection of the test item and an operational check prior to continuation of the test. An engineering judgment shall be made whether to continue testing with the specific item given the overtest, to obtain a new item, or to consider the test completed.

I-4.5 Failure analysis. All incidents where the test items do not meet the equipment operating requirements shall be analyzed to determine the cause and impact of such occurrences. Corrective actions shall be proposed or implemented as required to meet equipment performance requirements.

I-5. REFERENCES

a. Dreher, J.F., Lankin, E.D. Lankin, E.A. Tolle. "Vibroacoustic Environment and Test Criteria for Aircraft Stores during Captive Flight". Shock and Vibration Bulletin 39, Supplement (April 1969), pp 15-40.

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TABLE 515.3-I. Acoustic noise test category

Category 1/	Suggested Test Overall Sound Pressure Level (dB 2/, 3/)	Equipment Application	Vehicle Source	Equipment Location	Suggested Exposure Time 4/ (minutes)
A	165	Ground Based	Rocket	On launch site	8
B	150	Ground Based	Aircraft	Near runway/in jet engine run-up pads	30
C	150	Airborne	Aircraft	Near noise source and separated by thin partition	30
D	160	Airborne	Aircraft	Near noise source or in noise cone of aircraft	30
E	160	Airborne	Rocket	Majority of locations, exclusive of booster or engine compartments	8
F	165	Airborne	Rocket	Booster or engine compartment	8
G	140	Airborne	Aircraft	Majority of locations	30
H	See Table 515.3-III	Airborne	Aircraft	Near or in open cavities exposed to the airstream	See Table 515.3-III
I	See Table 515.3-II	Airborne	Aircraft	Externally-carried stores	See Table 515.3-II

1/ In the qualification test, the pressure levels and exposure times for categories A thru G are for the functional test. No separate endurance test is required
2/ Reference 20 μ Pa ($2x10^{-4}$ dynes/cm^2).
3/ Already adjusted for a reverberant test environment, see I-3.2.5.1.
4/ Use only 10 minutes of exposure for environmental worthiness test. If suggested duration is less than 10 minutes, use shorter duration.

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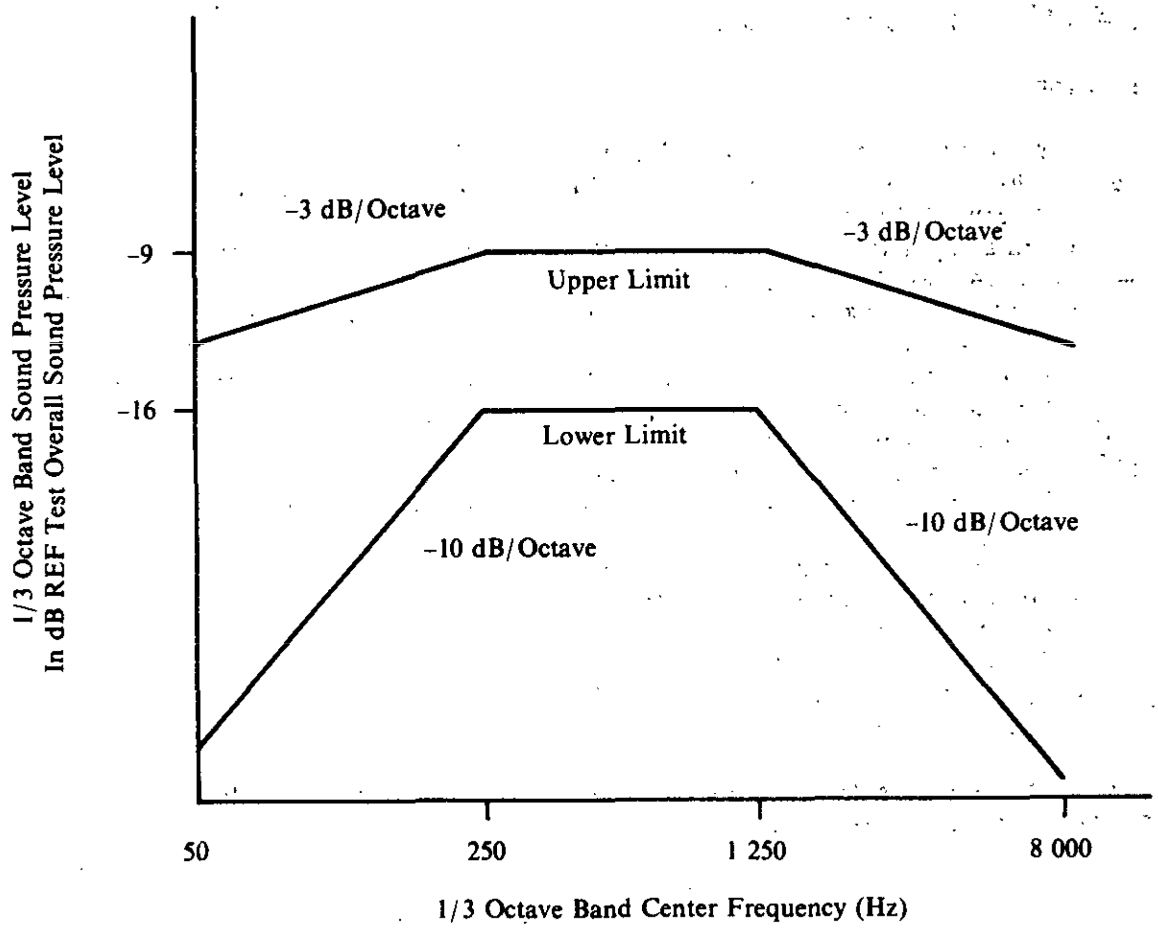

FIGURE 515.3-1. Suggested 1/3 octave band spectra for acoustical noise test.

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TABLE 515.3-II. Suggested acoustic test levels for assembled externally-carried aircraft stores.

Functional test

L_o 1/,5/,6/,7/ $= 20 \text{ Log } (q_1) + 11 \text{ Log } (X) + 7 \text{ Log } (1-\cos\beta) + G+H\text{dB}$

f_o 2/,3/ $= 600 \text{ Log } (X/R) + C$

Endurance test

L_o 1/,5/,6/,7/ $= 20 \text{ Log } (q_2/q_1) + 2.5 \text{ Log } (N/3T)$ + functional level dB

f_o 2/,3/ $= 600 \text{ Log } (X/R) + C$

Definitions

q_1 = captive flight dynamic pressure (lbs/ft^2) $\leq$ 1800
q_2 = 1200 psf or maximum captive flight dynamic pressure (whichever is lower) (lbs/ft^2)
N = maximum number of anticipated service missions (minimum N = 3)
R 4/ = local radius of store in inches
X = distance from nose of store along axis of store in inches
T = test time in hours (minimum T = 1 hour unless otherwise specified)
C = -200 locations within one D of either aft end of store or aftward of re-entrant angle
C = 400 all other locations
D 4/ = maximum store diameter in inches
β = local nose cone angle at X equals 1 / Tanβ = (R/X) (reference figure 515.3-4)
G = 72 unless measured data shows otherwise
E = 96 unless measured data shows otherwise
F = 84 unless measured data shows otherwise
H = 0 for 0.85 < M > 0.95
H = -3 dB for all other values of M
M = Mach Number

Representative parametric values to be used for captive flight when specific parameters are not available:

Store Type	N Endurance	Local Nose Cone Angle Degrees	q max	f_o Nose Section	f_o Middle Section	f_o Aft Section
Air-to-Air Missile	100	69	1600	500	1000	500
Air-to-Ground Missile	3	12	1600	800	630	630
Instrument Pod	500	69	1800	500	1000	500
Reusable Dispenser	50	11	1200	630	1000	400
Demolition Bomb	3	24	1200	500	1000	630
Flat Nose Store	3	90	1200	400	630	315

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NOTES

1. Raise computed L_o level by 3 dB for a store carried in a TER cluster rack; by 6 dB for a MER cluster rack.

2. If calculated f_o is above 2,000 Hz use upper frequency limit of 2,000 Hz. If calculated f_o is below 200 Hz use 200 Hz.

3. Round off f_o upwards to a one-third octave band center frequency.

4. For stores which do not have circular cross-sections the radius used in the formulas shall be the radius of the circle which circumscribes the cross-section of the store.

5. For locations on flat nose stores ($80^o \leq \beta \leq 90^o$) where X < 100:

Functional test

$$L_o = 20 \text{ Log } (q_1) - 6 \text{ Log } (X) + E + H$$

Endurance test

$$L_o = 20 \text{ Log } (q_2) - 6 \text{ Log } (X) + E + 2.5 \text{ Log } (N/3T) + H$$

6. For long cylindrical section, > 2D, use for locations more than one D aftward into the cylindrical section:

Functional test

$$L_o = 20 \text{ Log } (q_1) + F + H$$

Endurance test

$$L_o = 20 \text{ Log } (q_2) + F + 2.5 \text{ Log } (N/3T) + H$$

7. For changing radius section either aft of a long cylindrical section or when X > 100 on a flat nose store, redefine X so that X = 1 at beginning of this section:

Functional test

$$L_o = 20 \text{ Log } (q_1) + 11 \text{ Log } (X) + F + H$$

Endurance test

$$L_o = 20 \text{ Log } (q_2) + 11 \text{ Log } (X) + F + 2.5 \text{ Log } (N/3T) + H$$

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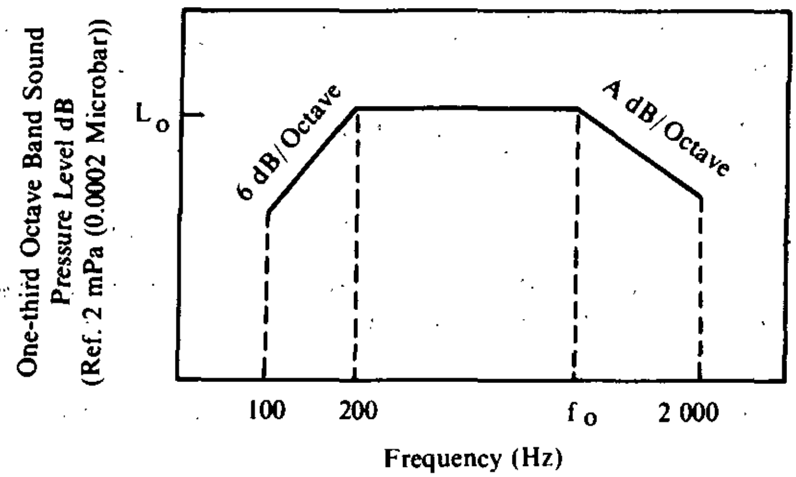

Note: See table 515.3-II for definition and calculations.

$f_o = 600 \log (X/R) + C$

$A = 6$ dB/octave when $f_o > 400$ Hz

$A = 2$ dB/octave when $f_o \leq 400$ Hz

FIGURE 515.3-2. <u>One-third octave band spectrum for acoustic testing of assembled externally carried aircraft stores</u>.

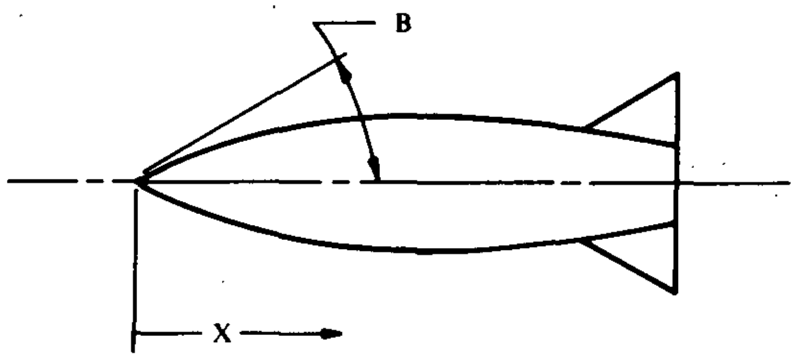

FIGURE 515.3-3. <u>Typical store profile</u>

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TABLE 515.3-III. Suggested cavity resonance acoustic test.

Parametric Equations for figure 515.3-4
Functional Test Level
$B_o = 20 \log(q) + 110$ dB (Ref 20 μPa (0.0002 microbar))
Endurance Test Level
$B_o = 20 \log(q) + 2.5 \log(H/T) + 110$ dB (Ref 20 μPa (0.0002 microbar))
$f_N = \frac{6.13(N-0.25)(2.4-M^2/2)^{1/2}}{0.57(L)(C) + (2.4-M^2/2)^{1/2}}$ Hz
Definitions
f_N = resonance frequency for the N mode (where N = 1,2,3,4, etc.)
N = mode number
C = speed of sound at altitude of flight (M/S)
L = length, radius, of opening exposed to airstream (meters)
M = Mach number
A second set of resonance frequencies shall be identified by using the distance parameter, L, as the depth of the cavity.
q = flight dynamic pressure when cavity is open (lbs/ft^2)
H = number of operational hours store is flown with cavity open. If H≤1, endurance test is not required.
T = duration of test in hours (minimum T = 1 hour)

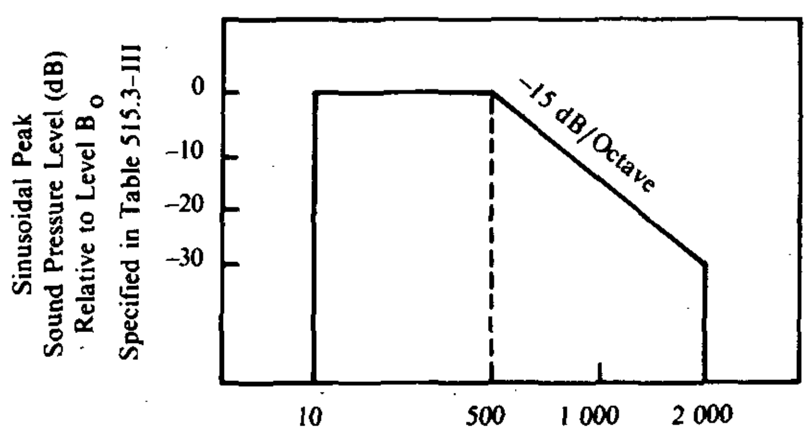

FIGURE 515.3-4. Cavity resonance Acoustic test levels

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METHOD 515.3

ACOUSTIC NOISE

SECTION II

II-1 APPARATUS. Acoustic noise tests can be performed using a reverberant test chamber of sufficient power and size. A reverberant test chamber should have a volume at least ten times the test item volume. With the chamber empty, the distribution of overall sound pressure levels should be uniform to within -2 and +4 dB of the desired value. If no test chamber is available, the noise field behind a jet engine can be used for acoustic noise testing, provided desired uniformity of test environment can be achieved. The spectrum and overall level should be measured and the test item placed in a suitable location to achieve best approximation to desired test conditions. It is difficult to achieve as uniform an acoustic environment as with a reverberent test chamber. This approach may be suitable primarily for development, test-analyze-fix, and environmental worthiness tests. However, because of the difficulty in controlling test conditions, this approach is not always suitable for qualification testing.

II-1.1 Controls. The acoustic test facility shall be able to produce acoustic noise at the desired levels and frequency range. Frequencies outside the desired frequency range may be inadvertently produced by the acoustic test facility but do not need to be controlled. The acoustic environment shall be within the tolerances for the particular test procedure.

II-2 PREPARATION FOR TEST

Step 1. Choose which test procedure shall be conducted (I-4.1).

Step 2. Determine overall acoustic test levels, durations, and spectra shapes to be produced during testing.

Step 3. Prepare test item in accordance with General Requirements, 4.5.2. The item shall be in the operational configuration.

Step 4. Mount test item. For Procedure IV, go to step 7. Suspend test item by means of springs or cords. If a mounting structure is required between the soft suspension and the test item or to hold the soft suspension, care must be exercised to assure that no spurious acoustic or vibratory inputs are introduced. The natural frequency of suspension shall be less than 25 Hz. The test item shall be exposed on every surface to the sound field by centrally locating it in the test chamber. The test volume shall be no more than 10 percent of the test chamber volume. When the test chamber is rectangular, no major surface of the test item shall be installed parallel to the chamber wall.

Step 5. For testing of assembled externally-carried stores, go to step 6. Position at least three microphones to measure the sound pressure field. These microphones shall be located in proximity to each major dissimilar test item surface, at least 45 cm (18 inches) from the test item surface or one-half the distance to the nearest chamber wall, whichever is less with the chamber empty. The average overall sound pressure distribution around the test item shall be measured and be uniform within -2 and +4 dB of the desired value.

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Step 6. Microphone Placement. Establish three reference planes perpendicular to the longitudinal axis of the store at positions one-sixth, one-half, and five sixths of the length of the store. In each of these reference planes, position three microphones around the store, 120° apart. Each microphone shall be within 45 cm (18 inches) of the store surface, but no further from the store than one-half the distance between the store and the nearest baffle.

Spectrum Control. The response of the microphones in each reference plane shall be averaged to give an average noise spectrum for each reference plane. The average noise spectrum for each reference plane shall be shaped to be within -3 dB and +6 dB unless otherwise stated.

Step 7. Go to appropriate test procedure.

II-3. PROCEDURES

II-3.1 Procedure I - Environmental worthiness test

Step 1. Mount test item in test chamber and position instrumentation as given in II-2.

Step 2. Expose test item to the required acoustic levels and spectra for the specified amount of time as in I-3.2.3. The test item shall not be energized during Step 2.

Step 3. Check test item for loose parts, chafed wires, and any other obvious damage. Correct or repair before proceeding to Step 4.

Step 4. Energize test item. Check test item functions for proper operations. Correct or repair any damage.

Step 5. Expose test item to the required acoustic noise for the specified amount of time with the test item being functioned as if it were in actual operation or flight.

Step 6. Check test item for loose parts, chafed wires, and any other obvious damage.

Step 7. Repair or correct as necessary before flight testing.

Step 8. Document test as in II-4.

II-3.2 Procedure II - Qualification test

Step 1. Mount test item as given in II-2.

Step 2. Position instrumentation as specified in II-2.

Step 3. Function the test item as if it was in operational or flight usage while being exposed to acoustic levels in Step 4.

Step 4. Expose test item to functional test levels as in I-3.2.

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Step 5. Expose test item to endurance levels as in I-3.2a.

Step 6. Check test item for functioning in accordance with General Requirements, 4.0.

Step 7. If test item is not a store, go to Step 10.

Step 8. If free flight test is required, expose test item to acoustic levels as specified in I-3.2.2a and check in Step 9.

Step 9. Function store through free flight performance requirements.

Step 10. Document test as in II-4.

II-3.3 Procedure III - Mission profile test

Step 1. Using the guidance of II-2, mount the test item in test chamber.

Step 2. Position instrumentation as given in II-2.

Step 3. Expose test item to the mission profile developed in I-3.2.3.1.

Step 4. During mission profile test, perform functional checks on the test item as required by General Requirements, 4.0.

Step 5. Conduct mission profile for desired number of missions.

Step 6. During Step 5 testing, function test item as given in General Requirements.

Step 7. Document test as in II-4.

II-3.4 Procedure IV - Cavity resonance test

Step 1. Conduct pretest inspection (reference II-2).

Step 2. Suspend the test item in the chamber so that only the cavities to be tested are subjected to direct impingement of acoustic energy. Protect other surfaces of the item so that sound pressure levels are at least 20 dB lower. Protection devices shall not damp test item vibrations.

Step 3. Position a microphone in the cavity to be tested. The microphone shall face outward so that its face can be seen when looking down into the cavity.

Step 4. Perform resonance dwells at significant cavity resonances. The response of the microphone mounted in Step 3 shall be ±3 dB of the levels required by I-3.2.2a. Resonance dwells can be done individually or simultaneously. Verify functioning of test item during acoustic exposure.

Step 5. Conduct post-test inspection.

Step 6. Document as given in II-4.

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II-4. INFORMATION TO BE RECORDED. The following data shall be included in test records.

a. Prior history of the test item.

b. Inspection and test procedures including inspection requirements, test criteria, instrumentation, data requirements, and failure criteria.

c. List of test equipment including noise generators, measurement and data analysis equipment, mounts, and fixtures.

d. Descriptions of the test setup and instrumentation locations including drawings and photographs as appropriate.

e. Log of all actions from pretest through post-test inspection.

f. Recorded data.

g. Analyses of all failures, malfunctions, and test incidents.

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METHOD 516.3

SHOCK

SECTION I

I-1 PURPOSE. Shock tests are performed to assure that materiel can withstand the relatively infrequent nonrepetitive shocks or transient vibrations encountered in handling, transportation, and service environments. Shock tests are also used to measure an item's fragility, so that packaging may be designed to protect it, if necessary, and to test the strength of devices that attach equipment to platforms that can crash.

I-2 ENVIRONMENTAL EFFECTS. Mechanical shocks will excite an equipment item to respond at both forced and natural frequencies. This response, among other things, can cause:

a. Failures due to increased or decreased friction, or interference between parts.

b. Changes in dielectric strength, loss of insulation resistance, variations in magnetic and electrostatic field strength.

c. Permanent deformation due to overstress.

d. More rapid fatiguing of materials (low cycle fatigue).

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS

NOTE: This test method should be applied at the end of the tailoring process discribed in section 4 of this standard.

a. Application. This method is applicable to all materiel which may be subjected to mechanical shock during its life cycle.

b. Restrictions. None.

c. Sequence. There are often advantages to applying shock and vibration tests before climatic tests, provided that this sequence represents realistic service conditions. Test experience has shown that climate-sensitive defects often show up more clearly after the application of shock and vibration forces.

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d. Test variations. The tests vary in apparatus, axes of test, and stress levels applied.

I-3.1 Choice of test procedures. Method 516.3 is divided into nine procedures:

a. Functional shock (Procedure I)
b. Equipment to be packaged (Procedure II)
c. Fragility (Procedure III)
d. Transit drop (Procedure IV)
e. Crash hazard (Procedure V)
f. Bench handling (Procedure VI)
g. Pyrotechnic shock (Procedure VII)
h. Rail impact (Procedure VIII)
i. Catapult launch/arrested landing (Procedure IX)

To find out whether a procedure is applicable, see subparagraphs a and b of the discussion of each procedure in this section. All shock environments anticipated for the test item during its life cycle, both in its logistic and operational modes, should be considered. The severity of one type of shock may obviate the need to perform another type of shock test, but the configuration of the test item during these tests must be considered thoroughly before making this decision.

I-3.2 Choice of related test conditions. Guidance for setting values for test conditions is found in this section in subparagraphs b, c, and d of the discussion of each procedure.

I-3.3 Procedure I - Functional shock

a. Application. Procedure I is intended to test equipment assemblies (including mechanical, electrical, hydraulic, and electronic) in their functional mode.

b. Restriction. This test procedure will not be required along any axis for which a sufficiently severe random vibration test procedure is required, provided that equipment operational requirements are comparable. Random test severity is sufficient if its shock response spectrum, based upon a three-sigma Gaussian acceleration response of single degree of freedom (sdof) systems, exceeds the shock test response spectrum everywhere in the specified range of natural frequencies. The quality factor Q (damping magnification factor or transmissibility at resonance) to be employed is ten, which is equivalent to five percent of critical viscous damping. The three-sigma shock response spectrum for the random test is given, as a function of natural frequency of the sdof system, by 3 (/2)G(f)fQ in units of acceleration, where G(f) is acceleration spectral density (ASD) at frequency f (reference a). A comparison of the shock response levels found in figure 516.3-1 with ASD levels is found in figure 516.3-2.

c. Test conditions

(1) Shock spectrum and transient duration. The shock response spectrum and the effective transient duration shall be derived from measurements of the test item's functional environment, or from dynamically scaled measurements of a similar environment, if available.

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(a) Measured data available. The shock response spectrum required for the test will be determined from reduction of the environmental data to obtain either maximum absolute acceleration spectra or equivalent static acceleration spectra. The spectra will be a composite of spectra for positive and negative directions, sometimes called maximax spectra. The analyses will be performed for Q = 10 at a sequence of natural frequencies at intervals of 1/6 octave or smaller to span at least 5 to 2,000 Hz. When a sufficient number of representative shock spectra are available, an appropriate statistical basis should be employed to determine the required test spectrum. Nonparametric statistical techniques are covered in reference e. Parametric statistics can be employed if the data can be shown to satisfactorily fit an assumed underlying probability distribution. (For example, in MIL-STD-1540 (USAF) the test levels are based upon a maximum predicted environment defined to be equal to or greater than the 95th percentile value at least 50 percent of the time. When a normal or lognormal distribution can be justified, appendix 516.3A provides a method for estimating such a test level.)

When insufficient data are available for statistical analysis, an increase over the maximum of the available spectral data should be used to establish the required test spectrum to account for variability of the environment and uncertainty in any predictive methods employed. The degree of increase is based upon engineering judgment and should be supported by a rationale for that judgment.

Effective transient durations, T_E, will also be determined from the time histories of the environmental data analyzed. The effective duration is defined to be the minimum length of time which contains all data magnitudes exceeding 1/3 of the peak magnitude associated with the shock event. Figure 516.3-3 illustrates this process. The shock input time history used for the response spectrum analysis will be $2T_E$ in duration starting at a time to include the most significant data prior to and following the effective duration T_E. An average of environmental shock duration, T_E, will be determined and included in the specification of the required test shock. In general, each individual axis of three orthogonal axes can have a different shock test spectrum and average effective duration.

(b) Measured data not available. If a data base is not available, the applicable spectrum from figure 516.3-1 can be employed as the test spectrum for each axis, provided that the effective (above 1/3 its peak value) duration of the test shock time history falls between six and nine milliseconds. (This spectrum approximates that of the perfect terminal sawtooth pulse shown in figure 516.3-4.) Any test transient is suitable if it equals or exceeds this spectrum requirement over the frequency range of 5 to 2000 Hz (for example, a half-sine pulse applied in both directions of each axis). As stated in I-3.3b, this shock testing may be omitted if random vibration testing is required with input acceleration spectral density in excess of the applicable spectrum in figure 516.3-2. A less desirable alternative, only permissible if the tester has no shock response spectrum analysis capability, is to employ a terminal peak sawtooth pulse that meets the tolerances given in figure 516.3-4 with application in both directions along each axis. The presence of superimposed ripple falling within the waveform tolerance band should be minimized to avoid significant overtesting at the frequency of such ripple.

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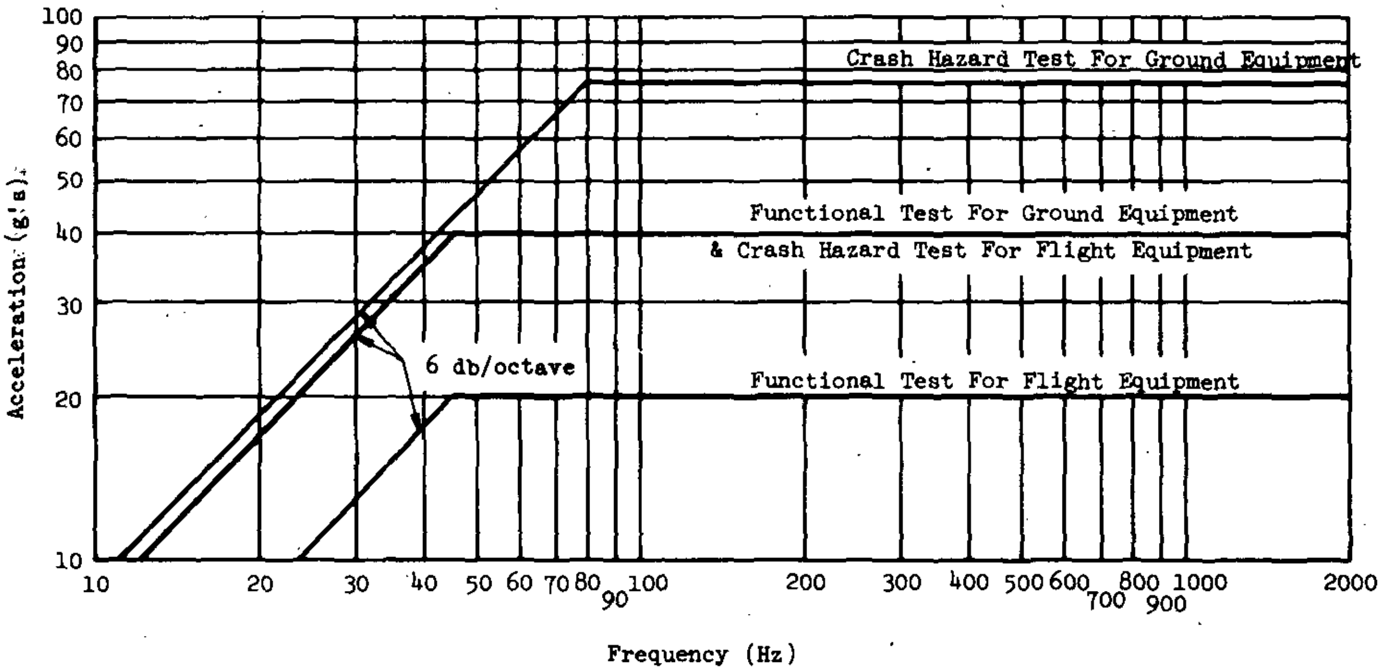

TEST PROCEDURE	PEAK ACCELERATION	T_E	CROSS OVER FREQUENCY
Functional Test For Flight Equipment	20 g's	6-9 ms	45 Hz
Functional Test For Ground Equipment	40 g's	6-9 ms	45 Hz
Crash Hazard Test For Flight Equipment	40 g's	6-9 ms	45 Hz
Crash Hazard Test For Ground Equipment	75 g's	3.5-5 ms	80 Hz

FIGURE 516.3-1. Test shock response spectrum for use if measured data is not available.

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(2) Test axes and number of shocks. The equipment undergoing test shall be subjected to a sufficient number of suitable shocks to meet the specified test conditions at least three times in both directions along each of three orthogonal axes. A suitable test shock for each direction of each axis is one that yields a response spectrum that equals or exceeds the required test spectrum over the specified frequency range when using a duration of twice the specified T_E value for the test shock time history, and when the effective duration of the shock is within twenty percent of the specified T_E value. The spectra are to be determined for positive and negative maximum accelerations (either maximum absolute or equivalent static), Q = 10, and at least 1/6-octave frequency intervals. If the required test spectrum can be satisified simultaneously in both directions along an axis, three shock repetitions will satisfy the requirement for that axis. If the requirement can only be satisfied in one direction, it is permissible to change the test setup and impose three additional shocks to satisfy the spectrum requirement in the other direction; setup change possibilities are to reverse the polarity of the test shock time history or to reverse the test item orientation.

It is permissible to simultaneously meet the test requirements along more than one axis with a single test shock. Consequently, it is conceivable that a minimum of three test shock repetitions will satisfy the requirements for both directions of all three orthogonal axes. At the other extreme, a total of eighteen shocks will be required if each shock only satisfies the test requirements in one direction of one axis.

(3) Operation of test item. The test item shall be operational before, during, and after test as is appropriate to its functional use.

d. Rationale. The intent of this test is to disclose failures which may result from, or adjustments necessitated by, shocks experienced by an item during use in the field. Even though an item has successfully withstood even more severe shocks during shipping or transit shock tests, there are differences in support and attachment methods and in functional checking requirements that make this additional test necessary. Tailoring of the test is required when data are on hand, can be measured, or can be estimated from related data using accepted scaling techniques. When such data cannot be gotten, pulse waveform control, as defined in figure 516.3-4, may be used, although testing in both directions is required to assure meeting the spectrum requirements of figure 516.3-1 in the negative direction.

I-3.4 Procedure II - Equipment to be packaged

a. Application. Procedure II is to be used when equipment will require a shipping container. It establishes a minimum critical acceleration level for a handling drop height. This acceleration level may later be furnished to a package designer as an acceptable critical acceleration.

b. Restrictions. Procedure II is not intended for testing extremely fragile equipment such as missile guidance systems, precision-alined test equipment, gyros, inertial guidance platforms, etc. When the critical acceleration is required, procedure III (I-3.5) will be used.

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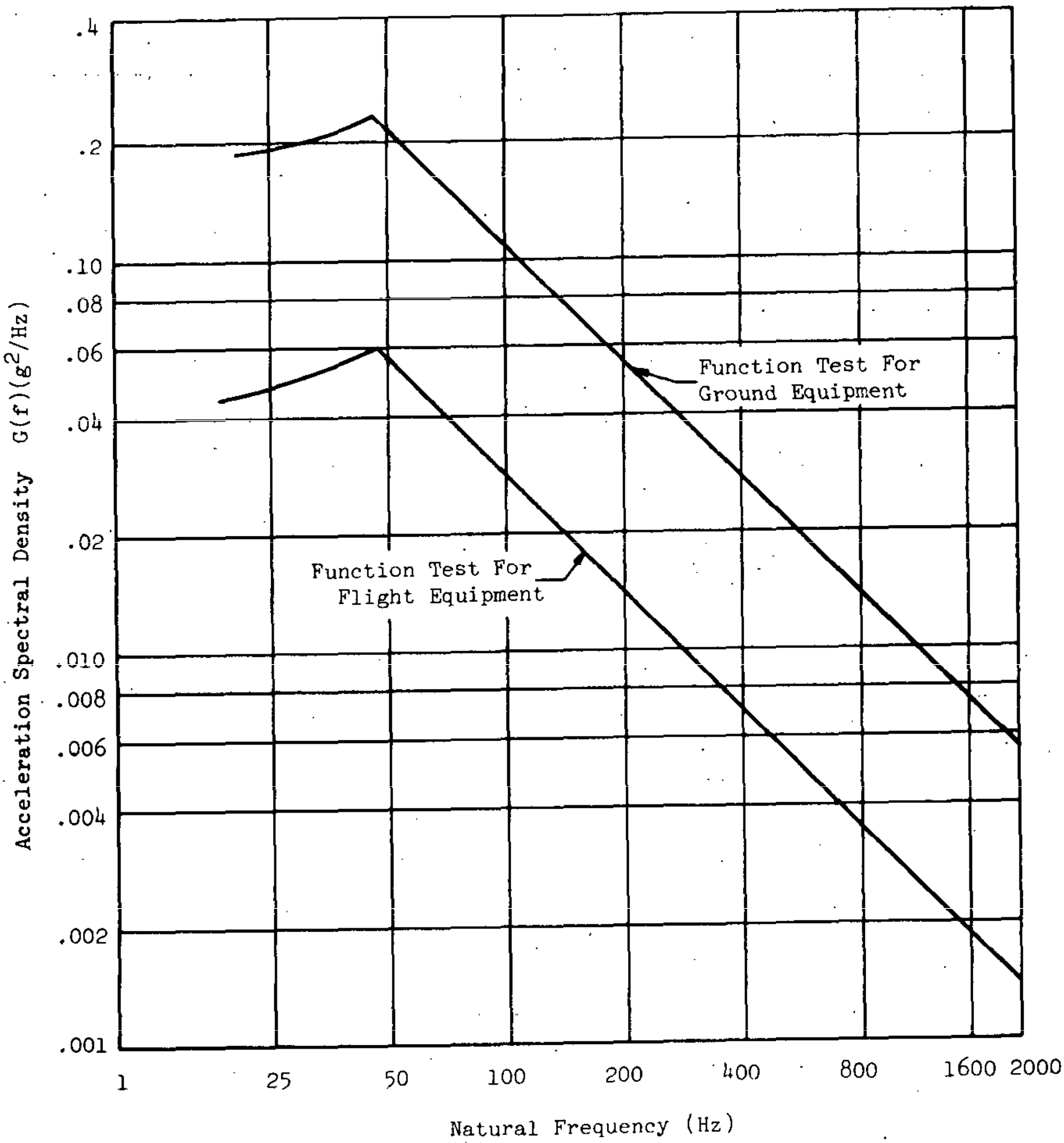

FIGURE 516.3-2. Random test input spectral density yielding equivalent test shock response spectra shown in figure 516.3-1.

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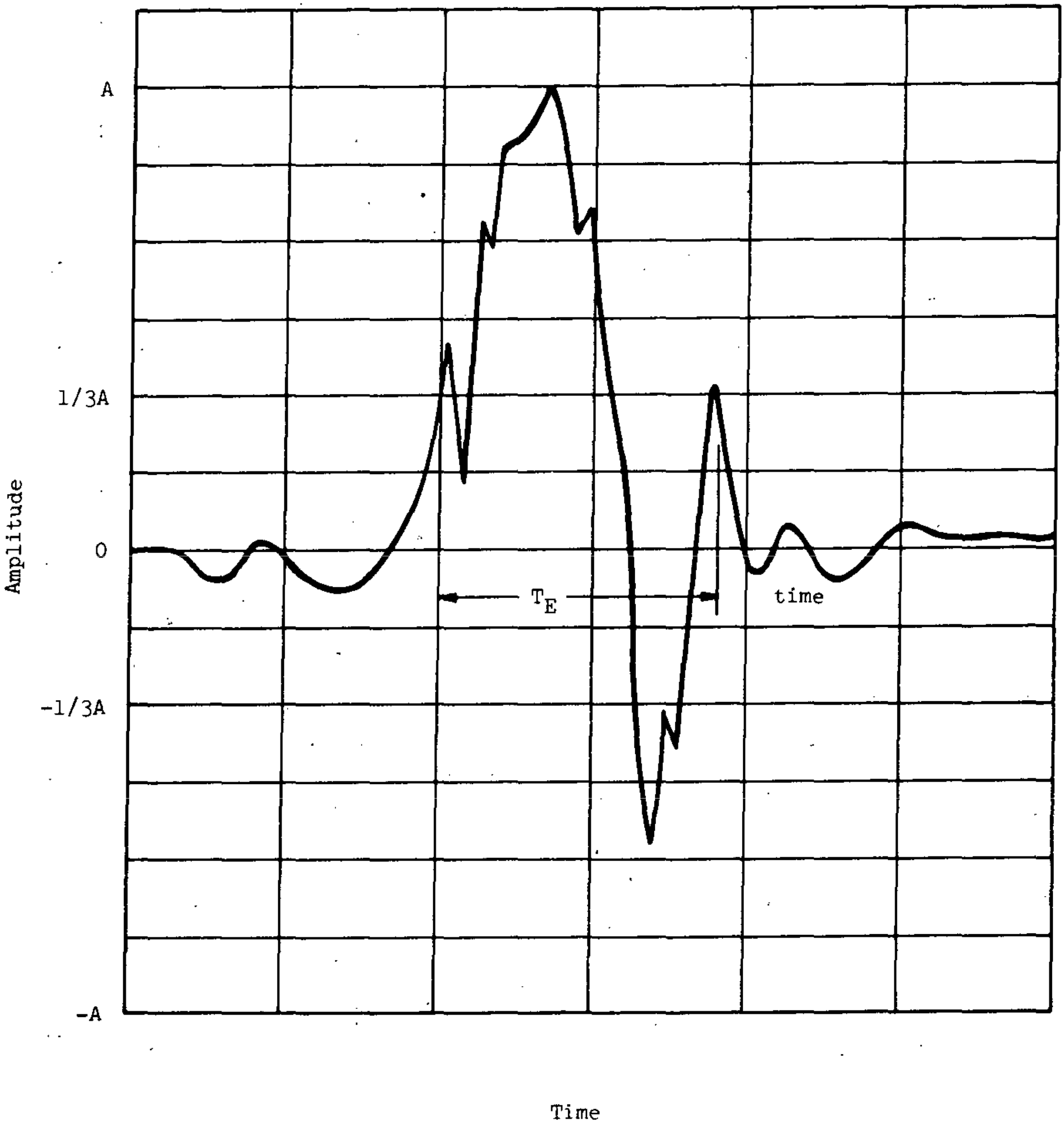

FIGURE 516.3-3. Example of a shock time history showing effective transient duration (T_E).

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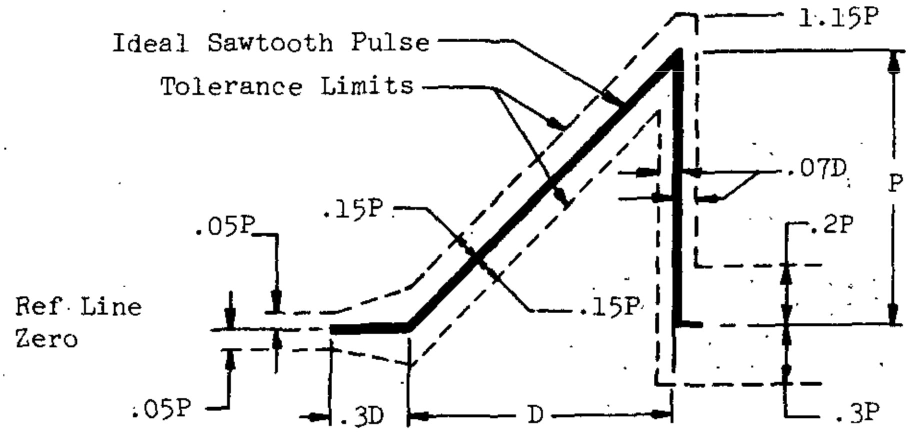

TEST	MINIMUM PEAK VALUE (P) g's		NOMINAL DURATION (D) ms	
	FLIGHT VEHICLE EQUIPMENT 1/ a	GROUND EQUIPMENT b	FLIGHT VEHICLE EQUIPMENT 1/ c	GROUND EQUIPMENT d
Operational Test	20	40 2/	11	11
Crash Safety	40	75	11	6

1/ Shock parameters a and c: recommended for equipment not shock-mounted and weighing less than 300 pounds.

2/ Equipment mounted only in trucks and semitrailers may use a 20g peak value.

NOTE: The oscillogram shall include a time about 3D long with a pulse located approximately in the center. The peak acceleration magnitude of the sawtooth pulse is P and its duration is D. The measured acceleration pulse shall be contained between the broken line boundaries and the measured velocity change (which may be obtained by integration of the acceleration pulse) shall be within the limits of $V_i \pm 0.1 V_i$, where V_i is the velocity change associated with the ideal pulse which equals 0.5 DP. The integration to determine velocity change shall extend from 0.4D before the pulse to 0.1D after the pulse.

FIGURE 516.3-4. Terminal-peak sawtooth shock pulse configuration and its tolerance limits (for use when shock response spectrum analysis capability is not available).

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c. Test conditions. The test item shall consist of the unpackaged equipment in a nonoperational mode. It shall be subjected to a series of trapezoidal 30-g shock pulses having a time duration to be determined from table 516.3-I and the equation

$$T_D = \frac{2\sqrt{(2\ h/g)}}{A_m}$$

The pulse will be in accordance with figure 516.3-5. A programmable shock machine will more than likely be required to produce these test conditions because of the displacement limitations of shakers.

d. Rationale. The trapezoidal waveshape was chosen because the computation of velocity change it produces (for comparison with design drop height) is much easier to make and more reproducible than most shock spectrum synthesis routines. Also it provides an upper bound on primary and maximax shock response spectra for given peak acceleration input levels.

I-3.5 Procedure III - Critical acceleration fragility

a. Application. Procedure III is used to determine an item's fragility level so that packaging can be designed for it, or so the item can be redesigned to suit packaging requirements.

b. Restrictions. Procedure III is to be used when the critical acceleration for an item must be determined.

c. Test conditions. A design drop height will be selected based on measurement of the test item's shipping environment, or from table 516.3-I when measured data are unavailable. (A design drop height is the height from which the test item might be dropped in its shipping configuration and be expected to survive.) A maximum test item velocity change may be taken from table 516.3-I or determined by using the following relationship:

$$\Delta V = 2\sqrt{2gh}$$

where

ΔV = maximum product velocity change cm/s (in/s) (summation of impact velocity and rebound velocity)

h = design drop height cm (in)

g = 980.6 cm/s^2 (386 in/s^2)

The shock machine is set to a maximum acceleration level (A_m) below the anticipated failure level. The approximate pulse duration is determined as follows (see figure 516.3-5):

$V = A_m\, g\, (0.9\ T_D)$ (T_F and T_R assumed to be 0.1 T_D)

$V = 0.5\ (g)\ A_m\ (2T_D - T_F - T_R)$ (T_F and T_R are known)

If an initial value for A_m does not exist, 15 g's may be used. If no damage occurs, then A_m will be increased incrementally while the maximum test item velocity change is held constant until damage to the test item occurs. This will be established as the test item's critical acceleration fragility level.

d. Rationale. Test levels used in this procedure represent the correlation of the best information currently available from research and experience. If more applicable test level data become available, they should be used (reference d).

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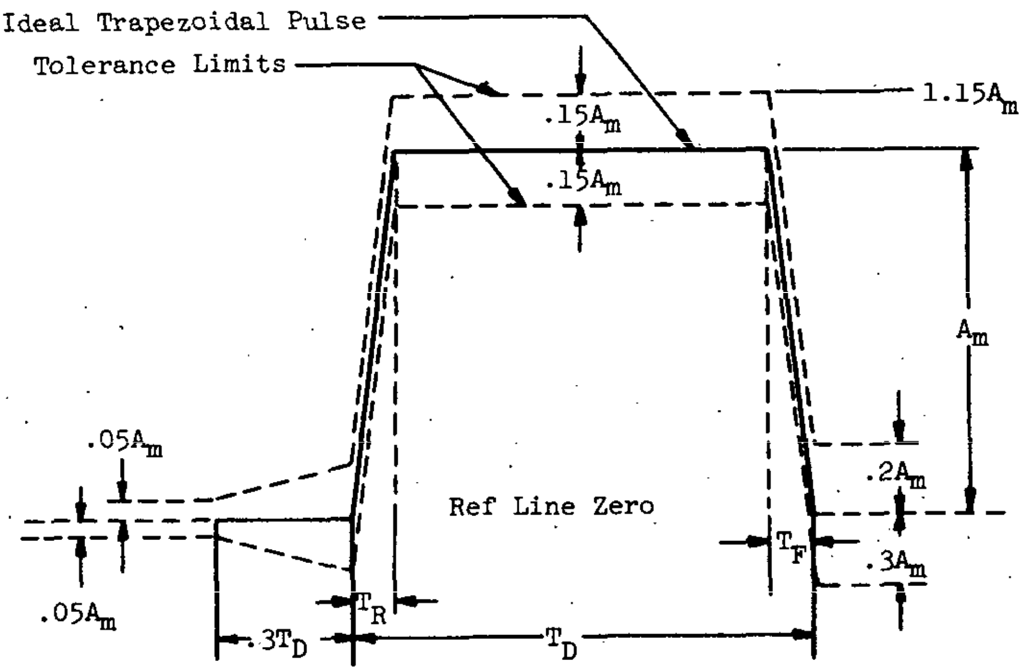

TEST	PEAK VALUE (A_m) g's	NOMINAL DURATION (T_D) ms
Fragility	10 to 50	$\frac{2\sqrt{(2\ h/g)}}{A_m}$
Packaged Shock	30	

NOTE: The time history display shall include a time about $3T_D$ long with a pulse located approximately in the center. The peak acceleration magnitude of the trapezoidal pulse is A_m and its duration is T_D. The measured acceleration pulse shall be contained between the broken line boundaries and the measured velocity change (which may be obtained by integration of the acceleration pulse) shall be within ten percent of the ideal pulse which approximately equals 0.5 A_m g $(2T_D-T_R-T_F)$. The integration to determine velocity change shall extend from $0.4T_D$ before the pulse to $0.1T_D$ after the pulse. Rise (T_R) and fall (T_F) times shall be less than or equal to $0.1T_D$.

FIGURE 516.3-5. Trapezoidal shock pulse configuration and its tolerance limits.

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TABLE 516.3-I. Suggested drop height for procedure III.

Package Gross Weight, Kg (lb)	Type of Handling	Design Drop Height cm (in)	Maximum Test Item Velocity Change,* cm/s (in/s)
0 to 9.1 (0 to 20)	manual handling	76 (30)	772 (304)
9.1 to 18.2 (20 to 40)	manual handling	66 (26)	722 (283)
18.2 to 27.2 (40 to 60)	manual handling	61 (24)	691 (272)
27.3 to 36.3 (60 to 80)	manual handling	46 (18)	600 (236)
36.3 to 45.4 (80 to 100)	manual handling	38 (15)	546 (215)
45.4 to 68.1 (100 to 150)	mechanical handling	31 (12)	488 (192)
68.1 to 113.5 (150 to 250)	mechanical handling	26 (10)	447 (176)
113.5 - (250 -)	mechanical handling	20 (8)	399 (157)

*for 100 percent rebound

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I-3.6 Procedure IV - Transit drop

a. Application. Procedure IV is intended for equipment in its transit or combination case as prepared for field use (carried to a combat situation by man, truck, rail, etc.). It is used to determine if the test item is capable of withstanding the shocks normally induced by loading and unloading of equipment.

b. Restrictions. Procedure IV is not intended for shocks encountered in a normal logistic shipping environment as experienced by shipping containers.

c. Test conditions. Test levels for this test are shown in table 516.3-II. The test item shall be tested in the same configuration that is carried into a combat situation. For test items under 45 Kg (100 pounds), the 26-drop requirement may be divided among up to five copies of the same test item if desired, in any combination. Toppling of the item following impact will occur in the field and, therefore, toppling of the test item following its initial impact should not be restrained as long as the test item does not leave the required drop surface.

d. Rationale. Levels for this test were set by considering how a field equipment item might commonly be dropped. (For example, a light equipment item might be carried by one man chest high; thus, it could drop 122 cm.) Field data have shown that a typical piece of man-portable equipment will be dropped from heights up to 122 cm (48 inches) an average of four to six times during its life cycle. The 26-drop requirement exists to insure that each vulnerable position (faces, edges, and corners) of a typical test item receives one impact.

I-3.7 Procedure V - Crash hazard

a. Application. Procedure V is for equipment mounted in an air or ground vehicle that could break loose from its mounts and present a hazard to vehicle occupants. It is intended to verify the structural integrity of equipment mounts during simulated crash conditions.

b. Restrictions. Procedure V is not intended for equipment transported as cargo. (For cargo, use method 514.3)

c. Test conditions. Use figure 516.3-1 as the test spectrum for the axis of test, provided that the effective shock duration T_E falls between 6 and 9 milliseconds for flight equipment and between 3.5 and 5.0 milliseconds for ground equipment. If shock spectrum analysis capabilities are not available, figure 516.3-4 may be used as an alternative to figure 516.3-1.

d. Rationale. An aircraft crash level of 40 g's is based on the fact that, during a survivable crash, localized g levels can approach 40 g's. Ground transportation vehicles are designed with a higher safety factor and, therefore, can sustain a much higher g level; thus, the higher test level.

I-3.8 Procedure VI - Bench handling

a. Application. Procedure VI should be used for equipment that may experience bench or bench-type maintenance. It is used to determine the ability of the test item to withstand the usual level of shock encountered during typical bench maintenance or repair.

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TABLE 516.3-II. Transit drop test.

Weight of Test Item and Case	Largest Dimensions	Notes	Height of Drop	Number of drops
Under 45.4 Kg (100 lbs)	Under 91 cm	A	122 cm (48 in)	Drop on each face, edge and corners
Manpacked or manportable	91 cm and over	A	76 cm (30 in)	Total of 26 drops[D/]
45.4 - 90.8 Kg (100-200 lbs) inclusive	Under 91 cm (36 in)	A	76 cm (30 in)	Drop on each corner; total of eight drops
	91 cm and over	A	61 cm (24 in)	
90.8 - 454 Kg (200-1000 lbs) inclusive	Under 91 cm (36 in)	A	61 cm (24 in)	
	91 to 152 cm (36-60 in)	B	91 cm (36 in)	
	Over 152 cm (60 in)	B	61 cm (24 in)	
Over 454 Kg	No limit	C	46 cm (18 in)	Drop on each bottom edge. Drop on bottom face or skids; total of five drops

NOTES:

A. Drops shall be made from a quick-release hook, or drop tester. The test item shall be so oriented that upon impact a line from the struck corner or edge to the center of gravity of the case and contents is perpendicular to the impact surface.

B. With the longest dimension parallel to the floor, the transit or combination case, with the test item within, shall be supported at the corner of one end by a block 13 cm (five inches) in height, and at the other corner or edge of the same end by a block 30 cm (12 inches) in height. The opposite end of the case then shall be raised to the specified height at the lowest unsupported corner and allowed to fall freely.

C. While in the normal transit position, the case and contents shall be subjected to the edgewise drop test as follows (if the normal transit position is unknown, the case shall be so oriented that the two longest dimensions are parallel to the floor):

Edgewise Drop Test: One edge of the base of the case shall be supported on a sill 13-15 cm (five to six inches) in height. The opposite edge shall be raised to the specified height and allowed to fall freely. The test shall be applied once to each edge of the base of the case (total of four drops).

D. The 26 drops may be divided among no more than five test items (see paragraph I-3.6).

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b. Restrictions. Procedure VI should not be used if it can be demonstrated that the shocks from the transit drop test are of a higher level. It is considered appropriate for medium-to-large test items that have a maximum dimension greater than approximately 23 cm (nine inches). (Small items will be tested to higher levels during transit drop.)

c. Test conditions. The test item in this test shall be raised at one edge four inches above a solid wooden bench top or until the chassis forms an angle of 45° with the bench top or until point of balance is reached, whichever is less. (The bench top must be at least 4.25 cm [1.675 inches] thick.) A series of drops shall be performed in accordance with II-3.6.

d. Rationale. The heights used during this test were set by examining the typical drops that are commonly made by bench technicians and assembly line personnel.

I-3.9 Procedure VII - Pyrotechnic shock

a. Application. Procedure VII is intended for equipment to be subjected to shock from explosive devices. The shock can be characterized as an oscillatory transient, with significant frequency content from 100 to 10,000 Hz, which decays to a few percent of its maximum acceleration in 5 to 15 milliseconds (reference b). The shock response spectrum often exceeds several thousand g's at frequencies above 1,000 Hz (for Q = 10). This procedure also applies to situations which may yield shocks of comparable severity, such as atmospheric reentry or water entry of missiles and high-velocity aerodynamic buffeting of high-performance weapon systems.

b. Restrictions. This test procedure will not be required along any axis for which both the following are satisfied: (1) the test spectrum from a random vibration test (see I-3.3b) or a functional shock test exceed this spectrum requirement and (2) if the test spectrum requirement above the frequency range specified for the random vibration or functional shock test does not exceed g values of 0.8 f, where f is the frequency in Hz. (The 0.8 f acceleration limit corresponds to approximately 50 in/sec spectral velocity. A basis for use of velocity as a criterion of severity is given in reference c. The value of 50 in./sec is selected because of limited observations (unpublished) that military-quality equipment does not tend to exhibit shock failures below a response spectrum velocity of 100 in./sec.)

c. Test conditions. Field measured data, or data obtained from a similar environment using appropriate dynamic scaling (reference b, vol. VI), will be used to define the shock test response spectrum requirement along each of three orthogonal axes. Measured data will be converted into test requirements in accordance with the guidelines outlined for the functional test conditions, I-3.3, with two exceptions:

(1) Measured or empirically scaled data will always be required to determine the test response spectrum.

(2) The allowed duration for the test shock time history used for response spectrum analysis can be 20 milliseconds or less, unless a longer duration can be justified by applicable data.

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d. Rationale. This procedure generally conforms to requirements for pyrotechnic shock testing in MIL-STD-1540 (USAF) for space vehicles. The pyrotechnic type shock test typically requires that the equipment to be tested be subjected to an intense, high-frequency oscillatory disturbance. An attempt to meet the test response spectrum using a single acceleration pulse will usually result in a severe overtest at the lower frequencies in order to meet the high-frequency requirements.

I-3.10 Procedure VIII - Rail impact

a. Application. Procedure VIII is for equipment that will be transported by rail. It is intended to determine the effect of normal railroad car impacts that occur during rail shipment.

b. Restrictions. Procedure VIII is not intended for testing small individually packaged pieces of equipment separately when they would normally be shipped (and tested) mounted on a pallet.

c. Test conditions. This test is conducted by mounting the test item in its rail shipment configuration in a rail car which undergoes a series of impacts at 13, 14.5, or 16.2 Km/hr (eight, nine, or ten miles per hour). If the test item can be shipped only in one orientation, it shall be impacted twice in each direction of that orientation at speeds of 13, 14.5, and 16.2 Km/hr (eight, nine, and ten miles per hour), ± five percent, for a total of 12 impacts. If the test item can be shipped in two orientations, it shall be impacted once in each direction of each orientation at speeds of 13, 14.5, and 16.2 Km/hr for a total of 12 impacts.

d. Rationale. Data for the rail impact test were derived from statistical data on frequency of impacts with relationship to speed and frequency of occurrence. Brakes are used on the buffer car to make the test conservative.

I-3.11 Procedure IX - Catapult launch/arrested landing

a. Application. This procedure is intended for equipment mounted in or on fixed-wing aircraft that are subjected to catapult launches and arrested landings.

b. Restrictions. None

c. Test conditions. Whenever possible, test conditions shall be derived from measured data on applicable carrying aircraft (see General Requirements, paragraph 4.3, Use of Field/Fleet Data), since shock responses can be affected by local influences such as wing and fuselage bending modes, pylon interfaces, and structural damping.

However, if acceptable field-derived data are not available, the following guidance is offered in which a sinusoidal burst is used to simulate each catapult or launch event.

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(1) Wave shape - damped sine wave
(2) Wave frequency - determined by structural analysis of specific aircraft and location fundamental mode
(3) Burst amplitude - same as above
(4) Wave Damping (quality factor) - Q = 20
(5) Axis - vertical, transverse
(6) Number of bursts - determined by the specific application (for example, 30 bursts, each followed by a 10 second rest period)

d. Rationale. The catapult launch/arrested landing shock environment differs from other typical shock events in that it is in reality a transient periodic vibration (roughly sinusoidal) at a relatively low frequency determined by aircraft mass and landing gear damping characteristics. Typical catapult launch and arrested landing shock time histories are shown in figure 516.3-6.

In general, catapult time histories will show two transient events corresponding to initial load application and catapult separation from the aircraft, with both transient events having a distinct oscillatory nature (reference f). For the purposes of this procedure, however, this time history has been simplified to a constant-amplitude sine burst of 2-second duration of approximately similar characteristics.

While the pulse amplitudes associated with this environment are low, the long periods of application and high frequency of occurrence have the potential to cause significant damage in improperly designed equipment.

A typical aircraft may fly as many as 200 sorties per year, of which more than two-thirds may involve catapult launches and arrested landings. However, for laboratory test purposes, 30 simulated catapult/landing events in each of two axes (longitudinal and vertical) should provide good confidence that the majority of significant defects will be identified for remedial action.

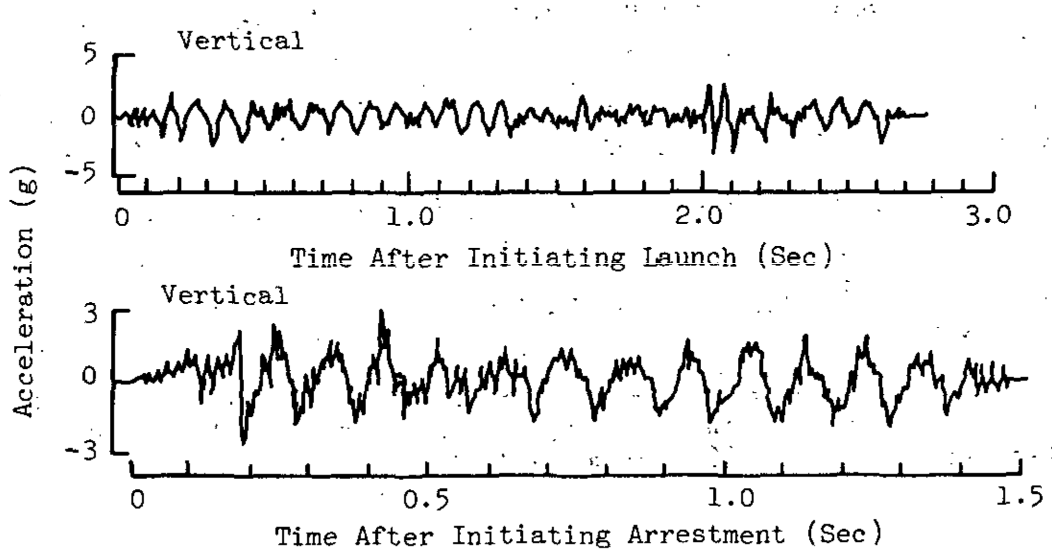

FIGURE 516.3-6. Typical response of equipment to catapult launches and arrested landings showing oscillatory nature of transient. (Reference f)

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I-4 SPECIAL CONSIDERATIONS

I-4.1 Test interruption. Generally, if interruption occurs during a pulse, that pulse shall be repeated. Care must be taken to ensure that stresses induced by the interrupted pulse do not invalidate subsequent test results. (See General Requirements.)

I-4.2 Related shock tests

I-4.2.1 High impact/shipboard equipment. Shock tests for shipboard equipment shall be performed in accordance with MIL-S-901. Attention is directed to the ability to tailor MIL-S-901 tests through design of the fixture attaching the test item to the shock machine. As much as possible, the fixture should provide compliance similar to that existing in the field environment of the test item.

I-4.2.2 Rough handling for packaged items. Tests for shipping and handling may be performed in accordance with MIL-P-116 or FED-STD-101.

I-4.2.3 Fuzes and fuze components. Shock tests for safety and operation of fuzes and fuze components may be performed in accordance with MIL-STD-331.

I-4.2.4 Combined temperature and shock tests. Tests may be performed at room ambient conditions unless a high or low temperature shock test is required.

I-5 REFERENCES

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METHOD 516.3

SHOCK

SECTION II

II-1 APPARATUS

II-1.1 Apparatus I. Apparatus I is used for procedures I, II, III, V, VII, and IX.

II-1.1.1 Test facility. The shock-producing apparatus shall be capable of producing the test conditions as determined according to the appropriate paragraphs of section I of this method. The shock apparatus may be of the free fall, resilient rebound, nonresilient, hydraulic, compressed gas, electrodynamic shaker, or other activating types. Procedure VII may require pyrotechnic devices to simulate field conditions. Procedures II and III require test apparatus capable of producing relatively large displacement.

II-1.1.2 Calibration. The shock apparatus will be calibrated for conformance with the specified test requirement from the selected procedure. Two consecutive shock applications to a calibration load shall be produced which satisfy the test conditions outlined in procedures I, II, III, V, VII or IX. The calibration load shall then be removed and the shock test will be performed on the actual test item.

II-1.1.3 Controls. The instrumentation used to measure shock pulses or shock acceleration spectra shall have the following characteristics.

a. Accelerometer

(1) Transverse sensitivity of less than or equal to 5%.

(2) An amplitude linearity within 10% from 5% to 100% of the peak acceleration amplitude required for testing.

(3) For procedures I, II, III, V and IX: A flat frequency response within ±10% across the frequency 5 - 2,000 Hz.

(4) For procedure VII: A flat frequency response within ±10% across the frequency 20 Hz to the highest frequency specified in I-3.9.

b. Analysis system

(1) Will not alias more than a 5 percent measurement error into the frequency band of interest. (20 Hz to 10 KHz typically.)

(2) If filters are used to meet the previous requirement, a filter having linear phase-shift characteristics shall be used.

(3) With filter (if used), shall have a pass band within 1 dB across the frequency range specified for the accelerometer (see II-1.1.3a).

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c. Apparatus

(1) The shock apparatus shall be capable of producing a transient that meets or exceeds the required spectral or pulse amplitude. For comparability or repeatability, the shock response spectrum of the transient should not exceed the test condition by more than 3.5 dB for procedures I, V and IX and 6.0 dB for procedure VII ($dB = 20 \log \frac{A}{A_0}$).

II-1.2 Apparatus II. The drop tester used to conduct procedure IV (Transit Drop) tests shall be capable of producing the required impacts to the test item(s).

II-1.2.1 Test facility. Drops for equipment mass up to 454 Kg (1000 pounds) and having its largest dimension less than 91 cm (36 inches) shall be made from a quick-release hook, or drop tester. The floor or barrier receiving the impact shall be of two-inch plywood backed by concrete. For equipment over 454 Kg, the floor or barrier shall be concrete.

II-1.2.2 Controls. Controls shall be adequate to assure that testing is conducted as specified in table 516.3-II.

II-1.3 Apparatus III. The platform used for performing procedure VI tests (bench handling) shall be a solid wood bench top at least 4.25 cm (1.675 inches) thick.

II-1.4 Apparatus IV

II-1.4.1 Test facility. The following equipment will be necessary to perform the rail impact test (procedure VIII).

a. Two ordinary railroad cars, equipped with a draft gear coupling that will be used during shipment.

b. A prime mover for moving the cars.

II-1.4.2 Controls. The following are minimum test control requirements.

a. A calibrated means to determine that the speed at the time of impact is 13, 14.5, or 16.2 Km/hr (eight, nine or ten miles per hour), within ± five percent.

b. Accelerometers and associated circuitry to measure the impact, shock, and equipment response, if these measurements are specified.

II-2 PREPARATION FOR TEST

II-2.1 Preliminary steps. Prior to initiating any testing:

a. Choose the appropriate test procedures (paragraph I-3).

b. Determine the shock levels for the procedures chosen.

II-2.2 Pretest checkout. All items require a pretest checkout at standard ambient conditions to provide baseline data. Conduct the checkout as follows:

Step 1. Conduct a complete visual examination of the test item with special attention to stress areas.

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Step 2. Document the results.

Step 3. Where applicable, install the test item in its test fixture.

Step 4. Conduct an operational checkout in accordance with the approved test plan.

Step 5. Document the results for compliance with General Requirements.

Step 6. If the test item operates satisfactorily, proceed to the first test as required by II.2.1a. If not, resolve the problem and restart at Step 1.

II-3 PROCEDURES.

II-3.1 Procedure I - Functional shock

Step 1. Following the guidance of paragraph I-3.3c, select test conditions and calibrate the shock apparatus as follows:

a. Select accelerometers and analysis techniques which meet the criteria outlined in II-1.1.3.

b. Mount the calibration load (the actual test item, a rejected item, or a rigid dummy mass) to the test apparatus in a manner similar to that of the actual test item. If the test item is normally mounted on vibration isolators, the isolators shall be functional during the test.

c. Perform calibration shocks until two consecutive shock applications to the calibration load produce waveforms which meet or exceed test conditions derived from paragraph I-3.3, for at least one direction of one axis.

d. Remove the calibrating load and install the actual test item on the shock apparatus.

Step 2. Perform a functional check on the test item.

Step 3. Subject the test item (in its operational mode) to the test transient.

Step 4. Record necessary data to show that the transients met or exceeded desired test levels. This includes test setup photos, test logs, and photos of actual shock transients. For shock/vibration isolated assemblies within the test item, measurements and/or inspections should be made to assure these assemblies did not impact with adjacent assemblies.

Step 5. Perform functional check on the test item. Record performance data.

Step 6. Repeat steps 3, 4, 5, and 6 three times for each orthogonal axis that is to be tested in both the positive and negative directions. (If negative and positive acceleration spectra of one transient meet or exceed desired test levels for an axis, they can be counted as two transients, one in each direction.)

Step 7. Document the test.

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II-3.2 Procedure II - Equipment to be packaged

Step 1. Following the guidance of paragraph I-3.4c, calibrate the shock machine as follows:

a. Mount the calibration load (the actual test item, a rejected item, or a rigid dummy mass) to the test apparatus in a manner similar to that of the actual test item. Use a fixture similar in shape and configuration to the shock attenuation system which will support the test item in its shipping container. (The fixture should be as rigid as possible to prevent distortion of the shock pulse imparted to the test item.)

b. Perform calibration shocks until two consecutive shock applications to the calibration load produce waveforms which are all within the tolerance envelope of the specified waveform (figure 516.3-5).

Step 2. Remove the calibrating load and install the actual test item on the shock apparatus.

Step 3. Perform a functional test on the test item.

Step 4. Subject the test item to the test pulse.

Step 5. Record necessary test data. This shall include test setup photos, test logs, and photos of the actual test pulse.

Step 6. Perform a functional test on the test item.

Step 7. Repeat steps 2, 3, 4, and 5 once in each direction for three orthogonal axes (six shocks).

Step 8. Document results.

II-3.3 Procedure III - Fragility

Step 1. Install the test item on the shock apparatus using a fixture similar in shape and configuration to the shock attenuation system which will support the test item in its shipping container. (The fixture should be as rigid as possible to prevent distortion of the shock pulse imparted to the test item.)

Step 2. Select the design drop height from paragraph I-3.5c.

Step 3. Adjust the shock apparatus to obtain a maximum test item velocity change obtained from measured data or as given in table 516.3-I. If maximum test item velocity change values are required for design drop heights other than those listed, the following relationship may be used.

$$\Delta V = 2\sqrt{(2\,gh)}$$

where ΔV = maximum test item velocity change, cm/s (in/s) (summation of impact velocity and rebound velocity)
h = design drop height, cm (in)
g = 980.6 cm/s^2 (386 in/s^2)

The drop height of the shock test apparatus will not necessarily be the same as the design drop height.

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Step 4. Set the shock test apparatus to obtain a maximum acceleration (A_m) and maintain the required velocity change below the anticipated failure level of the test item. If no information is available on anticipated failure level, set the shock test apparatus to obtain a maximum acceleration level of 15 g's. Pulse durations can be determined using the following relationship:

$$V = gA_m (0.9T_D)$$

Step 5. Perform one shock test using pulse shown in figure 516.3-5.

Step 6. Examine the recorded shock pulse to be certain the desired maximum acceleration (A_m) and velocity change were obtained. Methods for determining maximum acceleration and velocity change are given in step 3 above.

Step 7. Examine or functionally test the test item to determine if damage due to shock has occurred.

Step 8. If no damage has occcurred, set the shock test apparatus for a higher maximum acceleration (A_m) level while maintaining drop height (and thus velocity change) constant.

Step 9. For all faces, repeat steps 5, 6, 7, and 8 with incrementally increasing maximum acceleration (A_m) until test item damage occurs. The maximum acceleration prior to which damages occur is taken to be the shock-fragility level for the test item in the direction tested.

II-3.4 <u>Procedure IV - Transit drop</u>

Step 1. Install the test item in its transit or combination case as prepared for field use.

Step 2. From paragraph I-3.6, determine the height of the drops to be performed, the number of drops per test item, and the drop surface.

Step 3. Perform the required drops using the apparatus of paragraph II-1.2. The drops should be in accordance with table 516.3-II. It is suggested that the test item be visually and/or operationally checked periodically during the drop test to simplify any follow-on failure evaluation that may be required.

Step 4. Document the impact point or surface for each drop and any obvious damage.

Step 5. Following completion of the required drops, visually examine the test items(s).

Step 6. Document the results for comparison with data obtained in paragraph II-2.2, step 2.

Step 7. Conduct an operational checkout in accordance with the approved test plan.

Step 8. Document the results for comparison with data obtained in paragraph II-2.2, step 5.

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II-3.5 Procedure V - Crash hazard

NOTE: If calibration of the test apparatus is required, perform steps 1 and 2 of paragraph II-3.1 first.

Step 1. Secure the test item mount to the shock apparatus by its normal mounting means. The test item shall be a representative equipment item or a mechanically equivalent mockup. If a mockup is used, it will represent the same hazard potential, mass, center of mass, and mass moments about the attachment points as the item simulated.

Step 2. Perform two shocks in each direction (as determined in paragraph I-3.7c) along three orthogonal axes of the test item for a maximum total of 12 shocks.

Step 3. Perform a physical inspection of the test setup. Operation of the test item is not required.

Step 4. Document the results of the physical inspection including an assessment of potential hazards created by equipment breakage or deformation.

II-3.6 Procedure VI - Bench handling

Step 1. Configure the item as it would be for servicing - for example, with the chassis and front panel assembly removed from its enclosure. Position the item as it would be for servicing.

Step 2. Using one edge as a pivot, lift the opposite edge of the chassis until one of the following conditions occur (whichever occurs first).

a. The chassis forms an angle of 45° with the horizontal bench top.

b. The lifted edge of the chassis has been raised four inches above the horizontal bench top.

c. The lifted edge of the chassis is just below the point of perfect balance.

Let the chassis drop back freely to the horizontal bench top. Repeat, using other practical edges of the same horizontal face as pivot points, for a total of four drops.

Step 3. Repeat step 2 with the test item resting on other faces until it has been dropped for a total of four times on each face which the test item could be placed practically during servicing. The test item shall not be operating.

Step 4. Visually inspect the test item.

Step 5. Document the results for comparison with data obtained in paragraph II-2.2, step 2.

Step 6. Operate the test item in accordance with the approved test plan.

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Step 7. Document the results for comparison with data obtained in paragraph II-2.2, Step 5.

II-3.7 Procedure VII - Pyrotechnic. Same as II-3.1, except that measured or analytically derived data shall always be used as test conditions.

II-3.8 Procedure VIII - Rail impact

Step 1. Position one fully loaded railroad car on a level section of track.

Step 2. Set the airbrakes in the emergency application position on the buffer car. The total gross mass (which will include a buffer load securely mounted to the car to prevent shifting) shall be 99,880 Kg (220,000 pounds) minimum.

Step 3. Mount the test item on the end of the test car in direct contact with the floor and adequately blocked and secured to prevent any longitudinal, vertical, or lateral movement. Use metal banding, or wire, of sufficient size or strength to provide additional tiedown strength. Inspect blockings and tie-downs after each impact. If damaged or loosened, repair them prior to the next impact. However, do not alter or repair tiedown attachments that are built-in parts of the test item during the test. Specify positions of the equipment with respect to the test car and whether or not packaging is necessary. If loading and tiedowns are not specified, all loading and tiedowns shall be in accordance with recommended practices of the Association of American Railroads.

Step 4. Impact the test car into the loaded car.

Step 5. Impact shall be made in progressive steps with impacts of 13, 14.5, and 16.2 Km/hr (eight, nine, and ten miles per hour), ± five percent. Measure the speed just prior to impact by electronic or electrical means.

Step 6. Visually inspect the test item for physical degradation.

Step 7. Document the results for comparison with data obtained in paragraph II-2.2, step 2.

Step 8. Perform an operational checkout of the test item in accordance with the approved test plan.

Step 9. Document the results for comparison with data obtained in paragraph II-2.2, step 5.

II-3.9 Procedure IX - Catapult launch/arrested landing

Step 1. Mount the test item to its vibration fixture as described in method 514.3, paragraph I-4.2.5 for the first test axis.

Step 2. Attach accelerometers described in method 514.3 and other test instrumentation.

Step 3. Conduct an operational checkout and visual examination in accordance with the approved test plan.

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Step 4. Apply sine bursts to the equipment in the first test axis. (Each burst represents a single catapult or landing event.) Each burst should be followed by a rest period to prevent unrepresentative effects. The test item should be operated in its appropriate operational mode while the bursts are applied.

Step 5. If the equipment has not malfunctioned during testing, conduct an operational checkout and visual examination in accordance with the approved test plan. If a failure has occurred, it may be desirable to perform a thorough visual examination before proceeding with the operational checkout to avoid initiating additional hardware damage. When a failure occurs, the nature of the failure and corrective action along with the purpose of the test (engineering information or contractural compliance) should be considered in determining whether to restart the test or continue from the point of interruption.

Step 6. Repeat steps 1 through 5 for the second test axis.

Step 7. Document the test as described in General Requirements.

II-4 <u>INFORMATION TO BE RECORDED</u>. Test data shall be recorded as specified in General Requirements, and shall include the following:

a. Prior test methods to which the specific test item has been subjected.

b. Pretest data required (see General Requirements).

c. Procedure number.

d. Shock pulse selection, specifying shape, peak value, and duration; or measured data selected for use in conjunction with the shock response spectrum outlined in procedure I and VI.

e. (For procedure VIII only) Whether the rail impact shock pulse input and test item response are to be measured.

f. (For procedure VIII only) Test item positioning with respect to the test car and whether packaging is necessary for the rail impact test.

g. Temperature extremes (if the shock test is done in conjunction with temperature testing).

h. All instrumentation and filtering used.

i. Whether operation during the test is required, mode of such operation, and if and how the operation is to be monitored.

j. Loading and tiedowns.

k. Failure criteria.

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APPENDIX 516.3A

DEFINING TEST SHOCK FOR NORMAL OR

LOGNORMAL DISTRIBUTION OF FIELD DATA

For each 1/6th-octave (or more closely spaced) frequency, the test shock spectrum value G is given by

$$G = m + ks \tag{1}$$

where "m" is the mean and "s" is the standard deviation of the sample values. When the n sample values g_i are assumed on the basis of experience with similar data to be normally distributed

$$m = \frac{1}{n-1} \sum_{i=1}^{n} g_i \quad \text{and} \quad s^2 = \frac{1}{n-1} \sum_{i=1}^{n} (g_i - m)^2 \tag{2}$$

and when the sample values are assumed to be lognormally distributed

$$m = \frac{1}{n-1} \sum_{i=1}^{n} \log g_i \quad \text{and} \quad s^2 = \frac{1}{n-1} \sum_{i=1}^{n} (\log g_i - m)^2 \tag{3}$$

The value of k in equation (1) is taken from table 1 as a function of the number of sample values n to yield a G value equal to the 95th percentile at least 50 percent of the time. The use of this procedure becomes highly suspect for less than five data samples. Any such use should be undertaken in association with the approach recommended in I-3.3c when insufficient data are available for statistical analysis.

The above process is repeated for each frequency of the shock response spectrum. The resulting G values may be enveloped in a manner deemed appropriate by the responsible test organization.

TABLE A-I. Values of k. 1/

No of Test Runs	k	No of Test Runs	k
5	1.78	12	1.69
6	1.75	15	1.68
7	1.73	20	1.67
8	1.72	30	1.66
9	1.71	100	1.65
10	1.70		

1/ Owen, D.B. Factors for One-Sided Tolerance Limits and for Variables Sampling Plans. Sandia Corporation Monograph No. SCR-607, March 1963.

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METHOD 519.3

GUNFIRE VIBRATION, AIRCRAFT

Page

SECTION I

I-1 PURPOSE. The gunfire vibration test is performed to assure that equipment mounted in an aircraft with onboard guns can withstand the vibration levels caused by the overpressure pulses emitting from the gun muzzle.

I-2 ENVIRONMENTAL EFFECTS. The vibration resulting from repetitive gun blast pulses is two orders of magnitude above normal flight vibration levels. Gunfire vibration will cause the structure and equipment to respond in a violent manner. This response can cause intermittent electrical contact, catastrophic electrical failures, hydraulic malfunctions, and structural fatigue failures.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS. This test method should be applied at the end of the tailoring process described in section 4 of this standard.

a. Application. This test applies to equipment installed in aircraft that carry and fire onboard guns.

b. Restrictions. When an item will be installed in a location where the gunfire vibration is less than normal flight vibration, no gunfire testing is recommended. Use method 514.3.

c. Sequence. This test should be conducted early on in the testing of the test item because of the very severe nature of the gunfire-induced vibration environment. This is provided that the specific test item does not need to be tested in any other environmental test sequences.

NOTE: Items tested in their vibration isolation mountings should also pass the minimum integrity requirements of method 514, paragraph I-3.2.12.

d. Test variations. The test variables are vibration spectrum and intensity, and test duration.

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I-3.1 Choice of test procedures. There is only one procedure in this method.

I-3.2 Choice of related test conditions

I-3.2.1 Test spectrum. Onboard gunfire produces vibration from three different sources:

a. the overpressure pulses emanating from the gun muzzle,

b. the recoil kick of the gun on its mounts, and

c. the motion of ammunition-handling mechanisms as the gun is firing.

Of these, the one having the greatest effect at most equipment locations is the first. Therefore this test focuses on the vibration caused by the overpressure pulses from the gun muzzle.

The vibration environment that occurs at a specific equipment location is a complex combination of broadband random vibration and intense narrowband random vibration or sinusoidal peaks at specific frequencies. (See method 514.3, paragraph I-4.2.2.) This vibration is a combination of forced and free vibration of the vehicle's structure. The narrowband vibration--that is, the pressure pulses from a firing gun--is very intense and likely to have severe resonance effects on the aircraft's structure and equipment. These effects are hard to predict from a model and are better discovered by direct measurement. In the case of equipment that is structurally coupled to the gun or its mounting structure, test spectra should always be derived from measured data. The significant vibration occurs at frequencies between 10 and 2000 Hz.

I-3.2.1.1 Measuring gunfire vibration spectra. It is recommended that measured data be taken at the equipment location of interest while the onboard guns are fired. These data should cover a frequency range of at least 10 to 2000 Hz. The data should be analyzed using no greater than a 10-Hz constant bandwidth filter up to 500 Hz and a 20-Hz constant bandwidth filter from 500 Hz to 2000 Hz with a statistical degree of freedom of at least 50. These data should be recorded with the aircraft in actual flight because ground tests could result in data that aren't representative of actual conditions.

I-3.2.1.2 Predicting gunfire vibration spectra. If measured data are not available, test spectra may be calculated using the following technique.

NOTE: This technique may over-predict those frequencies where the structure or equipment responses become significantly nonlinear. Likewise, for those cases in which the structure or equipment resonances coincide with the frequencies in the gunfire, the vibration response could be under-predicted (resonance on resonance).

Figure 519.3-1 shows a generalized vibration spectrum for gunfire-induced vibration. It is characterized by four vibration peaks and broadband random. The vibration peaks are at frequencies that correspond to the nominal gunfire rate and its first three harmonics. The specific values for each of the parameters shown in figure 519.3-1 can be determined from table 519.3-I using the following distance factors.

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a. Vector distance (D). The vector distance from the muzzle of the gun to the mean distance between equipment support points as shown in figure 519.3-2. For configurations involving multiple guns, the origin of vector D is determined from the centroidal point of the gun muzzle as shown in figure 519.3-3.

b. Gun standoff distance (H). The distance normal to the aircraft's surface as shown in figure 519.3-4.

c. Depth parameter (R_s). The distance normal to the aircraft's skin to the equipment location inside the aircraft. If R_s is unknown, use R_s = three inches (see figure 519.3-2).

The vibration peaks bandwidths should be based on test data if possible. When data are not available, the vibration peaks' bandwidths can be calculated as:

$$BW_{3dB} = \frac{\pi\sqrt{F}}{4}$$

Where: BW_{3dB} = the bandwidth at a level 3dB below the peak PSD level
F = the fundamental frequency (F_i) or one of the harmonics: f_1, f_2, f_3, or f_4

For cases where the gun firing rate changes during a development program, it is desirable to perform sinusoidal sweeps within the proposed bandwidth for the fundamental and each harmonic.

I-3.2.2 Duration of test. The duration of the gunfire test in each of the three axes should be equivalent to the expected total amount of time the equipment will experience the environment in actual usage. This duration may be conservatively estimated by multiplying the expected number of aircraft sorties in which gunfiring will occur by the maximum amount of time that gunfiring can occur in each sortie. The number of sorties in which gunfire will occur will be tied to planned aircraft training and combat utilization rates, but will generally be in the vicinity of 200 to 300 sorties. The maximum gunfire time per sortie can be determined from table 519.3-II by dividing total rounds per aircraft by the firing rate. When a gun has more than one firing rate, the test should be run using both firing rates, with test time at each firing rate based on the expected proportion of time at each firing rate in service.

The guns carried by an aircraft are generally fired in short bursts that last a few seconds and testing should be performed accordingly. For example, vibration should be applied for two seconds followed by an eight- to ten-second rest period during which no vibration is applied. This two-second-on/eight-to-ten-second-off cycle is repeated until the total vibration time equals that determined for the aircraft type. This cycling will prevent the occurrence of unrealistic failure modes due to vibration isolator overheating in continuous vibration. Intermittent vibration can readily be achieved by several means including interrupting the shaker input signal and storing acceleration time history inputs on magnetic disc or tape.

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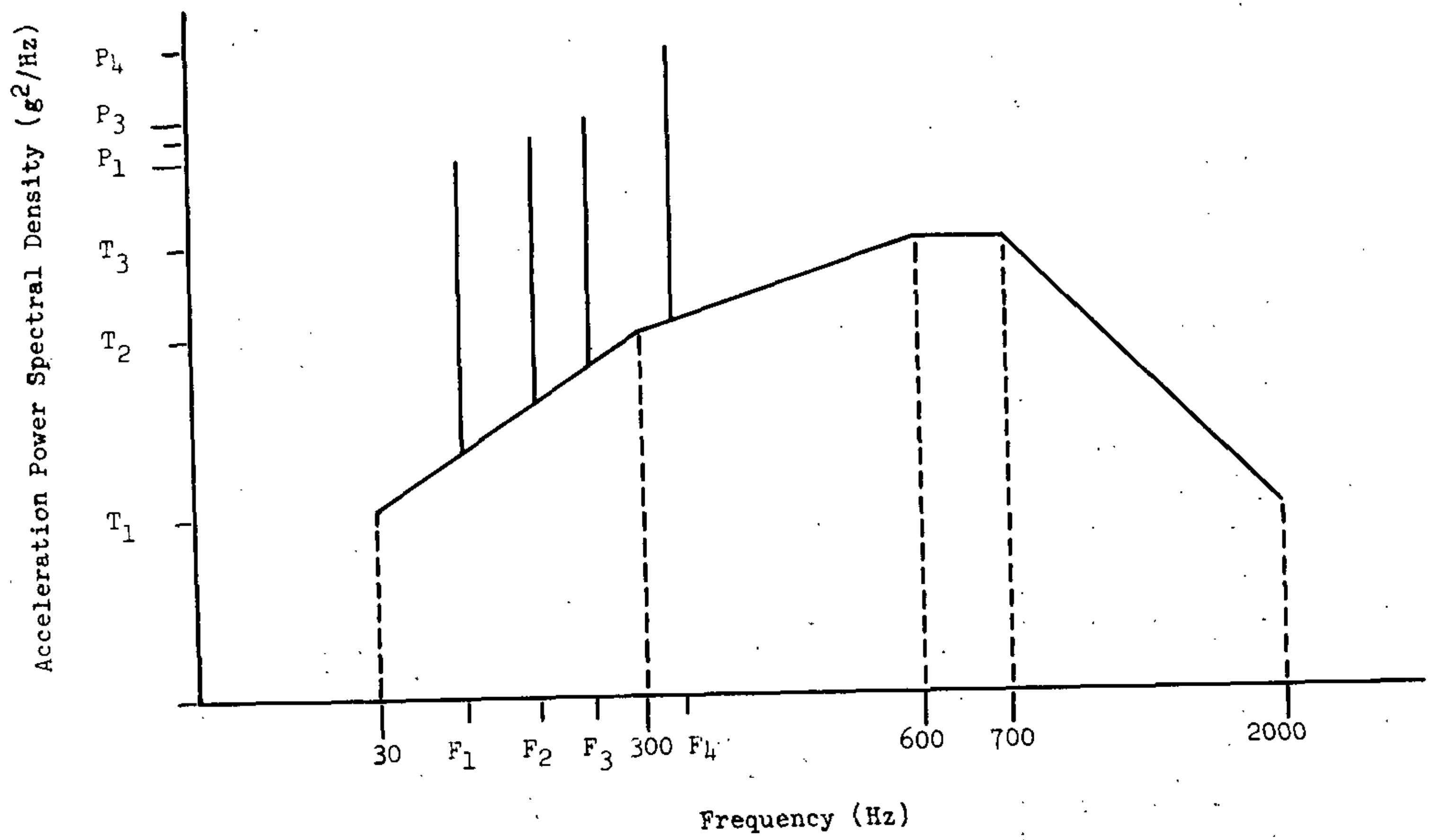

FIGURE 519.3-1. Generalized gunfire induced vibration spectrum shape.

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TABLE 519.3-I. Suggested generalized parametric equations for gunfire-induced vibration.

$$10 \log T_j = 10 \log (NF_1E) + H + M + W + J + B_j - 53dB$$

$$10 \log P_i = 10 \log T_3 + K_i + 17dB$$

Where:

N = Maximum number of closely spaced guns firing together. For guns that are dispersed on the host aircraft, such as in wing roots and in gun pods, separate vibration test spectra are determined for each gun location. The vibration levels, for test purposes, are selected for the gun that produces the maximum vibration levels.

E = Blast energy of gun (see table 519.3-III).

H = Effect of gun standoff distance (see figure 519.3-4).

M = Effect of gun location M = 0 unless a plane normal to the axis of the gun barrel and located at the muzzle of the gun does not intersect the aircraft structure, then M = -6 dB.

W = Effect of the weight of the equipment to be tested (use figure 519.3-5). If weight of equipment is unknown, use W = 4.5 kilograms.

J = Effect of equipment's location relative to air vehicle's skin (use figures 519.3-2 and 519.3-6).

B_j = Effect of vector distance from gun muzzle to equipment location (see figure 519.3-7).

F_1 = Gunfiring rate where F_1 = fundamental frequency from table 519.3-II. ($F_2 = 2F_1$, $F_3 = 3F_1$, $F_4 = 4F_1$)

T_j = Test level in g^2/Hz.

P_i = Test level for frequency F_i in g^2/Hz (where i = 1 to 4).

K_i = Effect of vector distance on each vibration peak, P_i (see figure 519.3-8).

NOTE: These equations are in metric units. The resultant dB values are relative to 1 g^2/Hz.

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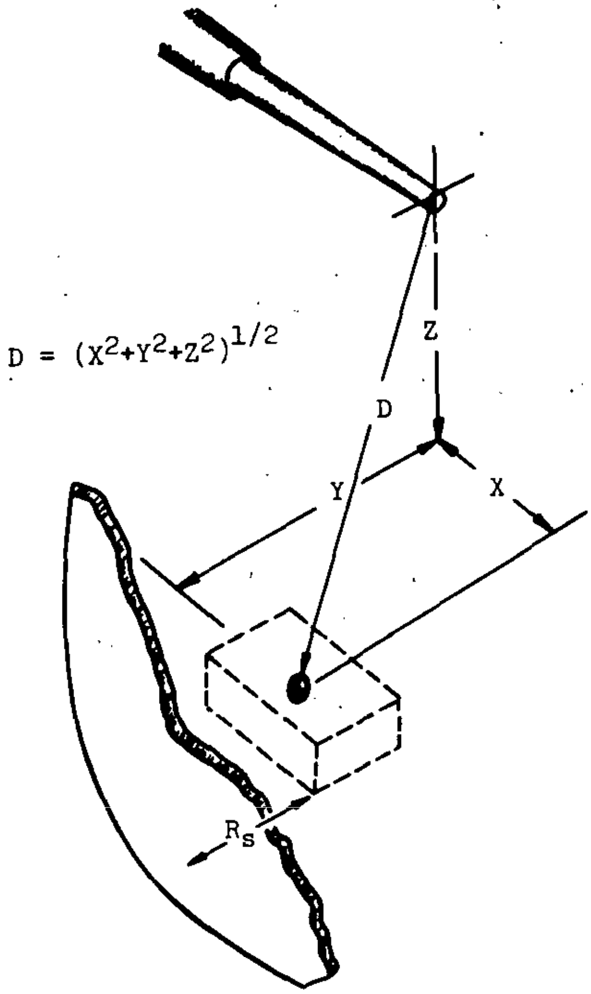

FIGURE 519.3-2. The distance parameter (D) and the depth parameter (R_s).

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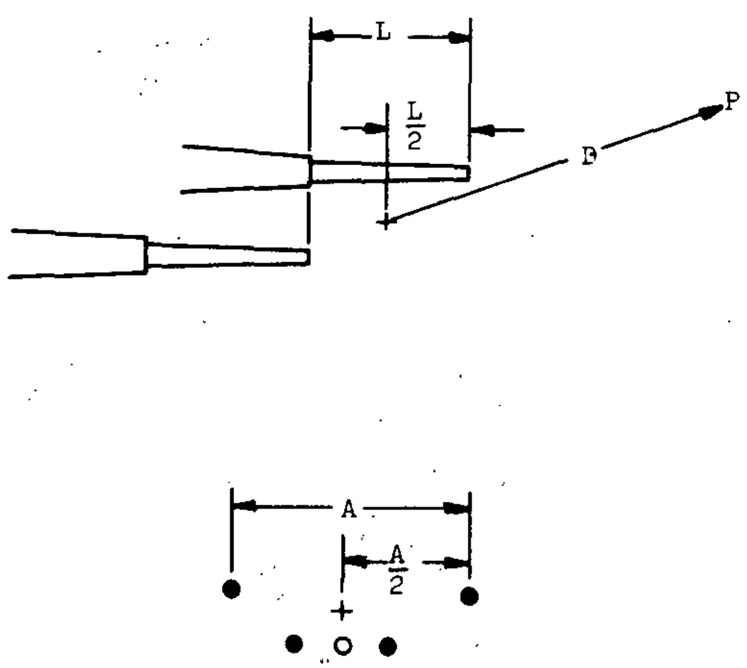

FIGURE 519.3-3. Multiple guns, closely grouped.

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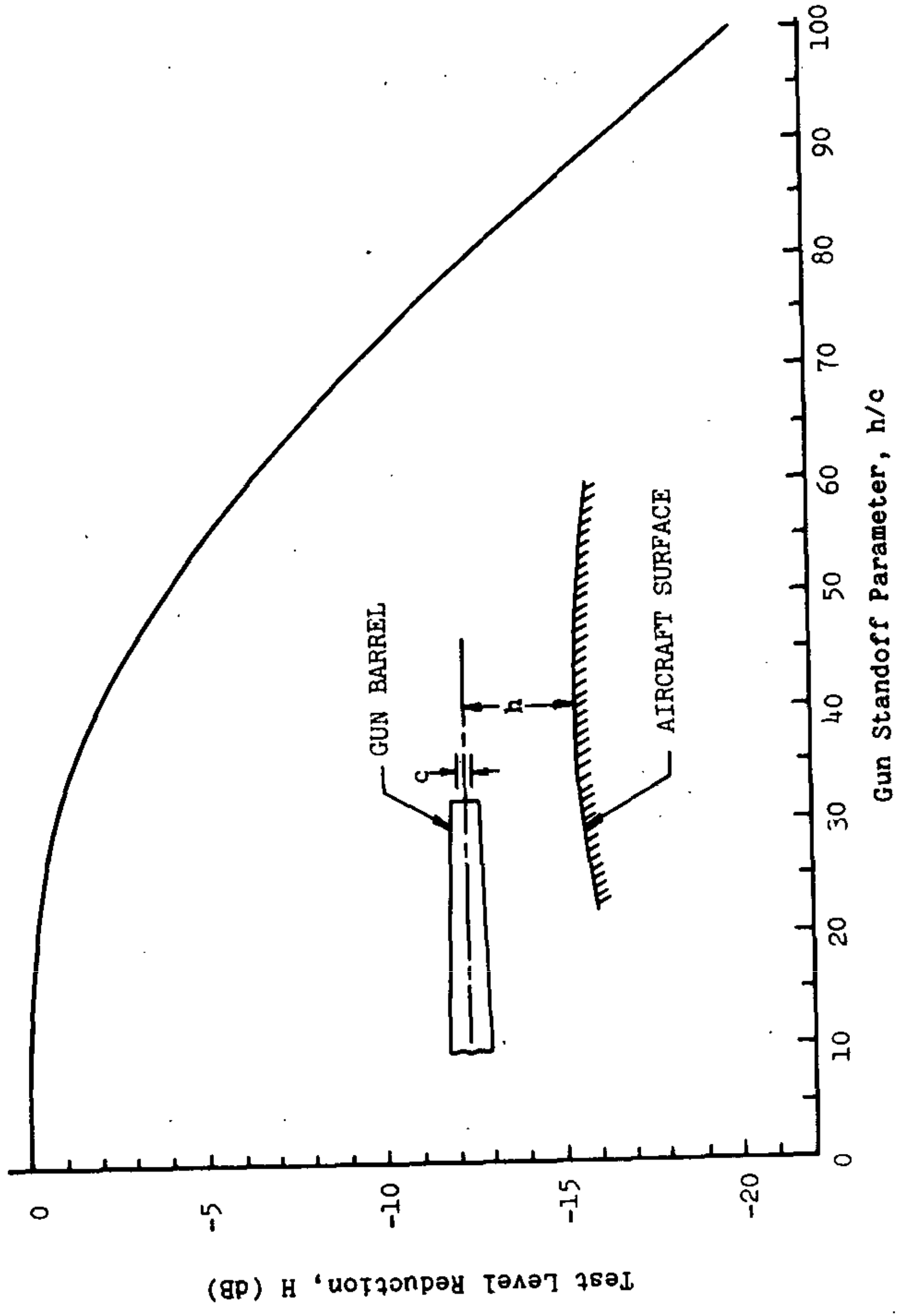

FIGURE 519.3-4. Test level reduction due to gun standoff parameter.

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TABLE 519.3-II. Typical gun configurations associated with aircraft classes.

Aircraft/POD	Gun (Quantity)	Location	Firing Rate (Rnds/Min)	Firing Rate (Rnds/Sec)	Rounds Capacity
A-4	MK12 (2)	Wing Roots	1000	16.6	100/Gun
A-7D	M61A1 (1)	Nose, Left Side	4000 & 6000	66.6 & 100	1020
A-10	GAU-8/A (1)	Nose	2100 & 4200	35 & 70	1175
A-37	GAU-2B/A (1)	Nose	6000	100	1500
F-4	M61A1 (1)	Nose	4000 & 6000	66.6 & 100	638
F-5E	M39 (2)	Nose	3000	50	300/Gun
F-5F	M39 (1)	Nose	3000	50	140
F-14	M61A1 (1)	Left side of Fuselage	4000 & 6000	66.6 & 100	676
F-15	M61A1 (1)	Right Wing Root	4000 & 6000	66.6 & 100	940
F-16	M61A1 (1)	Left Wing Root	6000	100	510
F-18	M61A1 (1)	Left Side of Cockpit	4000 & 6000	66.6 & 100	570
F-101	M39 (4)	Fuselage	1600 & 1800	26.6 & 30	200/Gun
F-104	M61A1 (1)	Fuselage	6000	100	750
F-105	M61A1 (1)	Fuselage	5000	83.3	2084
F-111	M61A1 (1)	Underside of Fuselage	5000	83.3	2084
GEPOD 30	GE430 (1) (GAU-8/A)	POD	2400	40	350
SUU-11/A	GAU-2B/A (1)	POD	3000 & 6000	50 & 100	1500
SUU-12/A	AN-M3 (1)	POD	1200	19	750
SUU-16/A	M61A1 (1)	POD	6000	100	1200
SUU-23/A	GAU-4/A (1)	POD	6000	100	1200

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TABLE 519.3-III. Gun specifications.

Gun	Gun Caliber (mm)	Gun Caliber (in)	Blast Energy, E (J)*
GAU-2B/A	7.62	.30	6,700
GAU-4/A	20	.79	74,600
GAU-8/A	30	1.18	307,500
AN-M3	12.7	.50	26,000
M3	20	.79	83,000
M24	20	.79	80,500
M39	20	.79	74,600
M61A1	20	.79	74,600
MK11	20	.79	86,500
MK12	20	.79	86,500

* joules (J) x 0.7376 = foot-pounds

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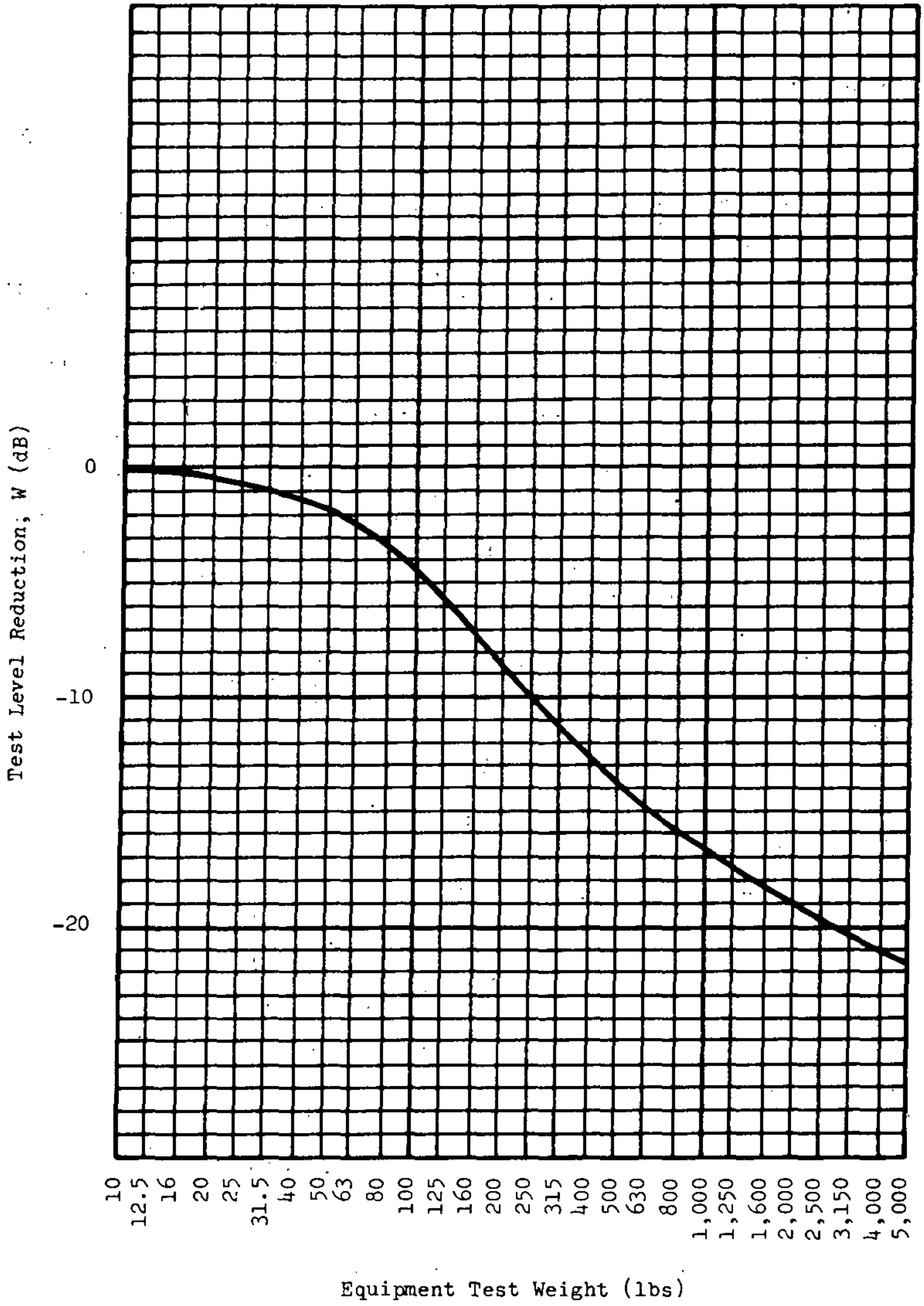

FIGURE 519.3-5. Test level reduction due to equipment mass loading.

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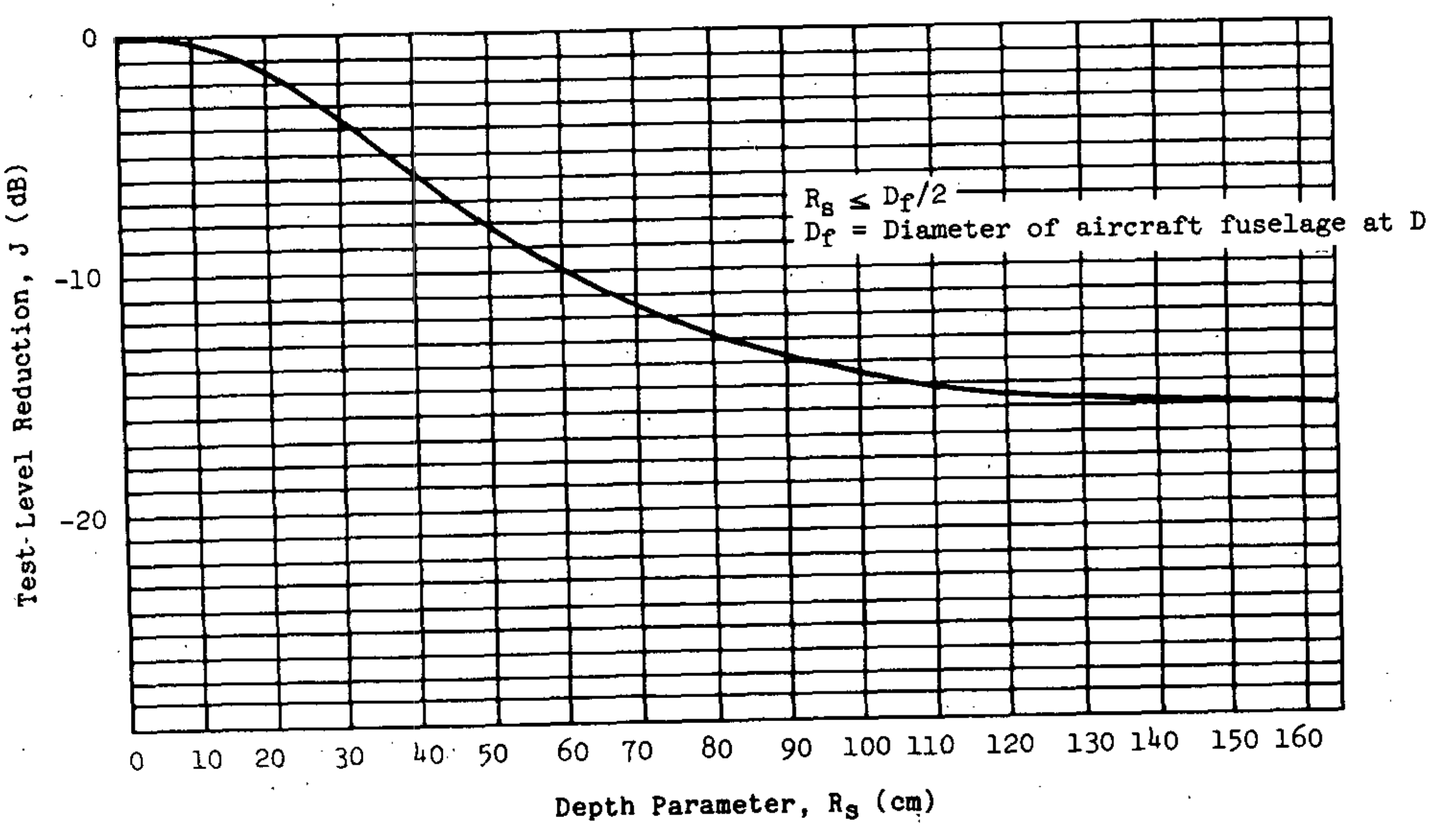

FIGURE 519.3-6. Test level reduction due to depth parameter.

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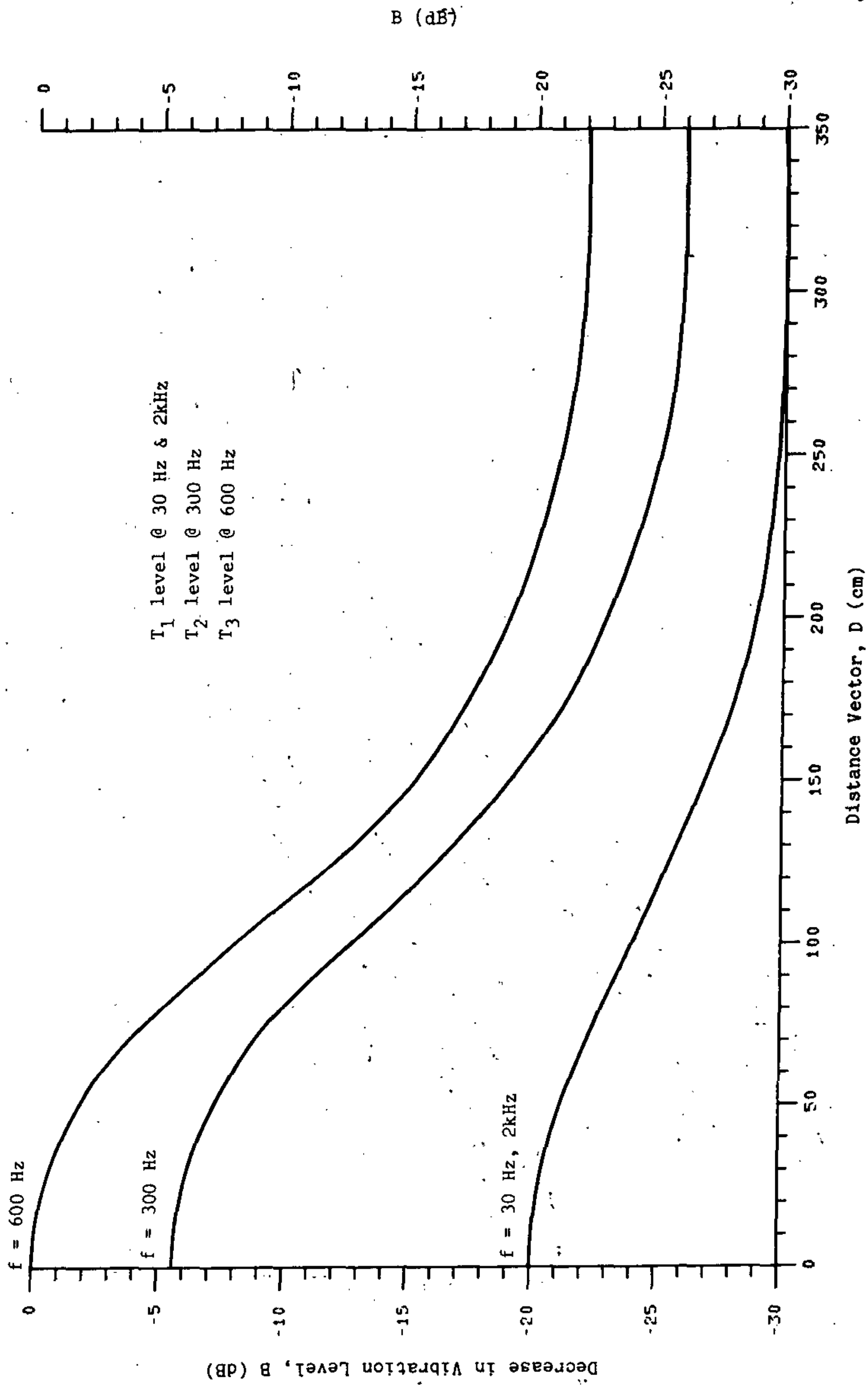

FIGURE 519.3-7. Decrease in vibration level with vector distance from gun muzzle.

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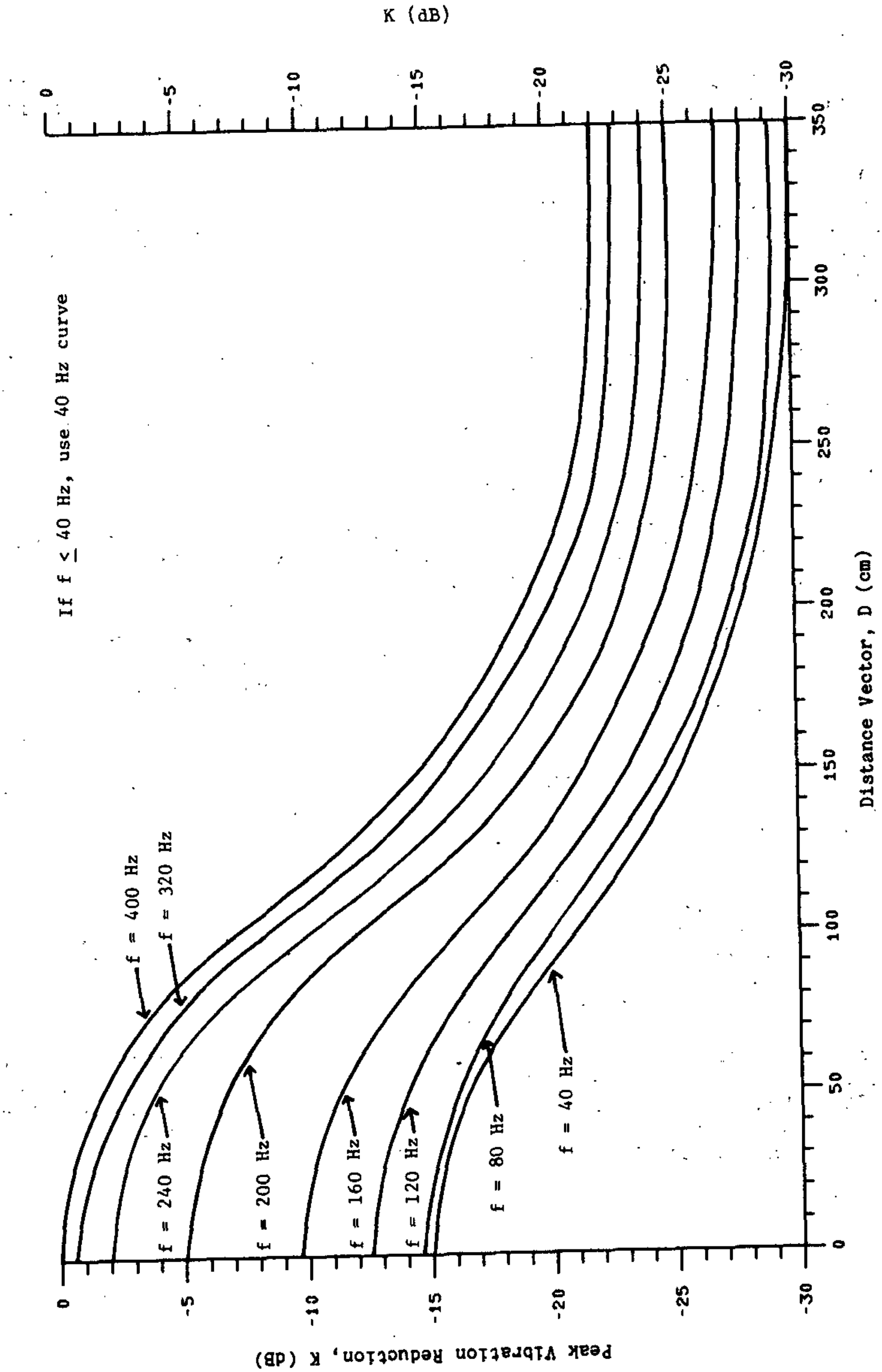

FIGURE 519.3-8. Gunfire peak vibration reduction with distance.

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I-4 SPECIAL CONSIDERATIONS

I-4.1 Test interruptions. In the event of the occurrence of an unprogrammed test interruption, the test shall be initiated from the point of interruption using the same specific test item.

I-4.2 Overtest. Any interruption in the test that results in a more extreme exposure of the test item than required by the equipment specification should be followed by a complete physical inspection of the test item and an operational check prior to continuation of test. An engineering judgment shall be made whether to continue testing with the overtested item, to obtain a new item, or to consider the test completed.

I-4.3 Failure analysis. All incidents where the test items do not meet the equipment operating requirements shall be analyzed to determine the cause and impact of such occurrences. Corrective actions shall be proposed or implemented to meet performance requirements.

I-4.4 Spectrum generation techniques

I-4.4.1 Pulse method. Gunfire vibration testing is done using pulses repeated at the gunfire rate. The generated spectra should have discrete acceleration magnitudes whose frequencies (f) correspond to the expression $f = f_1$; where f_1 is the basic gunfire rate and = 1, 2, 3, . . . K. The last integer (K) is that value for for which f_1 is nearest to the maximum test frequency of 2000 Hz. The pulse test spectrum shall be defined by an envelope that outlines the amplitudes determined from the prediction method given in paragraph I-3.2.1.2 or measured data.

I-4.4.2 Broadband random method. Gunfire vibration testing can be done using a properly shaped broadband random vibration spectrum. It is characterized by broadband random vibration with four vibration peaks that occur at the first three harmonics and the fundamental frequency of the firing rate for the onboard guns.

It has been experienced that the dynamic range required to produce and control this broadband random vibration is beyond the ability of most available vibration controllers. A way of working around this problem is to enter into the vibration controller the desired broadband random spectrum with its strong vibration peaks. At those frequencies which have the intense vibration peaks, sine waves can be electronically added to the input to the vibration shaker amplifier. The amplitude of these sine waves should be such that the vibration levels produced at those frequencies is slightly less than the desired spectrum level. The vibration controller can make the final adjustment to achieve the needed test level. This method allows the gunfire test to be done in a closed loop with commonly available laboratory test equipment.

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I-5 REFERENCES

a. Sevy, R.W., and E.E. Ruddell. Low and High Frequency Aircraft Gunfire Vibration Prediction and Laboratory Simulation. AFFDL-TR-74-123. December 1975. DTIC number AD-A023-619.

b. Sevy, R.W., and J. Clark. Aircraft Gunfire Vibration. AFFDL-TR-70-131. November 1970. DTIC number AD-881-879.

c. Smith, L.G. Vibration Qualification of Equipment Mounted in Turboprop Aircraft. Shock and Vibration Bulletin 51, Part 2. May 1981.

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METHOD 519.3

GUNFIRE VIBRATION, AIRCRAFT

SECTION II

II-1 APPARATUS. A random vibration source of sufficient capability to perform the required test.

II-1.1 Test setup. The test item shall be installed in a vibration fixture which simulates the actual application configuration. To the extent practical, the vibration test setup should incorporate actual mounting and isolation provisions from the carrying aircraft. Fixture designs which utilize the maximum amount of platform structure possible will allow the test item to respond to the laboratory excitation in a manner more closely related to the actual field environment.

II-1.2 Controls. The accuracy of the instrumentation for the gunfire vibration test shall be as specified in method 514.3 of MIL-STD-810D for random vibration. For the broadband random method, the test tolerances will be as follows: at f_1, f_2, f_3, and f_4 ±6 dB, and at frequencies above 400 Hz ±6 dB. If the controller used to shape the vibration spectra does not have sufficient capability to produce the required test spectrum shape, the produced spectrum shall envelope the required spectrum.

II-2 PREPARATION FOR TEST

Step 1. The test item shall be prepared in accordance with section 4, General Requirements.

Step 2. Mount accelerometers following the practices for accelerometer mounting, output averaging, and data analysis techniques outlined in method 514.3 of MIL-STD-810D.

II-3 PROCEDURES

Step 1. Mount test items on vibration shaker.

Step 2. Operate the test items in accordance with equipment specifications.

Step 3. Begin vibration exposure to the required test levels and spectra per paragraph I-3.3.

Step 4. Operate the test item during vibration exposure in accordance with equipment specifications. Duration of vibration exposure shall be per paragraph I-3.2.

Step 5. Operate the test items in accordance with equipment specifications.

Step 6. Rotate test item to an axis perpendicular to just-completed test.

Step 7. Repeat steps 1 through 5.

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Step 8. Rotate test item to the remaining axis that is mutually perpendicular to the two axes of test.

Step 9. Repeat steps 1 through 5.

Step 10. Document test per paragraph II-4.

II.4 INFORMATION TO BE RECORDED

a. Test procedure number.

b. Test levels, spectra, durations.

c. Previous testing done using the specific test item(s).

d. Location of accelerometers used to measure vibration.

e. Test results.

f. Failure criteria.

g. Analysis of each failure.

h. Proposed corrective actions.

i. Analysis bandwidth.

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METHOD 520.0

TEMPERATURE, HUMIDITY, VIBRATION, ALTITUDE

SECTION I

I-1 PURPOSE. The purpose of this test is to identify failures that temperature, humidity, vibration, and altitude can induce in aircraft electronic equipment either individually or in any combination, during ground and flight operations. It may be used for other similar purposes.

I-2 ENVIRONMENTAL EFFECTS. Studies have shown that thermal effects, vibration, moisture, humidity, and, in certain cases, altitude have the greatest effect on the life of aviation electronic equipment in the operational environment. These forcing functions collectively account for all but 12 percent of the environmentally induced failures in the field. (Of course other stresses such as sand and dust, salt fog, etc., are also significant and must be considered in a fully integrated test program.) Temperature, humidity, vibration, and altitude can interact to produce failures such as the following:

a. Shattering of glass, vials, and optical equipment.

b. Binding or slackening of moving parts.

c. Separation of constituents.

d. Changes in electronic components.

e. Electronic or mechanical failures due to rapid water or frost formation.

f. Cracking of solid pellets or grains in explosives.

g. Differential contraction or expansion of dissimilar materials.

h. Deformation or fracture of components.

i. Cracking of surface coatings.

j. Leakage of sealed compartments.

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I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS. This test method should be applied only at the end of the tailoring process described in section 4 of this standard.

a. Application. This method is primarily intended for electronic equipment mounted inside an aircraft. The procedures of this method can be used for engineering development, for support of flight testing, and for qualification.

b. Restrictions. This method does not apply to electronic equipment transported as cargo in an aircraft.

c. Sequence. Procedure I is intended to be used before final equipment designs are fixed.

d. Test variations. The test variables are temperature, humidity, vibration, altitude, cooling airflow, electrical stresses, rates of change, and test duration.

I-3.1 Choice of test procedures

I-3.1.1 Procedure I - Engineering development test. The engineering development test is used to find defects in a new design while it is still in the development stage. The test is failure-oriented, meaning that the tester should hope to uncover as many defects as possible. A combined environment test is good for this purpose, since it does not require the tester first to predict which stress states are most critical and then to tailor the test to emphasize those states. This test is generally accelerated by eliminating benign conditions or by using higher stresses than the item is likely to encounter in the field.

I-3.1.2 Procedure II - Flight or operation support test. This test is performed in preparation for, or during, flight or operational testing. Its purpose is to minimize delays in the flight testing program due to environmental factors. This test is not accelerated; the damage accumulation in the test is no faster than in operational or in-flight testing. Therefore, development hardware can be interchanged between laboratory and flight or operational testing. This means that when unusual problems develop in flight or operational testing, the equipment system can be brought into the laboratory to help identify any environmental contribution to the observed problem.

I-3.1.3 Procedure III - Qualification test. The qualification test is a formal test intended to demonstrate compliance with contract requirements. Generally, qualification testing is an accelerated test that emphasizes the most significant environ- mental stress conditions. The use of Procedure I of this test method for qualification is not recommended. The qualification test shall include the maximum amplitude of each stress and any unique combinations of stress types that were found to be important in the engineering development testing of the test item.

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I-3.2 Choice of related test conditions

I-3.2.1 Procedure I - Engineering development test

I-3.2.1.1 Use the analysis outlined in paragraph I-3.2.2, flight or operational support test, to determine realistic environmental stress levels, durations and rates of change. The more benign portions of the test profile can be eliminated for an engineering development test. Likewise the amplitude of environmental stresses can be increased to accelerate the occurrence of failures. Depending upon available facilities, environmental stresses may be tested in combination or singly.

I-3.2.1.2 It is recommended that a Procedure II test of short duration be done when the test item is fairly mature and its design stable. This would test the accuracy of the prejudgments made as to which environmental stresses are benign.

I-3.2.2 Procedure II - Flight operational support test. The combined environment test combines the environmental stresses of temperature, vibration, humidity, and, if required, altitude and cooling airflow in a manner occurring in actual deployment. Mission profiles are used as the basis for formulating the environmental stresses. The failure data obtained from this test will help determine the corrective actions to be performed on the item to prevent failure in the operational environment. Generally, the combined environment test simulates those environmental effects that occur for the majority of the deployment life.

I-3.2.2.1 Environmental conditions for test. This section describes the step-by-step approach in the measurement, prediction, and choice of forcing functions for a combined environment test. Figure 520.0-1 is a flow diagram for generating a test profile, as described throughout this section.

I-3.2.2.2 Test cycle formulation. A test cycle is defined as a unit of time where several mission profiles are simulated under different atmospheric conditions. A test cycle shall consist of at least three atmospheric segments of the sequence, composed as follows: cold and dry, warm and moist, and hot and dry. Within each atmospheric segment of the test cycle, several different mission profiles may be simulated. A mission profile is defined as a Mach number-altitude-time history that an aircraft can fly. For example, a fighter aircraft may predominantly fly three different missions: air superiority, ground support, and interdiction; therefore, this aircraft has three mission profiles. Each mission profile is divided into flight phases, such as takeoff, cruise, combat, low-level penetration, etc. (figure 520.0-2). During a test cycle, temperature, vibration, humidity, altitude, and cooling airflow shall be varied. Altitude simulation may be considered for a test item that is hermetically sealed, uses pressurized cooling paths to transfer heat, has components that contain a vacuum, has voltages of sufficient potential to arc in the presence of rarefied air, long range missions, or for other appropriate cases. Cooling airflow is required for all test items that use supplementary airflow in the aircraft.

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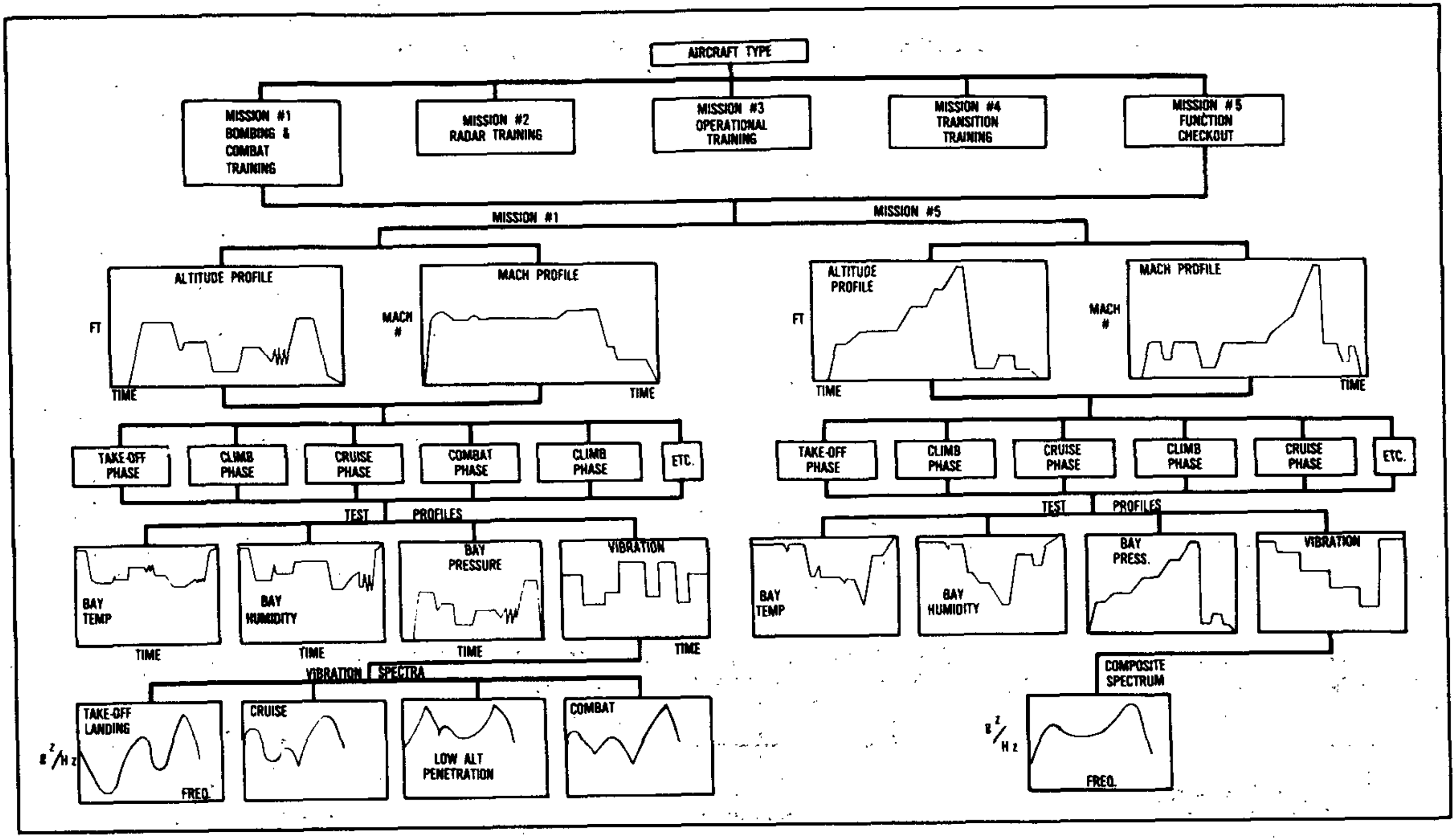

FIGURE 520.0-1. Test profile generation flow diagram.

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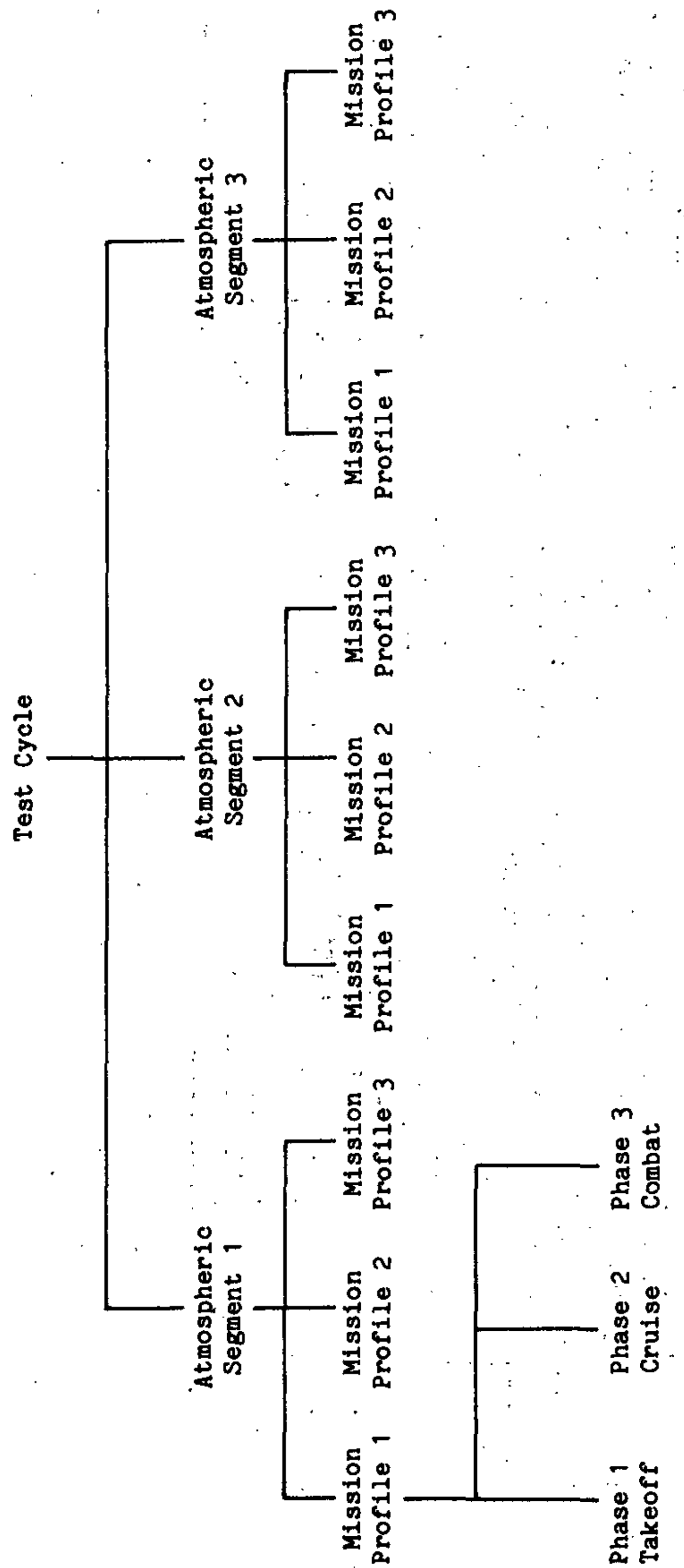

FIGURE 520.0-2. Bottom up view of a test cycle.

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I-3.2.2.3 Mission profile selection. The first step in constructing a combined environment test is to select the mission profiles to be used. An individual aircraft is designed to operate within a specified flight envelope (Mach number/altitude regime) and to fly specific mission profiles. Generally, an aircraft can fly many different missions, such as training, air superiority, interdiction, ground support, etc. In addition, aircraft are flown under specialized conditions that simulate a high-threat combat environment. These wartime skill exercises, such as Red Flag, are designed to train operational squadrons under realistic wartime conditions.

Usually, not all the missions flown by the aircraft need to be included in the test cycle. It is possible to identify two or three of the most highly utilized mission profiles that, as a group, reasonably approximate the aggregate effect of all the missions flown by the aircraft. This will adequately simulate the routine deployment life. In addition, the utilization of wartime skill exercises as part of the mission profile will stress the equipment under simulated combat conditions. To select the mission profiles to be used, the following approach is recommended.

a. Identify all aircraft missions and the utilization rate for each mission of the aircraft in which the equipment is to be installed. This information may be obtained from the operational commands or the flight manual used by aircraft crews. For aircraft under development, the design flight envelopes, design mission profiles, and the design utilization rate of each mission shall be used when actual flight data are not available.

b. Determine the missions that comprise a majority (if possible, 80 percent of total flown) of the total routine, daily mission utilization. To do this, examine the utilization rates for all mission profiles of the aircraft and rank them in order from highest to lowest. Then, take the mission profiles that compromise the majority utilization rate and use these as mission profiles for combined environment testing. Missions with similar functions and flight characteristics can be lumped together to minimize the number of profiles to be generated. Table 520.0-I shows an example distribution of missions.

c. In order to simulate the high-threat environment, missions flown under the wartime skill exercises shall be separately identified. These data may be obtained from the operational command or provided by the procuring agency.

Once these data have been obtained, two separate test cycles can be constructed according to paragraph I-3.2.2.2. One test cycle using the mission profiles in paragraph I-3.2.2.3b will be developed to simulate routine usage and another test cycle using the mission profiles in paragraph I-3.2.2.2c will be developed to simulate usage under combat or combat-training conditions.

Obtain the altitude and Mach number versus time values for each mission profile selected, as shown schematically in figure 520.0-3. These parameters of the mission profile are used to calculate the environmental stresses.

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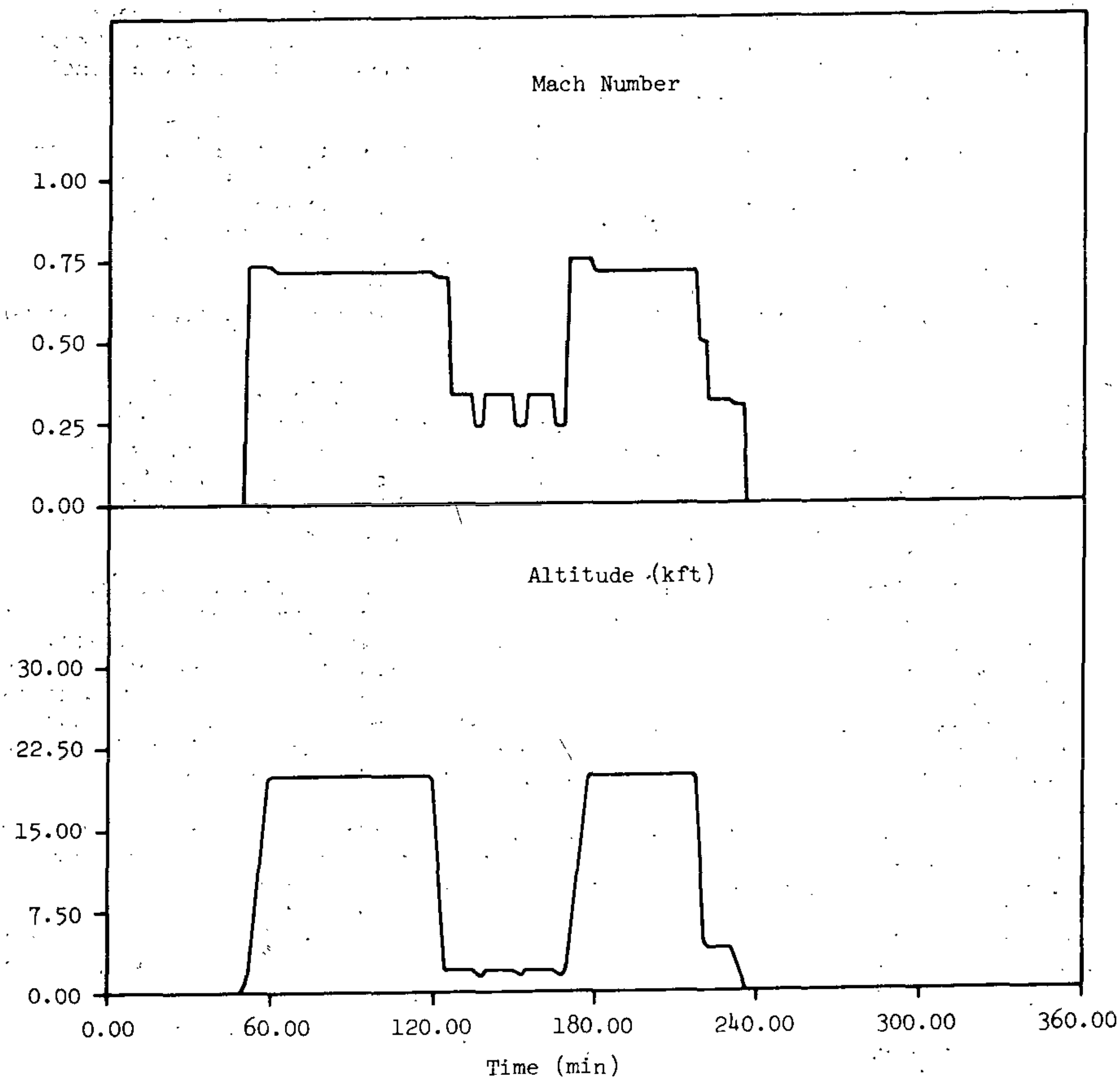

FIGURE 520.0-3. Schematic mission profile, altitude and mach number.

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I-3.2.2.4 Environmental stresses. The second step is to determine environmental stresses include vibration, temperature, supplemental cooling, humidity, altitude, and electrical stresses. Test levels for each stress are determined from mission profile information in the manner described in I-3.2.2.5 thru I-3.2.2.9. Other information, such as engine rpm or data on the aircraft's environmental control system (ECS) may also be needed.

TABLE 520.0-I. Example utilization rates of mission profiles.

Mission	Percent Utilization Rate
Ground Attack, Training	40
Ground Attack, Combat	20
Defensive Maneuvers	20
Search and Rescue	10
Functional Check	5
Training Cycle	5
	100%

Since the first three missions, as a group, total 80 percent of the utilization rate, then these three mission profiles would be selected for combined environment testing. If any of the other missions are determined to include extreme or sustained environmental conditions not encountered in the first three missions, then those missions containing these extreme or sustained conditions and adding the most diversity to the test cycle also should be selected. If the first mission selected is utilized twice as much as the other two missions, then Mission 1 should be run twice as much per cycle.

I-3.2.2.5 Vibration stress. Random vibration shall be applied to all equipment items designated for jet aircraft installation. Random vibration or sine superimposed on random vibration should be used for all equipments designated for propeller aircraft. Vibration of an appropriate level and spectrum shape shall be applied continuously during mission profile simulation in the test cycle. Unless measured data exist, it is recommended that the appropriate tables and figures of method 514 of MIL-STD-810 be used to determine vibration conditions except as modified in table 520.0-II.

Short duration vibration events and those that occur infrequently need not be included in the test cycle. These events include firing of onboard guns, general aircraft motion, and shock of hard landings. These events may be tested separately using the appropriate MIL-STD-810 test method.

The vibration stresses to be considered for the test cycle are those due to both attached and separated aerodynamic airflow along the vehicle's external surfaces, jet engine noise, or pressure pulses from propeller or helicopter blades on the aircraft structure. The vibration spectrum and level can be determined for each mission segment by careful use of measured data. Guidance written below shall be applied in those cases.

In many instances, measured flight data are not available for the specific aircraft, equipment location in the aircraft, or flight phases. In such cases, there are several analytical techniques for vibration spectrum and level prediction that can be used to determine vibration test conditions (ref. a).

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The scaling of vibration test conditions from data measured on another aircraft, at a different equipment location, or for a different flight condition has to be done with extreme care because of the numerous nonlinear relationships involved and the limited amount of data being utilized. For example, maneuver-induced vibration conditions generally cannot be predicted from cruise vibration data. A more prudent approach is to utilize the linear dynamic pressure models in method 514.

In all cases, measured flight vibration should be in acceleration power spectral density (PSD) format based on one-third octave analysis or 20 Hz or narrower constant-bandwidth analysis. Experience has shown that the use of a standardized vibration spectrum shape and the modified levels of method 514 of MIL-STD-810 yield as good results in terms of equipment deficiencies as the use of the highly shaped vibration spectra (ref. b).

Because of the nature of vibration control equipment, it is difficult to change vibration level and spectrum shape in a continuous, smooth manner. Therefore, the mission profile has to be divided into segments over which it will be assumed that the vibration level and spectrum shape is constant for test purposes.

I-3.2.2.6 Bay thermal stress. The thermal stresses that internally-carried avionics equipment experiences during a mission are dependent upon the ambient conditions, flight conditions, and the performance of the ECS. For the purposes of this test, the ambient outside air conditions shall be as shown in table 520.0-III for the hot, warm moist, and cold day environments. Hot and cold ambient environments of table 520.0-III are based on the 20 percent worldwide climatic extreme envelopes from MIL-STD-210B, tables XXII and XIII. The warm moist environment is based on the tropical environment shown in table V of MIL-STD-210A. These temperatures values are to be used as the ambient conditions for thermodynamic analyses for the development of the mission profile test conditions. The ground soak temperatures in each mission are not necessarily related to measured data. The values shown in table 520.0-III are extreme conditions that have been used in previous programs to accelerate time and reduce time between transitions from mission to another.

The specific environmental test conditions for any test item are dependent on the type of cooling for the compartment in which the equipment is to be located (air-conditioned or ram-air cooled). Avionics equipment systems that consist of more than one black box may require different environmental test conditions for each black box. (For example, when boxes are in different aircraft compartments.) For the common case of a two-black-box system where one box is cooled by supplemental air or fluid and the other box is ambiently cooled, both boxes can be tested in one chamber as long as appropriate vibration and altitude simulation for each box can be achieved. The thermal stimulation would be realistic since the ambient-cooled box would respond to the ambient temperature simulation while the box that required supplemental cooling would be primarily responsive to the supplemental cooling air or fluid.

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TABLE 520.0-II. Suggested random vibration test criteria for aircraft equipment.

JET AIRCRAFT

Use table 514.3-III with these modifications:

$K = 6.8 \times 10^{-9}$ for cockpit panel equipment and equipment attached to structure in compartments adjacent to external surfaces that are smooth, free from discontinuities.

$K = 3.5 \times 10^{-8}$ for equipment attached to structure in compartments adjacent to or immediately aft of external surfaces having discontinuities (cavities, chines, blade antennas, speed brakes, etc.) and equipment in wings, pylons, stabilizers, and fuselage aft of trailing edge wing root.

If Mach number is not in the range of 0.85 to 0.95 the calculated levels can be reduced by 5 dB.

For propeller aircraft and helicopters, use appropriate tables in method 514.3 of MIL-STD-810.

For those segments with the same vibration spectrum shape, the following analysis can be used to reduce the number of vibration test levels. The discussion is in terms of the suggested spectrum shapes for jet, rotary wing or propeller aircraft of method 514 of MIL-STD-810.

For test purposes a W_0 vibration level for each mission segment can be determined using the altitude and Mach number plots for each mission. (Note: For test purposes the larger of W_0 due to aerodynamic or W_0 due to jet engine noise is utilized at any point in time in the mission.) The maximum W_0 value that occurs in each mission shall be identified. All segments of the mission that have W_0 values within three dB of the maximum shall be considered, for test purposes, as having a constant W_0 value determined using the value of W_{OMAX} -3 dB. All segments of the mission that have dynamic pressure values between W_{OMAX} -3 dB and W_{OMAX} -6 dB shall be considered for test purposes as W_{OMAX} having a constant W_0 value determined using the value of W_{OMAX} -4.5 dB. This process of identifying three-dB bands of dynamic pressure values, over which W_0 is considered to be a constant and whose value is determined by using the dynamic pressure values of the band's midpoint, is continued until the calculated W_0 value is less than 0.001. For test purposes, segments of the mission with calculated values of W_0 less than 0.001 can be set equal to 0.001 unless the test facility can control below this test level.

The value of W_1 reflects the changes in aerodynamic flow field around the aircraft. A cruise W_1 value reflects normal angle of attack flight, while a maneuver W_1 value reflects highly separated flow conditions which induce intense low-frequency aircraft vibration.

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TABLE 520.0-III. Ambient outside air temperatures.

HOT ATMOSPHERE MODEL:

Altitude (km)	Altitude (kft)	World-Wide Air Operations (°C)	World-Wide Air Operations (°F)	Relative Humidity (%)	Dew Temperature (°C)	Dew Temperature (°F)
0	0.00	43	109	< 10	4	40
1	3.28	34	93	< 10	-2	29
2	6.56	27	81	< 10	-6	21
4	13.10	12	54	< 10	-17	2
6	19.70	0	32	<100	0	32
8	26.20	-11	12	<100	-11	12
10	32.80	-20	-4	<100 1/	-20	-4
12	39.40	-31	-24	<100	-31	-24
14	45.90	-40	-40	<100	-40	-40
16	52.50	-40	-40	<100	-40	-40
18	59.10	-40	-40	<100	-40	-40
20	65.60	-40	-40	<100	-40	-40
22	72.20	-39	-38	<100	-39	-38
24	78.70	-39	-38	<100	-39	-38
26	85.30	-38	-36	<100	-38	-36
28	91.90	-36	-33	<100	-36	-33
30	98.40	-33	-27	<100	-33	-27
Hot Ground Soak 2/		71	160	≤ 10	26	78

COLD ATMOSPHERE MODEL:

Altitude (km)	Altitude (kft)	World-Wide Air Operations (°C)	World-Wide Air Operations (°F)	Relative Humidity (%)	Dew Temperature (°C)	Dew Temperature (°F)
0	0.00	-51	-60	<100 1/	-51	-60
1	3.28	-49	-56	<100	-49	-56
2	6.56	-31	-24	<100	-31	-24
4	13.10	-40	-40	<100	-40	-40
6	19.70	-51	-60	<100	-51	-60
8	26.20	-61	-78	<100	-61	-78
10	32.80	-65	-85	<100	-65	-85
12	39.40	-67	-89	<100	-67	-89
14	45.90	-70	-94	<100	-70	-94
16	52.50	-82	-116	<100	-82	-116
18	59.10	-80	-114	<100	-80	-114
20	65.60	-79	-112	<100	-79	-112
22	72.20	-80	-114	<100	-80	-114
24	78.70	-80	-114	<100	-80	-114
26	85.30	-79	-112	<100	-79	-112
28	91.90	-77	-108	<100	-77	-108
30	98.40	-76	-105	<100	-76	-105
Cold Ground Soak 2/		-54	-65	<100	-54	-65

1/ Uncontrolled humidity

2/ Ground soak temperatures are not necessarily related to measured data but are extreme levels to reduce ground soak test time.

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TABLE 520.0-III. Ambient outside air temperatures - continued.

WARM MOIST ATMOSPHERE MODEL:

Altitude (km)	Altitude (kft)	World-Wide Air Operations (°C)	World-Wide Air Operations (°F)	Relative Humidity (%)	Dew Temperature (°C)	Dew Temperature (°F)
0	0.00	32.1	90	≥ 85	29	85
1	3.28	25.0	77	≥ 85	22	72
2	6.56	19.0	66	≥ 85	17	62
4	13.10	4.0	39	≥ 85	2	35
6	19.70	-11.0	13	≥ 85	-13	9
8	26.20	-23.0	-10	≥ 85	-25	-13
10	32.80	-38.0	-36	<100 1/	-38	-36
12	39.40	-52.0	-62	<100	-52	-62
14	45.90	-67.0	-88	<100	-67	-88
16	52.50	-78.0	-108	<100	-78	-108
18	59.10	-73.0	-100	<100	-73	-100
20	65.60	-65.0	-85	<100	-65	-85
22	72.20	-58.0	-72	<100	-58	-72
24	78.70	-53.0	-63	<100	-53	-63
26	85.30	-48.0	-54	<100	-48	-54
28	91.90	-43.0	-45	<100	-43	-45
30	98.40	-38.0	-36	<100	-38	-36
Ground Soak 2/		43.0	109	≥ 75	37	98

1/ Uncontrolled humidity (dry as possible)
2/ Ground soak temperatures are not necessarily related to measured data but are extreme levels to reduce ground soak time.

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For the purposes of this test, the following type of thermodynamic analysis is adequate. A more detailed analysis can be utilized, if desired.

The mission profile time history of altitude and Mach number from paragraph I-3.2.2.3 is analyzed to identify each break point at which the slope of either the altitude or Mach number plots change. A thermodynamic analysis is done at each break point using steady-state thermodynamic relationships. Between each break point, linear interpolation is done on each stress to construct a continuous profile for each environmental stress. At each such break point, the thermal stress conditions for a test shall be determined in accordance with paragraphs I-3.2.2.6.1 and I-3.2.2.6.2.

I-3.2.2.6.1 Ram-cooled compartments. This section is to be used to determine the bay temperature for an avionics system in a compartment that is ram-cooled. The thermal stress in a ram-air-cooled compartment can be determined from the following relationship.

$$T = T \; [1 + 0.18 \; M^2]$$

where T = ambient air temperature at altitude being flown in degrees Kelvin from table 520.0-III
M = Mach number being flown

I-3.2.2.6.2 Supplemental-air-cooled bay. This section is to determine the bay temperature for an avionics system located in a bay that receives its cooling from the aircraft's ECS. The mass flow rate and temperature level of supplemental air needs to be determined at each break point in the mission profile. The onboard ECS is modeled in terms of its primary components such as pressure regulators, heat exchangers, turbomachinery, water separator, etc. Also, calculate the mass flow rate being injected into the bay and the location of other systems in order to determine if the heat load from these systems should be considered (refs. c and d). The calculation of the bay temperature stress can be done using the following simplified thermodynamic analysis.

a. Assume that steady-state thermodynamic relationships are valid.

b. Assume constant but nominal or typical efficiency constants that can be achieved from good design practices for turbomachinery and heat exchangers.

c. Neglect secondary effects in components of ECS (i.e., pressure losses in heat exchanger, temperature losses in ducts).

I-3.2.2.6.3 Equipment supplemental thermal stress. This section is used to determine the thermal and mass flow for an avionics system that requires forced or supplemental cooling from the aircraft. Paragraph I-3.2.2.6.2 recommends an approach to determine the bay thermal stress for an avionics system located in a supplementally cooled compartment. This same approach is recommended here with one addition: continue the thermodynamic analysis to determine the temperature and mass flow being injected directly into the avionics system. The same sources used to obtain the information for paragraph I-3.2.2.6.2 are also applicable here.

I-3.2.2.7 Humidity stress. The humidity stress that an internally carried avionics system experiences is dependent upon the ambient humidity conditions and the performance of the water separator of the environmental control. (Some

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aircraft do not cool equipment with ECS air, thus the equipment sees only ambient humidity conditions.) For the purposes of this test, whenever the cold day environment is being simulated, humidity will be uncontrolled, but less than or equal to the dew temperature shown in table 520.0-III. For the hot environment, dew temperatures will be less than or equal to values shown in table 520.0-III. In the case of the warm moist day, dew temperatures will be greater than or equal to the values found in table 520.0-III up to 10km. Above 10 km, the dew temperature shall be less than or equal to the values found in table 520.0-III. If the platform has an ECS, the design specifications for the water separator shall be used to define humidity conditions for the warm moist day. When the efficiency of the ECS is unknown, the approximation technique put forth above should be used.

Note: The formation of free water on the test items during combined environment testing can be a normal condition. It will occur whenever the temperature of the test item is cooler than the dewpoint temperature of the air being delivered by the ECS or from ram airflow. This is normal and a realistic condition.

I-3.2.2.8 Altitude stress. Altitude simulation should be employed when there is reason to believe that system performance may be affected by variations in air pressure. Examples of such situations are: hermetically sealed units that use pressurized cooling parts to maintain sufficient heat transfer, vacuum components where the seal is maintained by air pressure, and units where change in air pressure may cause arcing or change of component values. When altitude effect is to be tested, the altitude stress, or reduced atmospheric pressure variations, shall be applied according to the mission profiles selected for test. The altitude, or reduced pressure, is initially applied at the simulated aircraft takeoff and continues at the pressure changes corresponding to the various flight phases from climb-out to landing. The rate of change of pressure should reflect the climb or descent rate of the aircraft while performing the various flight mission phases. The maximum pressure (minimum altitude) used for the test shall be that of ground elevation at the test site.

I-3.2.2.9 Electrical stress. Electrical stresses are deviations of the equipment's electric supply parameters at the equipment terminals from their nominal values. The test procedure must assure that all electrical stresses occurring during normal operation in service (mission profile) are simulated to the required extent.

It is not the purpose of this test method to simulate extremes specified for special situations or to take the place of special electrical stress tests. Special conditions, like emergency operation of certain aircraft equipment within the electrical/electronic system, shall be simulated only on request.

Depending upon the requirements and the availability of data, the simulation may cover the range from the exact reproduction of the specific electric supply conditions within a special aircraft for a specific mission profile, down to a standardized simplified profile for generalized applications. The following conditions and effects must be taken into consideration to determine whether they affect the operation and reliability of the equipment to be tested.

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a. AC system normal operation stresses

b. Normal ON/OFF cycling of equipment operation

c. DC system normal operation stresses

d. Electrical stresses induced by mission-related transients within the electrical system.

I-3.2.2.9.1 AC system normal operation stresses. Voltage variations are quasi-steady changes in voltage from test cycle to test cycle. Input voltages shall be maintained at 110 percent of nominal for the first test cycle, at the nominal for the second test cycle, and at 90 percent for the third test cycle. This cycling procedure is to be repeated continuously throughout the test. However, if a failure is suspected, this sequence may be interrupted for repetition of input voltage conditions.

I-3.2.2.9.2 Normal ON/OFF cycling of equipment operation. The equipment shall be turned on and off, in accordance with equipment operating procedures outlined in appropriate technical manuals, to simulate normal use.

I-3.2.2.9.3 DC system normal operation stresses.

a. Voltage variation. See I-3.2.2.9.1

b. Ripple voltage. Ripple is the cyclic variation about the mean level of the DC voltage during steady-state DC electric system operation. Values shall be taken from actual flight data or from the applicable system specification if flight data are not available. Ripple voltage shall be applied continuously during the mission simulation portion of each test cycle.

I-3-2.2.9.4 Electrical stresses induced by mission-related transients within the electrical system. Unless the equipment has its own power supply which is not affected by the transients mentioned, or the equipment is not influenced by these electrical stresses at all, these stresses must be reproduced during test. The reproduction has to cover all transients -- like power surges, voltage peaks, electrical current changes, phase unbalance, etc. -- which may influence the equipment on test and are induced by the mission-related operation of the aircraft's electrical/electronic equipment taken as a whole (switching equipment on or off, operating with changing power output, short-time system overload, differing generator rpm, operation of regulating devices, etc.).

The test should reproduce measured transients exactly. If this is not possible, tolerances should be calculated individually for each transient type. Tolerances should be narrow for stresses the equipment is more sensitive to, and vice versa. The basis for calculations shall be the requirements document -- stress values that the equipment must be able to withstand during normal operation -- provided the actual measured stresses of the electrical system do not exceed these limits.

In the absence of any other means of simulating power line transients, the equipment shall be cycled on while performance measurements are made and then backed off for five minutes prior to the normal turn-on at the end of each ground park phase.

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I-3.2.3 Procedure III - Qualification test. Qualification can be accomplished either with a single test which combines all the appropriate environmental stresses or with a series of separate tests. It is not recommended to run all environmental stresses in separate tests. When the use of separate environmental tests is selected, the following single and combined environment stress tests are recommended: vibration; a combined temperature, altitude, and humidity test; and a combined supplemental cooling airflow with humidity, temperature, and mass flow rate as test parameters. The following guidance is recommended for each separate test.

I-3.2.3.1 Vibration stress. Use the test conditions and durations recommended in method 514 of MIL-STD-810 for qualification testing.

I-3.2.3.2 Temperature-altitude-humidity test. This test is for the conditions inside an equipment bay or cockpit. Identify the maximum and minimum temperatures to be experienced in anticipated deployment by the item to be tested. Identify the maximum and minimum temperatures under which the test item is expected to operate. These temperatures can be obtained from the analysis outlined in paragraph I-3.2.2 of procedure II. If such an analysis was not accomplished, tables 520.0-V and 520.0-VI and figure 520.0-4 can be used.

The values in tables 520.0-V and 520.0-VI are based on measured data and are representative of extreme temperature conditions (air temperature, not equipment temperature). Therefore, there is reasonable confidence that these test levels will sufficiently stress the test item.

The maximum altitude to be experienced by the item to be tested should come from the analysis outlined in paragraph I-3.2.2. Often the altitude (air pressure) inside a cockpit or equipment bay is different from that outside the aircraft because of cabin pressurization. If an analysis has not been done, use maximum flight altitude or, if unknown, use 16 km (52,500 ft.).

The recommended durations of stress exposure in table 520.0-VI are based upon anticipated extreme-case exposure durations. It is not recommended to force the test item to reach thermal stability. As would happen in actual usage, the mass of the test item will determine how close the test item will get to the imposed temperature.

The humidity stress is based upon reasonable levels that can be experienced in actual usage. Unless analysis such as outlined in paragraph I-3.2.2 of procedure II shows that the equipment bay or cockpit environment is significantly more or less humid, the level shown in table 520.0-V is recommended.

I-3.2.3.3 Supplemental-cooling-air humidity, mass flow rate, and temperature test. This test is for supplemental cooling airflow that flows directly through an equipment system. The temperature, humidity and mass flow rate can be determined from an analysis as outlined in paragraph I-3.2.2 of procedure II. If such an analysis is not available, the levels in table 520.0-V and combined as shown in table 520.0-VI and figure 520.0-5 are recommended.

I-3.2.3.4 Electrical stress. Unless otherwise defined, use the electrical stress conditions outlined in paragraphs I-3.2.2.9.1 and I-3.2.2.9.2 as applicable.

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TABLE 520.0-IV. Combined environment test cycle structure.

Test Phase Definition	Temp (°C)	Relative Humidity	Vibr	Supp Cooling Air (°C)	Altitude	Test Item--Operating/Nonop	Duration (min)
Ground Cold Day	-54	<100%	Off	-54	Ambient	Nonoperating	60
Mission 1	*	*	On*	*	*	*	*
Ground Cold Day	-54	<100%	Off	-54	Ambient	Nonoperating	60
Mission 2	*	*	*	*	*	*	*
Ground Cold Day	-54	<100%	Off	-54	Ambient	Nonoperating	60
Mission 3	*	*	*	*	*	*	*
**							
Transition to Hot							>20
Ground Hot Day	71	< 10%	Off	71	Ambient	Nonoperating	60
Mission 1	*	*	*	*	*	*	*
Ground Hot Day	71	< 10%	Off	71	Ambient	Nonoperating	60
Mission 2	*	*	*	*	*	*	*
Ground Hot Day	71	< 10%	Off	71	Ambient	Nonoperating	60
Mission 3	*	*	*	*	*	*	*
**							
Transition to Moist							>20
Ground Warm Moist Day	43	75%	Off	43	Ambient	Nonoperating	60
Mission 1	*	*	*	*	*	*	*
Ground Warm Moist Day	43	75%	Off	43	Ambient	Nonoperating	60
Mission 2	*	*	*	*	*	*	*
Ground Warm Moist Day	43	75%	Off	43	Ambient	Nonoperating	60
Mission 3	*	*	*	*	*	*	*
**							
Transition to Cold							>20

* Determine from aircraft mission profile.
** The number of different missions in each segment is determined in accordance with I-3.2.2.2.
*** These values are based upon historical experience, reference f.

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TABLE 520.0-V. Suggested extreme qualification test levels when no other data exists.

EQUIPMENT BAYS	MIN TEMP (°C)	MIN OPER TEMP (°C)	MAX TEMP (°C)	MAX OPER TEMP (°C)	MAX HUMIDITY (RH)	MASS FLOW RATE (KG/MIN)
Supplementally Cooled	-54	-40	60	54	75% at 43°C	--
Ram Air Cooled	-54	-40	60	54		--
Unconditioned	-54	-40	60	54		--
CREW STATION						
Open Areas	-54	-40	60	25	75% at 43°C	--
Behind Instrument Panels	-54	-40	100	75		--
Supplemental Cooling Airflow to Equipment	-51	-51	54	54	75% at 43°C	+0% of design -80% point

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TABLE 520.0-VI. Qualification test cycle.

TIME	TEMP	ALTITUDE	HUMIDITY	SUPPLEMENTAL COOLING AIR			EQUIPMENT ON/OFF
				TEMP	MASS FLOW RATE	HUMIDITY	
0	T_{min}			T_{min}	M_{max}		Off
60	T_{min}			T_{min}	M_{max}		On
*							
60	$T_{oper_{min}}$			T_{min}	M_{min}		On
90	$T_{oper_{min}}$			T_{min}	M_{min}		On
*							
90	$T_{hum_{soak}}$		max RH	$T_{hum_{soak}}$	M_{max}	max RH	On
150	$T_{hum_{soak}}$		max RH	$T_{hum_{soak}}$	M_{max}	max RH	On
*							
150	T_{max}	max		T_{max}	M_{max}		Off
210	T_{max}	max		T_{max}	M_{max}		Off
*							
210	$T_{oper_{max}}$			T_{min}	M_{min}		On
240	$T_{oper_{max}}$			T_{min}	M_{min}		On
*							
Return to time zero							

* The amount of time to ramp temperature is dependent upon the test facility change rate and is not counted in the four hours of the test cycle.

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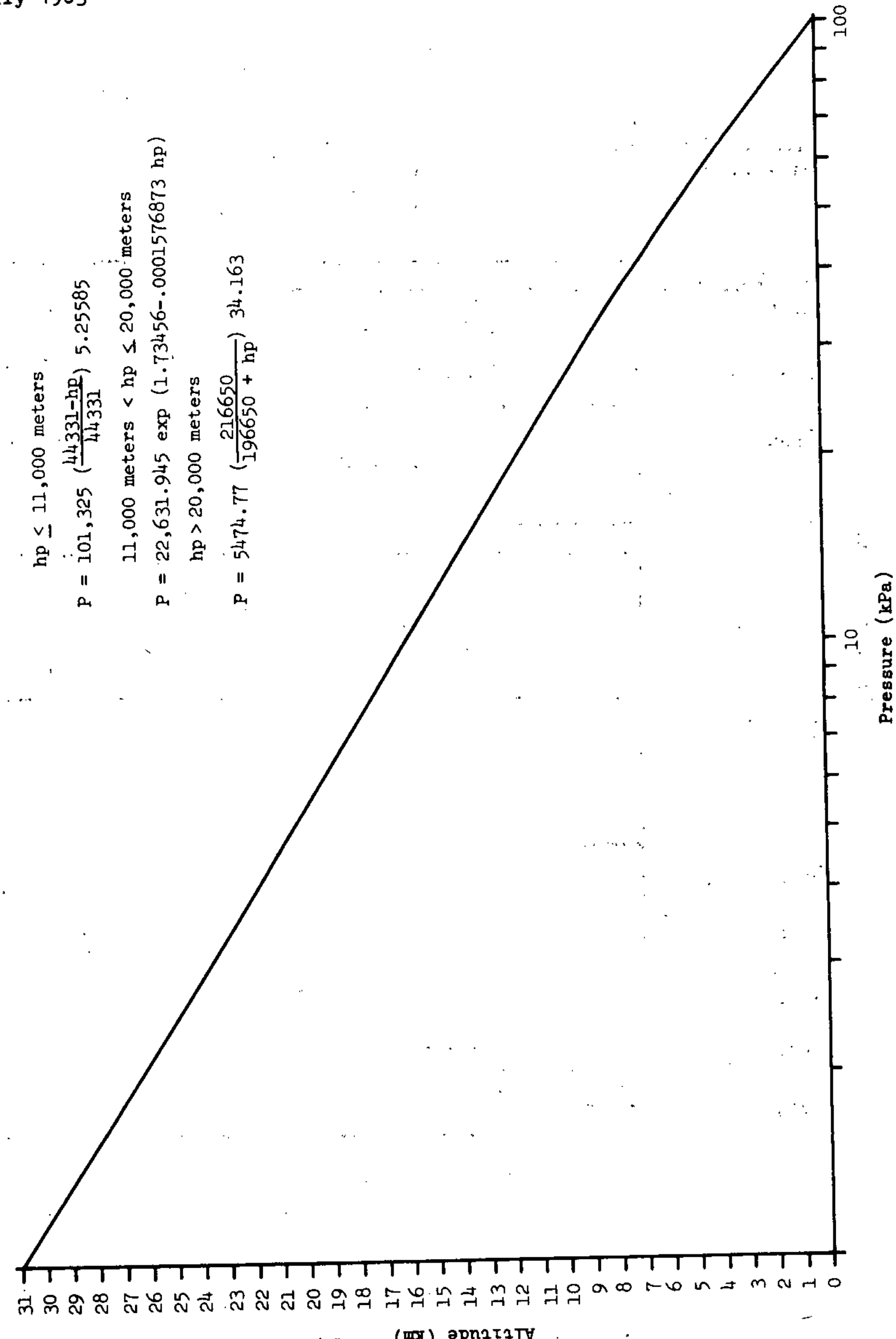

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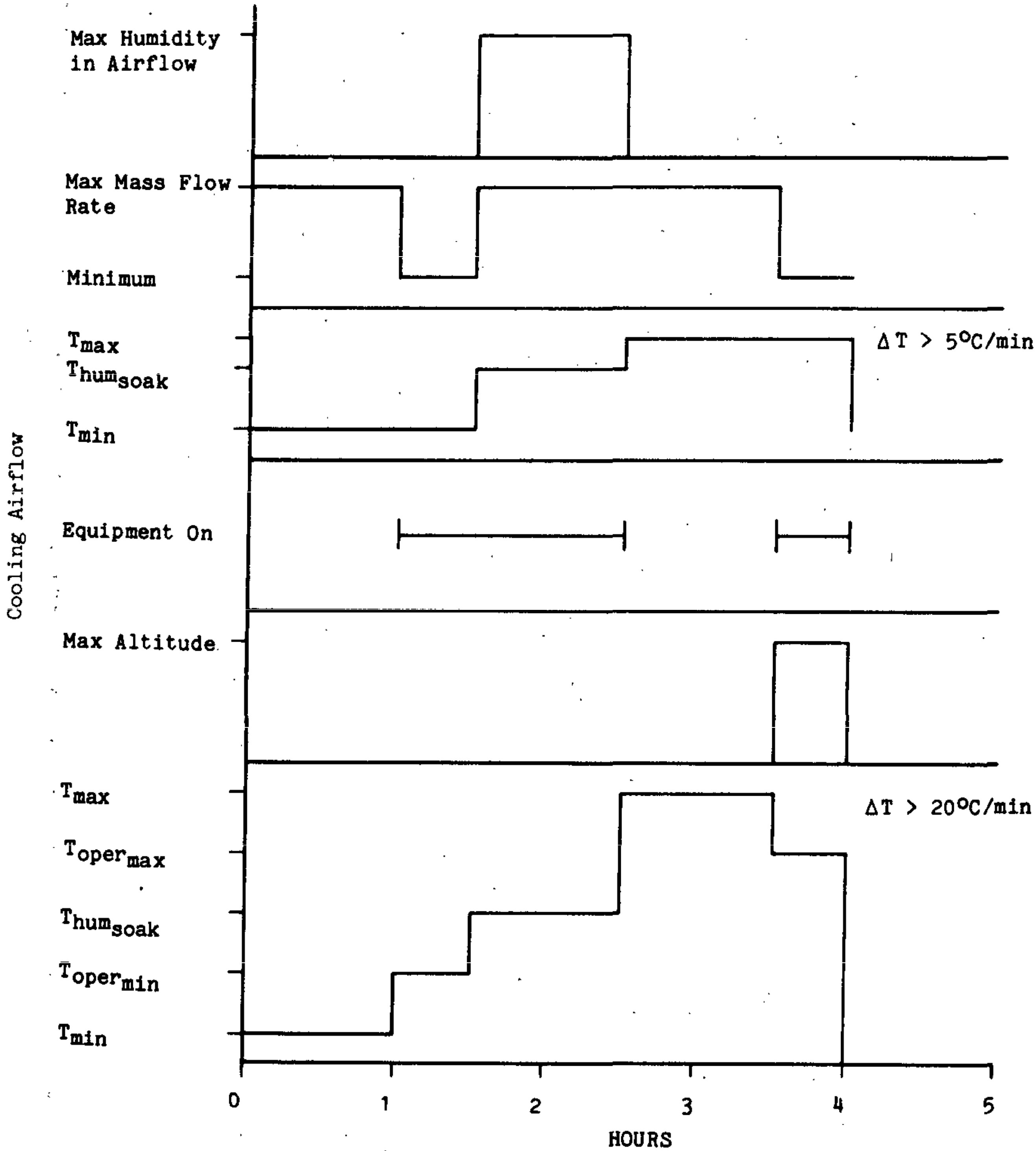

FIGURE 520.0-5. Qualification test cycle example.

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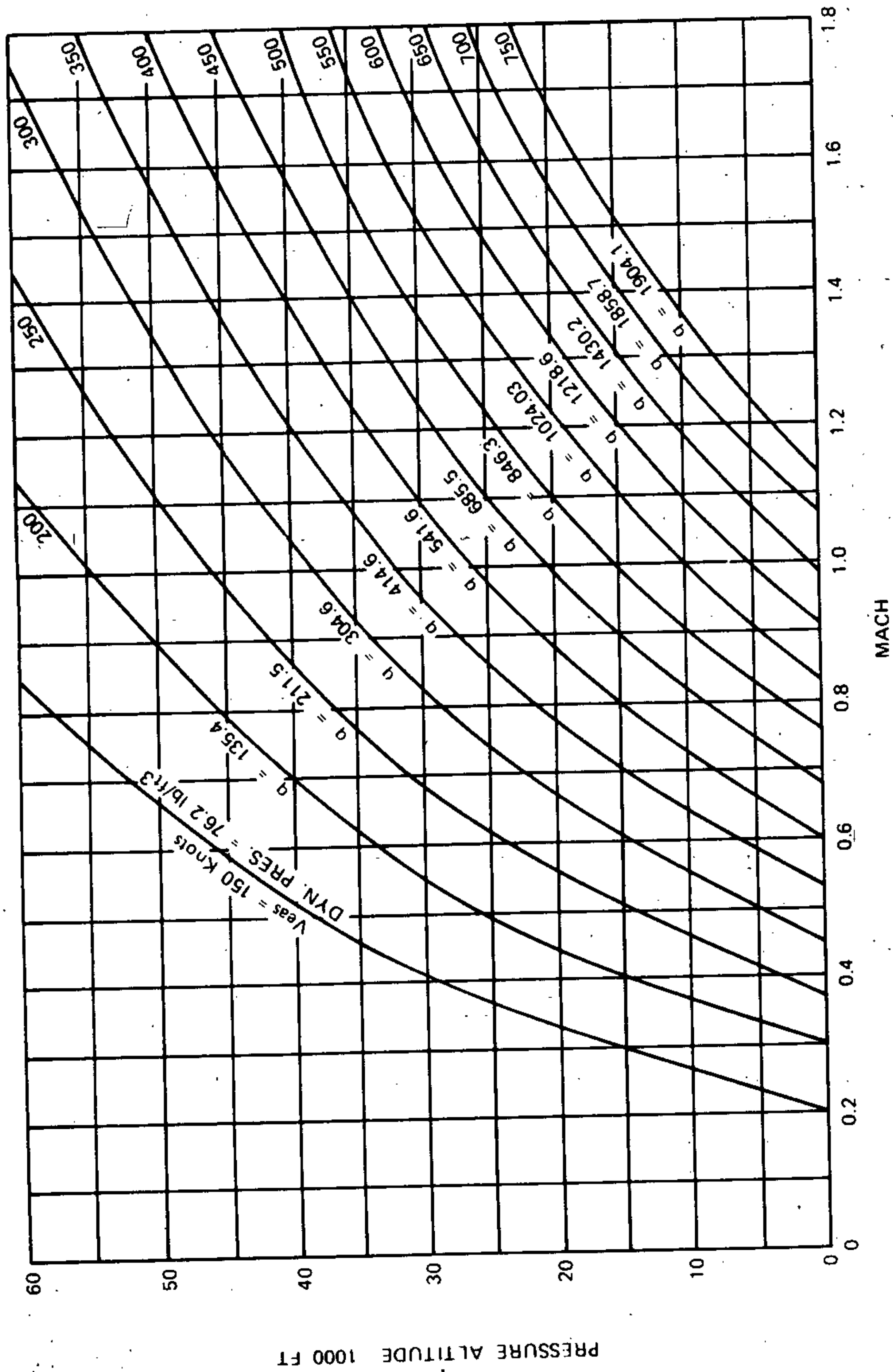

FIGURE 520.0-6. Dynamic pressure (q) as function of mach number and altitude.

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I-3.2.3.5 Test item operation. The item shall be operated throughout each test except when being exposed to maximum and minimum temperatures that occur in equipment bays or the cockpit. If separate tests are conducted, the test item shall be turned on and off using the same schedule as if the test environments were all combined.

I-3.3 Test duration

a. Procedure I. The test should be conducted so that the test item experiences 300 to 600 mission hours of stress exposure. The rate of occurrence of defects in conjunction with schedule and cost generally determines the duration of an engineering development test. If few or no failures are occurring, little new information is being generated as to how or where to improve the test item and the test should be terminated.

b. Procedure II. Test duration shall be sufficient either (1) to give the tester confidence that environmental factors will not cause significant problems during the flight test program or (2) to resolve a problem that arises during flight or operational testing.

c. Procedure III. Procedure III shall be conducted for ten test cycles per figure 520.0-5, or its equivalent (40 environmental stress hours with 30 hours of equipment turned on). This is somewhat arbitrary, but reflects the duration of previous temperature-altitude-humidity tests.

I-4 SPECIAL CONSIDERATIONS

I-4.1 Test interruption. In the event of an unplanned test stoppage due to an event such as a facility failure, the following is recommended. If the item has not failed and there is no apparent damage to the test item, the test continues. If the test item was damaged when the unplanned event occurred, testing should not be resumed until it can be determined whether the stress combinations during the unplanned event are likely to occur in the deployment environment. Testing should be resumed at the point of interruption and failed test article(s) removed before beginning the next phase, unless the nature of the failure precludes any useful equipment operation.

I-4.2 Failure criteria. All incidents where the test item does not meet equipment operating requirements shall be analyzed to determine the cause and impact of such occurrences. Corrective actions shall be proposed or implemented as required to meet equipment performance requirements.

I-4.3 Chamber/sensor tolerances. The accuracy required in General Requirements of MIL-STD-810 applies for each stress measurement system. The ability of a given test chamber to control to the specified stress conditions is a function of the chamber's design and appropriate placement of transducers. Thus, in evaluating the test tolerances for any given combined environment test, the test plan should clearly identify the placement of the stress measurement transducer relative to the test item.

I-4.4 Test profile tolerances. The tolerances for each stress in each phase of procedure II can be derived from design specifications. For example, the design specification may call for a phase of cruise between 20,000 and 30,000 feet. For the test mission, this can be translated into an altitude of 25,000 feet with a tolerance of ±5,000 feet.

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I-5 REFERENCES

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METHOD 520.0

TEMPERATURE, HUMIDITY, VIBRATION, ALTITUDE

SECTION II

II-1 APPARATUS. The combined environment test chamber(s) shall be capable of producing the required combinations of temperature, altitude, humidity, random vibration, and cooling air mass flow. All instrumentation shall be able to meet the accuracy specified in section 4 of General Requirements.

II-2 PREPARATION FOR TEST. Select which test procedure shall be implemented. Identify if the test shall be a combined environment test or a series of single and appropriate environmental combinations tests. Select which of the following steps are appropriate for the environmental stresses being included in the test of interest.

Step 1. For vibration testing in Procedure I or II, the individual equipment test item(s) should be subjected to random vibration in either the aircraft vertical or lateral axis, whichever seems to offer the greatest potential for defect disclosure. If neither axis seems to offer a distinct benefit, the test axis may be selected to suit facility convenience. When practical, diagonal vector vibration (vibration applied diagonally at a test item corner through its center of mass, rather than along a single orthogonal axis) may be applied to provide multi-axis excitation using a single test setup. For Procedure III, conduct vibration test in accordance with method 514.3.

Step 2. For tests that do not include vibration, mount test items in their normal orientation with the ground plane when the carrying aircraft is parked on the ground.

Step 3. For Procedures I and II, mount at least two vibration pickups to measure the vibration environment for each test item. Follow practices for the accelerometer mounting, output averaging, and data analyis techniques outlined in method 514 of this standard.

Step 4. For test items that require supplemental cooling air, measure mass flow rate, humidity, and temperature. Mount instrumentation so that these values are known as close as possible to where the air enters the test item(s).

Step 5. Bay air conditions around the equipment shall be measured as specified in General Requirements, paragraph 4.6.2. The air temperature around the equipment under test shall be used to control this environmental stress.

Step 6. Mount humidity sensor to measure bay air humidity. A single-point measurement is adequate as long as the measurement point is not shielded from the bulk conditions around the test item.

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II-3 PROCEDURES

II-3.1 Procedure I - Engineering development

Step 1. Mount test item in accordance with paragraph II-2.

Step 2. Confirm that the test item is operational.

Step 3. Start test and test to conditions specified in test plan developed as outlined in paragraph I-3.2.1.

Step 4. Conduct test and monitor performance of test item against failure criteria.

Step 5. Continue test until malfunction occurs (see I-4.2).

Step 6. Analyze failures and take corrective actions.

Step 7. Document malfunctions per paragraph II-4 and I-4.3.

Step 8. Continue test until a suitable number of hours of environmental exposure have been achieved (see I-3.3a).

Step 9. Repeat steps 1 through 8 for each single stress or combination of stresses until all the stresses have been combined.

Step 10. Document entire test per paragraph II-4.

II-3.2 Procedure II - Flight/operational support test

Step 1. Mount test item in accordance with paragraph II-2.

Step 2. Confirm that test item is operational.

Step 3. Start test cycle with a cold-day park simulation and continue the sequence as shown in table 520.0-IV.

Step 4. Monitor test item performance throughout environmental exposure.

Step 5. Continue test until a test item malfunction occurs.

Step 6. Analyze and document malfunction per paragraph II-4 and I-4.3.

Step 7. Continue test until a suitable number of hours of environmental exposure have occurred on at least one specimen (see paragraph I-3.3b).

Step 8. Document entire test per paragraph II-4.

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II-3.3 Procedure III - Qualification test

Step 1. Mount the test item and instrumentation per paragraph II-2.

Step 2. Start the test cycle developed from paragraph I-4.2.2.

Step 3. Function the test item while being exposed to environmental stresses in Step 4.

Step 4. Expose the test item to the number of test cycles decided on per paragraph I-3.3c.

Step 5. Check the test item for functioning in accordance with General Requirements paragraph 4.5.

Step 6. Repeat steps 1 through 5 for each of the single or combined environment tests specified in paragraph I-3.3.2 unless they were conducted as one test that combines all the environments.

Step 7. Document test as given in paragraph II-4.

II-4 INFORMATION TO BE RECORDED

a. Pretest, during test, and post-test performance data according to General Requirements, and the individual test specification and/or test plan.

b. Test cycle, including environmental conditions applied.

c. Test time history of each failure occurrence.

d. Nature of failure, including environmental effects.

e. DC ripple voltage, as applied during the mission simulation portion of each test cycle.

f. AC voltage variation, as conducted during the mission-simulation portion of each test cycle.

g. Type, location, and orientation of stress-measuring sensors.

h. Description and calibration status of data recording and analysis equipment.

i. Voltage modulation, as applied during the mission-simulation portion of each test cycle.

j. Frequency modulation, as applied during the mission-simulation portion of each test cycle.

k. Electrical stress induced by mission-related transients within the electrical system.

l. Prior test history of test item.

m. Corrective action proposed.

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METHOD 521.0
ICING/FREEZING RAIN

SECTION I

I-1 PURPOSE. The icing/freezing rain test is conducted to evaluate the effect of icing produced by a freezing rain, mist, or sea spray on the operational capability of materiel. This method also provides tests for evaluating the effectiveness of deicing equipment and techniques, including field expedients.

I-2 ENVIRONMENTAL EFFECTS. A buildup of ice occurs in three principal ways: from rain falling on an item whose temperature is below freezing (0°C), from freezing rain falling on an item at or near freezing, or from sea spray which coats equipment when temperatures are below freezing. MIL-STD-210 identifies two conditions commonly encountered: (clear) glaze ice and (granular) rime ice. Glaze ice occurs when rain or drizzle freezes on objects, and it is nearly as dense as pure ice. Rime ice occurs when fog droplets or drizzle falls on surfaces colder than 0°C. It is white and, since it is saturated with air, is much less dense than glaze ice. Since glaze ice is more difficult to remove and has a weight approximately four times greater than rime ice, it is a more significant factor and will be the focus of this test. The Synopsis of Background Material for MIL-STD-210B (reference f, p. 104, p. 149) identifies extremes for ice accumulation. These extremes may be used for calculating design and structural evaluations but are not suitable for establishing test conditions. Ice formation can impede equipment operation and survival and affect the safety of operating personnel by creating the following problems:

a. Binds moving parts together.

b. Adds weight to radar antennas, helicopter rotors, etc.

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c. Increases footing hazard.

d. Interferes with clearances between moving parts.

e. Induces structural failures.

f. Reduces airflow efficiency.

g. Impedes visibility through windshields and optical devices.

h. Affects transmission of electromagnetic radiation.

i. Leads to increased probability of damage to equipment from the employment of mechanical, manual, or chemical ice removal measures.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS

NOTE: This test method should be applied at the end of the tailoring process described in section 4 of this standard.

a. Application. This method is applicable to materiel which may be exposed to icing or freezing rain conditions during normal use.

b. Restrictions. This method does not simulate snow conditions, nor does it simulate ice buildup on aircraft flying through supercooled clouds.

c. Sequence (See General Requirements, 4.4.4.) The possibility of structural damage to the test materiel due to the icing test should be considered when determining test sequence. This test should follow the rain tests (method 506.2) and precede the salt fog tests (method 509.2) and mechanical tests (such as 513.3 through 519.3) so that parts will not be loosened before the icing tests.

d. Test variations. The freezing rain test contains one test procedure that is applicable for most equipment. All test variables should be specified in the test plan before actual testing is initiated.

I-3.1 Choice of test procedure

a. Test objectives. This method is designed to determine if the materiel and ancillary equipment (mounted so that it is directly exposed to the environment) can operate after ice accumulation from rain, drizzle, fog, splash, or other sources. Where ice removal is required before operation, the use of the integral deicing equipment or expedients normally available to the operator in the field will be employed. Deicing equipment and expedients will be evaluated to assess their effectiveness and the potential for damage that may degrade performance.

b. Test procedure. When an icing test is deemed necessary, the procedure included in this method is considered suitable for most test items. Since natural icing conditions will be the same for all materiel located

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out-of-doors on land, the same test is applicable for all such equipment. This test involves a 6mm layer of ice followed by a 13 mm layer of ice. For marine materiel which may be exposed to sea spray, a third thickness of 75 mm is suggested.

I-3.2 Choice of related test conditions. The test variables are configuration, temperature, rain rate, rain delivery method, droplet size, and wind velocity. The values chosen for the variables are primarily dependent on the intended use of the test item, and the level of severity desired.

a. Configuration and orientation. The following factors are to be considered:

(1) All equipment will receive icing on all sides and on top.

(2) Equipment must be in the configuration that it would be in when deployed. If required, duplicate tests may be performed in the shipping or outside storage configuration.

(3) Some equipment covered with ice will be expected to operate immediately without first undergoing deicing procedures; other equipment would not be expected to operate until some form of deicing has taken place (e.g., clearing windshields).

(4) Ice removal will involve a combination of the built-in ice-removal system together with expedient means which could be expected to be employed by military personnel in the field.

b. Test temperature. Test temperatures are recommended in the test procedure that may be used to produce the required environmental conditions. If extremes other than those shown are known, they should be used instead of the recommended values.

c. Rain delivery rate. The rain delivery rates identified in the test procedure are based on data used for previous testing (I-5a and b). These rates are considered representative of the spectrum encompassing both typical and worst-case conditions. Rain delivery rates are furnished as suggestions only. The objective is to produce a clear, uniform coating of glaze ice. Variations in delivery rate that produce uniform coatings of glaze ice are acceptable.

d. Rain delivery method. Rain delivery in the form of a uniform spray can be achieved by any of the arrangements described below:

(1) Nozzle arrays directing spray to the top, sides, front, and rear of the test item.

(2) Nozzle arrays that direct spray straight down onto the test item. Sidespray coverage is achieved by using wind or a manual method.

(3) A single, hand-held nozzle directing the spray over the surfaces of the test item.

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e. Droplet size. Droplet size is not considered to be of any particular significance; however, fine spray (1.0 to 1.5 mm nominal droplet size is suggested) may be necessary to produce the icing.

I-4 SPECIAL CONSIDERATIONS

I-4.1 Failure analysis. (See General Requirements, 4.5.7.)

a. The test item shall be considered to have failed the test if:

(1) For equipment that must operate without ice removal, the performance of the test item has been degraded below that specified in the requirements document.

(2) For equipment that can await ice removal before operation, the performance of the item has been degraded below the specified requirements after normal ice-removal efforts have been undertaken or if ice removal damages the equipment.

(3) A nonapparent hazardous situation has been created. (A slippery platform would not be considered a nonapparent hazard.)

b. The failure of a test item to satisfy its operational and maintenance requirements must be analyzed carefully, and related information must be considered, such as:

(1) Degradation allowed in operating characteristics following the freezing rain conditions.

(2) Necessity for special kits or special operating procedures.

I-4.2 Summary of test information required. The following information must be provided in the test plan for the adequate conduct of the tests of section II:

a. Test item configuration.

b. Test temperature conditions.

c. Rain delivery method.

d. Wind velocity (if applicable).

e. Additional guidelines.

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METHOD 521.0

ICING/FREEZING RAIN

SECTION II

II-1 APPARATUS

II-1.1 Test facilities

a. The required apparatus consists of a chamber or cabinet with auxiliary equipment which has the ability to establish and maintain the test conditions specified. The chamber must be equipped so that test conditions within the chamber can be stabilized within a reasonable time after the test item is loaded. Water delivery equipment (nozzles and drains) shall be arranged to preclude the collection of puddles in the chamber. The chamber shall be equipped with instrumentation capable of maintaining and continuously monitoring the test conditions. (See General Requirements, 4.4.2.)

b. The thickness of the ice and the temperature during equipment operation are the important parameters. The precise methods for depositing the ice on the equipment are not important. (See I-3.2d.)

II-1.2 Controls. Before each test, critical parameters shall be verified. A spray pattern wide enough to guarantee uniform impingement for all test wind velocities shall be assured. Suggested techniques for spray calibration (if specified or considered essential) can be found in reference I-5j. Unless otherwise specified in the equipment specifications (or other documents), if any action other than test item operation (such as opening the chamber door) results in a significant change in the test item or chamber air temperature (more than 2°C (3.6°F), the test item will be restabilized at the required temperature before continuation. If the operational check is not completed within 15 minutes, reestablish the test item temperature conditions before continuing.

II-1.3 Test interruption. (See General Requirements, 4.5.4.)

a. Undertest interruption. Interruption of a freezing rain test is unlikely to generate any adverse effects and normally the test shall be continued from the point of interruption once the test conditions have been reestablished.

b. Overtest interruption. Any interruption that results in more extreme exposure of the test item than required by the requirements document or equipment specification should be followed by a complete operational and physical check. If no problems are encountered, the test item shall be restored to its pretest condition and the test reinitiated.

II-2. PREPARATION FOR TEST

II-2.1 Preliminary steps. Before initiating any testing:

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a. Determine from the test plan the test item configuration and other test parameters.

b. Determine from the test plan the operational requirements.

c. Clean all traces of oil and grease from all outside surfaces of the test item which are not oily in the normal operating mode. Even thin films of oil or grease will prevent ice from adhering to the test item and change the test results.

d. To facilitate measurement of ice thickness, copper bars or tubes 2.5 cm in diameter and at least 60 cm in length shall be mounted in a horizontal position in places where they will receive the same general rainfall as the test item. Other thickness measurement techniques may be used if they can be shown to accurately measure and indicate the ice thickness.

NOTE: Structures with large height variations, such as antenna masts, should have test bars placed at the different heights, since artificially produced freezing accretion rates tend to depend upon the distance between the test item and the spray frame.

e. Water used in the spray system should be cooled to between 0^{o} and $3^{o}C$ ($37^{o}F$). When chilled water cannot be obtained, unchilled water will produce acceptable results. The main factor affected by the warmer water temperature is the ice buildup rate.

II-2.2 Pretest standard ambient checkout. All test items require a pretest standard ambient checkout to provide baseline data. Conduct the checkout as follows:

Step 1. Insert the test item into the chamber and stabilize the test item at standard ambient conditions per General Requirements, 4.4.

Step 2. Conduct a complete visual examination of the test item.

Step 3. Prepare the test item in accordance with General Requirements, 4.5.2, and required test item configuration (I-3.2a).

Step 4. Conduct an operational checkout in accordance with the approved test plan.

Step 5. Operate any integral deicing equipment, such as defroster, wipers, etc., to assure satisfactory operation.

Step 6. Record the results for compliance with the requirements document(s).

Step 7. If the test item operates satisfactorily, proceed to Procedure 1 (II-3). If not, resolve the problems and restart at step 1 above. Repeat steps 1 through 6 until the test item operates acceptably.

II-3 PROCEDURE I - Glaze ice. The following test procedure provides the basis for collecting the necessary information concerning the test item in a freezing rain environment.

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Step 1. Stabilize the test item temperature at approximately 2 ± 1°C.

Step 2. Deliver a uniform rain spray of precooled water for 1 hour (a water temperature of 5°C (41°F) at 2.5 cm/hr has proven satisfactory). Delivery can be any convenient method per I-3.2d.

Step 3. Lower the chamber air temperature to -10°C (+14°F) or as specified and maintain the rain rate until 6 mm of ice has accumulated on all sides and on the upper surface. Wind or a side spray may be used to accumulate ice on the sides.

NOTE: For tests representing sea spray on marine equipment, increase the ice deposit to 37 mm, and use 75 mm in step 7.

Step 4. Adjust the chamber air temperature to -6°C (+21°F) for 2 to 6 hours. Attempt to operate the test item and all subsystems at -6°C and examine for safety hazards.

Step 5. If step 4 has resulted in failure or if the specification allows ice removal, remove the ice. Limit ice removal to integral methods plus simple, expedient, and obvious methods. Note the effectiveness of ice removal techniques.

Step 6. Attempt to operate the test item and all subsystems at -6°C and examine for safety hazards.

Step 7. Repeat steps 1 through 6 with a 13 mm coating of ice (75 mm for sea spray).

Step 8. Return the chamber temperature to ambient and restabilize the test item temperature. Perform a post-test operational checkout.

Step 9. Document (with photographs if necessary) the results for comparison with those obtained in II-2.2.

II-4 INFORMATION TO BE RECORDED

a. Previous test methods to which the test item has been subjected.

b. Ice thickness.

c. Results of each performance check and visual examination:

(1) Pretest.

(2) Post test.

d. Ice removal method (if employed).

e. Configuration of the test item (i.e., shipping or operational).

f. Specific test conditions employed.

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METHOD 523.0

VIBRO-ACOUSTIC, TEMPERATURE

I-1 PURPOSE

I-1.1 Objective. This method seeks to reproduce the combined temperature, vibration, and other operating stresses as needed, that an externally-carried aircraft store will experience during in-service flights.

I-2 ENVIRONMENTAL EFFECTS

I-2.1 Observable effects. Possible effects of a combination of vibration, acoustic, and high temperature stresses include all those effects which each of these factors can cause separately (see method 501, 514, 515). Also, the combined environments may interact to give effects which are not predictable from the results of single-environment tests, but which do occur in actual service use.

I-2.2 Effect mechanisms

I-2.2.1 Relative importance. All environmental stresses do not contribute equally to deterioration of store reliability. Analysis of service failures caused by aircraft environmental stress (reference 2) has identified the four most significant stresses causing aircraft equipment failures. These are operation, temperature, vibration and moisture. Other environmental stresses may produce failure modes in a given type of store and should be investigated for their possible relation to service failures.

I-2.2.2 Temperature. The source of the heat that causes reliability problems in electronic components of aircraft stores will generally be an external surface. This heat in combination with the heat generated within the electronics causes decreased operating life or Mean-Time-To-Failure (MTTF). Another stress aspect of the temperature environment is rapid temperature change (thermal shock). A thermal shock or transient registered at the outside surface of the store does not appear as a shock to components somewhat thermally isolated within. Internal components experience thermal shock when the unit is turned on and quickly warms up to operating temperature.

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The temperature of the external surface of the store tends to become that of the boundary layer air, due to high convective heat transfer at flight speeds. Boundary layer air temperature is primarily a function of flight speed and altitude. An expression relating this temperature to flight conditions is:

$$T_r = T_h \left(1 + \frac{r(k-1)M^2}{2}\right)$$

Where:

T_r = adiabiatic recovery temperature (Kelvin)

T_h = ambient air temperature (Kelvin) as a function of altitude

R = recovery factor

k = ratio of specific heats (1.4 for air)

M = Mach number

When the expression within the brackets, the aerodynamic heating factor, is evaluated for atmospheric air brought to rest by friction along a store with a cylindrical surface, it reduces to a function of aircraft velocity alone. The equation for a store with a cyclindrical surface is:

$$T_r = T_h \quad (1 + 0.174\ M^2)$$

Higher Mach number flights tend to occur at higher, thus colder, altitudes and there is a corresponding tendency for the velocity-dependent heating effect to cancel the effect of decreasing temperature with altitude. When the above expression is evaluated for normal mission profiles, flown in a standard atmosphere, 90% of the time the skin temperature will be within the temperature band -15°C to 35°C.

Temperature patterns at points deep within the store will depart considerably from the corresponding skin temperature patterns, due to thermal lag in conduction from the skin and internal heating sources such as electrical or electronic components. A thermal model of the store can be generated to calculate internal temperature patterns.

An additional thermal parameter needed to satisfy mission conditions is that of climatic departure from the standard atmosphere, which depends on the global and seasonal variations of atmospheric temperatures (the T_h in the T_R formula above).

I-2.2.3 Vibration. Experimental evidence has shown that captive flight vibrations are due largely to aero-acoustic loads (reference 3). This acoustic forcing function, typically consisting of broad-band random noise, is modified as it is transmitted through the store structure to the component. When there is sufficient transmission of frequencies causing resonances of the unit or its components or structural mechanisms, a vibration failure can occur. Environmental testing, using a reverberant acoustic chamber, tries to duplicate the directional, spatial and spectral distributions of vibration expected throughout the store during captive flight.

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The turbulent boundary layer is the most significant source of aero-acoustic loads because it is always present during flight and acts on the total surface area of the store over a broad frequency range which includes resonant frequencies of electronic components and structural parts. The intensity of the turbulent boundary layer pressure fluctuation and resulting store vibration primarily depends on flight dynamic pressure, q, a function of flight speed and altitude:

$$q = \frac{k P_h M^2}{2}$$

Where:

q = dynamic pressure (pounds per sq. ft.)

k = ratio of specific heats ($\sim$ 1.4 for air)

P_h = ambient pressure as a function of altitude (pounds per sq. ft.)

M = Mach number

Store vibration also includes lower frequencies (usually less than 100 Hz) mechanically transmitted from the aircraft through the store's support mechanism. Low frequency vibration is discussed in I-3.4.2.

I-2.2.4 Operating stress. Operating stresses are usually estimated because the service conditions (e.g., on-time/off-time, aircraft power fluctuations) are seldom measured and recorded. This stress cannot be omitted, unless the store has no operating mode while carried on aircraft.

I-2.2.5 Moisture. In combined environments testing, moisture often condenses on the test item during transitions from low to high temperatures. Its presence, although uncontrolled, is useful as a test condition to indicate leakage or sensitivity to moisture. Where humidity or corrosion problems are expected, separate tests are advised.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS

This method should be applied only by qualified personnel at the end of the tailoring process described in section 4 of this standard.

a. Application. This method applies to reliability-related testing of externally carried aircraft stores (see table 523.0-I).

b. Restrictions. This method is intended primarily for the electronics and electro-mechanical assemblies within the store.

c. Sequence. This method applies the environmental stresses occuring in the final phases of the store's logistic cycle, and when used in combination with other test methods, should follow those methods.

d. Test variations. Unlike the other methods in this standard, this method contains no step-by-step procedure for generating valid test data. The vibro/acoustic/temperature environment is too complex, and the variety of equipment applications too great, for such detailed instructions to be given here. Instead, this method provides guidance for writing a test procedure which will be more or less unique for the item under consideration.

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I-3.1 Background. Experiments have shown (reference 1) that the only way to reproduce the service failure distribution is to reproduce the service stress distribution. Stress distribution is a range of stresses, in proper proportion, of level and durations determined by mission profiles. The proportioning is applied to vibration, temperature, thermal shock and electrical stress. Procedure I uses combinations of temperature, acoustic vibration, mechanical vibration, and store operating patterns to simulate in-service missions.

I-3.2 General. Military aircraft service use may be characterized by a set of specialized missions, with a duration and relative frequency assigned to each mission type. Each mission type is described by its "mission profile ", an idealized mission history which specifies altitude, velocity and operating state as a function of time; and which locates the occurrence of stressful events such as special maneuvers, gunfire and landings. From such mission profiles, corresponding mission environment histories (e.g., vibration levels, skin temperatures) can be constructed. Data from instrumented flights may be used in this construction. By treating the mission environment profiles probabilistically, summing the durations of each stress level in each mission, and weighting by the relative frequency of each mission, a service distribution function for each stress may be obtained. A composite environment profile may then be constructed for each stress of interest. This composite environmental profile is a sequence of stress levels constructed to simulate the service environment profiles for the different missions taken together. Its total duration should be no longer than a few missions, it must represent realistic flight conditions, and it must reflect the calculated combined service distribution function for the stress. A composite mission profile consists of the combination of composite environmental profiles for each environment, so coordinated that the mixture of stress levels at any point in time represents the typical service condition being simulated. Simulation of typical (5th to 95th percentile) values is emphasized. If extreme values were used, similar to qualification test levels, the results would not correlate with field experience.

I-3.3 Mission analysis. The first step in developing the composite mission profile is to determine the types of aircraft and the types of missions with which the store is to be employed. For each aircraft type, each mission will have its own typical mission operational profile, usually charted as altitude and velocity versus time and indicating critical points or periods. A typical aircraft mission operational profile is shown in figure 523.0-1.

The relative frequency for each type of store-carrying mission must be established for each aircraft type along with the proportion of total store use expected for each aircraft type. Tables, such as table 523.0-II. are usually prepared to handle this information.

Since both vibration-causing acoustic fields and skin temperatures of a store can be related to altitude and aircraft speed, the pattern of expected altitude/velocity combinations will be needed for each relevant mission. Table 523.0-III shows one method organizing such data, by dividing each mission into segments or phases. Similar charts for each mission of each aircraft type are suggested. Additionally, a frequency-weighted mean of mission durations should be calculated.

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I-3.4 Environment analysis

I-3.4.1 Temperature profile. With a Standard Atmosphere Table the corresponding ambient temperature for each altitude used in the mission analysis may be found. Corresponding store skin temperatures may then be calculated from the ambient temperature when the aircraft velocity is known (see I-2.2.2). Sometimes skin temperature data from instrumented flights is available to provide a check for the calculated temperatures. For each pertinent mission, a chart of expected skin temperature versus time is prepared. Figure 523.0-2 is an example of a temperature profile for a single mission.

The next step is to prepare a frequency distribution of store skin temperatures for a standard day. One method of accomplishing this is to divide each mission into a group of representative stabilized temperature levels (temperatures stabilized for a period of 3 minutes or more) and then determine the total mission duration for each level. These mission temperature level durations are then weighted for the relative frequency of each mission (i.e., multiplied by the fraction of total mission operations time for the store that the individual mission type is used). A composite distribution can now be generated by performing a sum of the weighted mission durations for each temperature level used.

With a composite frequency distribution of temperature levels at hand, a composite mission temperature profile may be constructed by arranging the composite temperature level durations in segments ordered to simulate a typical mission or a few missions. Such a standard composite mission temperature profile is shown in figure 523.0-3. When the temperature profiles of the various missions are dissimilar, segments may be separated into groups of similar characteristics and the composite profile constructed to include a mission or mission phase requirements for each of the groups. Total duration at each temperature level must still reflect the distribution function calculated.

The standard composite mission temperature profile must now be adjusted for climatic temperature variations since the standard atmosphere, based on the "standard day", represents only an abstract climatic condition. Temperatures both higher and lower than "standard day" values are commonly met due to seasonal or geographical changes in mission operations. Preparation of temperature versus altitude information to cover all likely climatic mission situtations would become too involved for practical consideration. Therefore, estimation of the overall temperature range to be encountered, and a fair judgment of the relative frequency of expected occurrence of temperatures within this range, is normally resorted to. Temperature extremes (frequency of occurrence 5% or less) may be omitted. A climatic atlas is helpful at this step.

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Climatic temperature estimates may be incorporated into the test by selecting a representative group of fixed temperature offsets which add to or subtract from the standard composite mission temperature profile. By having these offsets represent equiprobable temperature intervals, a full climate set of these temperature profiles can simulate the whole temperature system which the store could experience. A sample composite mission temperature profile climatic set is shown in figure 523.0-4. Note that the profiles are clustered around the standard value to reflect the higher frequency of operations in more temperature climates. For practical test operation, each test cycle (one composite mission) will trace a composite temperature profile, starting and ending at a resting temperature. The resting period between consecutive test cycles should be sufficient to allow internal store temperature to stabilize, thus simulating the ground time occurring between service missions. A climatic set of test cycles will consist of a sequence of test cycles (usually 6 to 15) in which the composite mission temperature pattern is offset stepwise upward and downward from zero offset. Figure 523.0-5 illustrates a typical offset sequence for an 8-cycle climatic set. To provide uniformity and consistency from one test to the next, it is important that several full climate sets be completed before the expected Mean-Time-To-Failure of the store is reached. A test minimum of five sets is recommended.

I-3.4.2 Vibration profile. A composite mission vibration profile may be generated by determining the dynamic pressures during each stable segment of aircraft flight (refer to I-2.5). A rough profile can now be constructed. The periods of changing temperature will usually also be periods of changing q since both are dependent on aircraft altitude and velocity. However, since vibration in the laboratory may be changed almost instantaneously (not with lag, like temperature) and is more easily controlled at fixed levels, the q profile is usually laid out as series of steps. Figure 523.0-6 shows a typical composite mission dynamic pressure profile matching the corresponding figure 523.0-7 temperature profile. Data from instrumented flights is used to determine the spectral envelope for various mission phases and the translation from q to vibration level.

The simplified vibration profile shows intensity only. The spectrum envelope and the spatial distribution (including directivity) of the vibration are additional variables that, when uncontrolled, can cause error in the simulation process. Experimental adjustment should be done in the test chamber so as to achieve a reasonable correlation between accelerometer vibration records from captive-flights and from the store under test.

I-4 SPECIAL CONSIDERATIONS. None.

I-5 REFERENCES

a. Meeker, D.B. and Piersol, A.G., "Accelerated Reliability Testing Under Vibroacoustic Environments," Reliability Design for Vibracoustic Environments, ASME AMD-Vol. 9, New York, NY 1974.

b. Dantowitz, A., Hirschberger, G., and Pravidlo, D., "Analysis of Aeronautical Equipment Environmental Failures," Air Force Flight Dynamics Laboratory, TR-71-32, May 1971.

c. Meeker, D.B. and Everett, W.D., "U.S. Navy Experience on the Effects of Carrier-Aircraft Environment on Guided Missiles," AGARD conference proceedings No. CP270, May 1979.

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TABLE 523 0-I. Typical applications.

TEST TYPE	PURPOSE	APPLICATION	TYPE OF INFORMATION REQUIRED: FAILURE MODES	TIME-TO-FAILURE
Test, Analyze, and Fix (TAAF)	Reveal and correct design weaknesses.	Development of a more reliable design prior to production.	Essential to induce potential service failures.	Not important.
Reliability Demonstration	Show whether or not a design meets the specified reliability.	Start of production is usually based on a successful reliability demonstration.	Important only if the demonstration is unsuccessful.	Essential.
Debugging or Screening	Reveal workmanship or component defects before a production unit leaves the factory, i.e., while repair is cheap.	Part of the manufacturer's internal testing to assure delivery of reliable units during production.	Essential to induce failures in defective areas; such failures should not then appear in service.	Not important.
Lot Acceptance	Estimate the MTTF of the lot units from the time-to-failure of a small sample.	Determination as to whether the lot is to acceptable quality.	Important only if the lot is rejected.	Essential that successive lot measures be consistent and comparable. Baseline similarity to service MTTF is desirable.
Source Comparison	Determine the relative reliability of units from the time-to-failure of a small sample.	Determination as to which of two sources should get the larger share of a production buy.	Important for improvements at the poorer source.	Only consistency comparability is essential.

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TABLE 523.0-II. Relative frequency of mission types.

MISSION TYPE	A/C TYPE	% OF SORTIES
1. Patrol Mission I	Fighter A	50
	Fighter B	30
2. Patrol Mission II	Fighter A	20
	Fighter B	20
3. Strike Escort Mission	Fighter A	30
	Fighter B	30
4. Strike Mission	Fighter B	20

TABLE 523.0-III. Mission phase analysis (fighter B, strike mission).

MISSION PHASE	MACH NUMBER	ALTITUDE (KM)	DURATION (MIN.)	ADDITIONAL FACTORS	DUTY CYCLE OF STORE
Takeoff & Climb				Catapult shock?	Off to Ready
Travel					Ready
Refuel					"
Ingress					On (radiate)
Maneuver				Buffet?	Ready
Return					"
Refuel					"
Descend and Land				Landing shock?	Off

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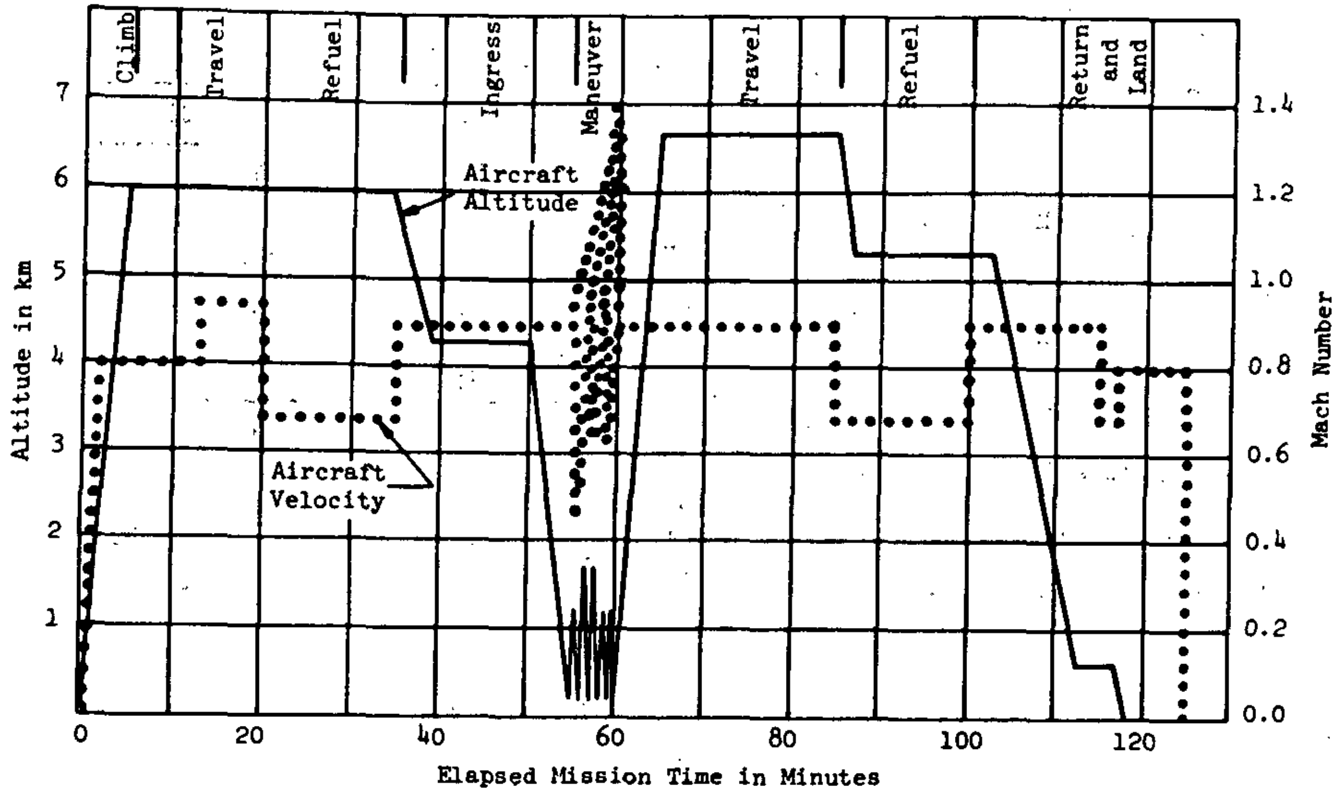

FIGURE 523.0-1. Typical aircraft operational mission profile.

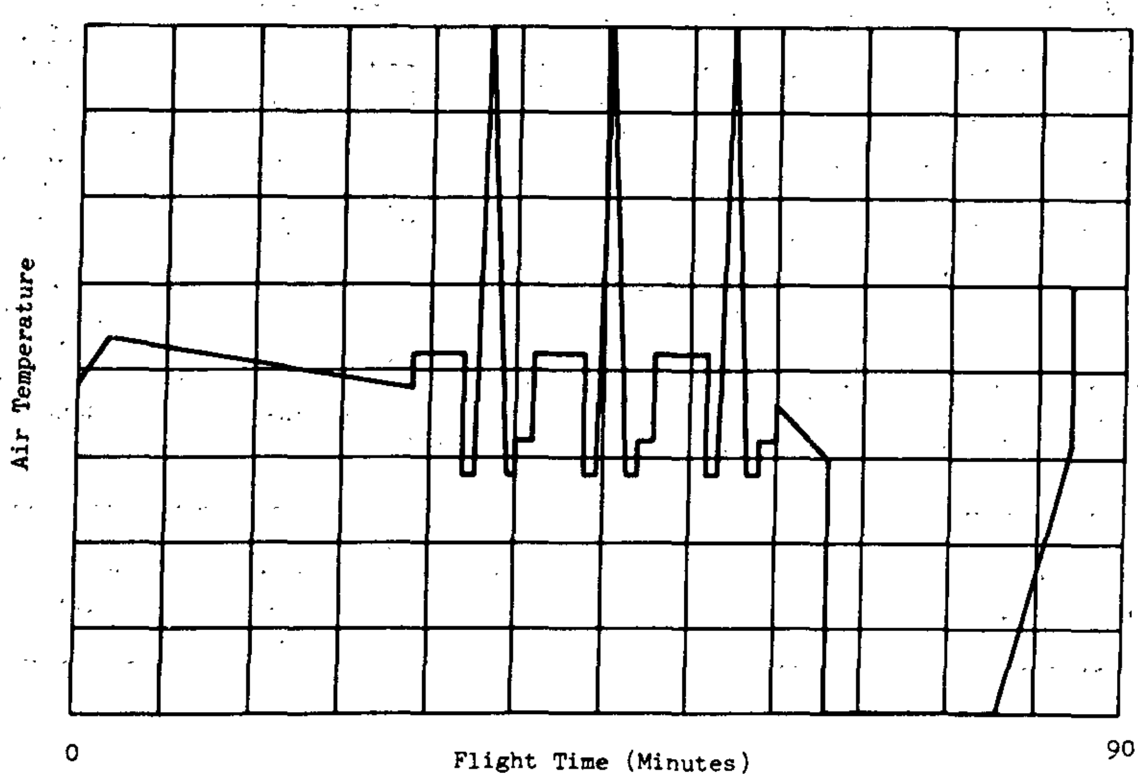

FIGURE 523.0-2. Temperature profile for a single mission type.

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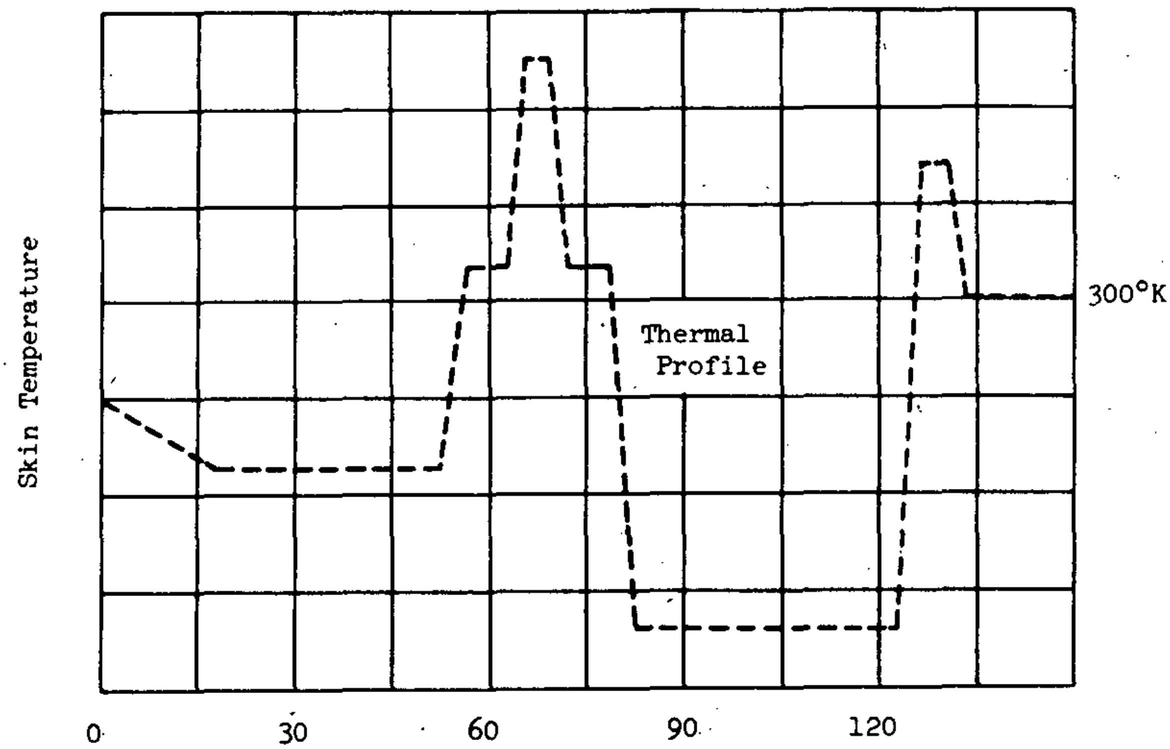

FIGURE 523.0-3. Temperature profile for composite mission.

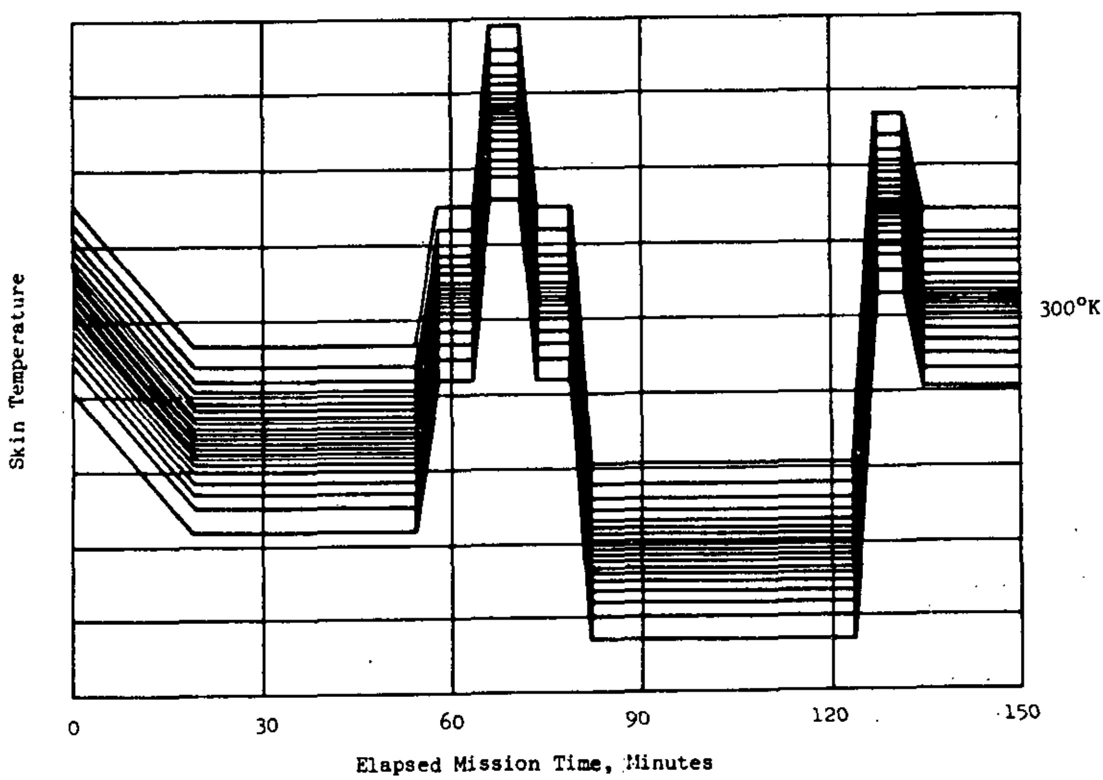

FIGURE 523.0-4. Climatic set of temperature profiles for composite mission.

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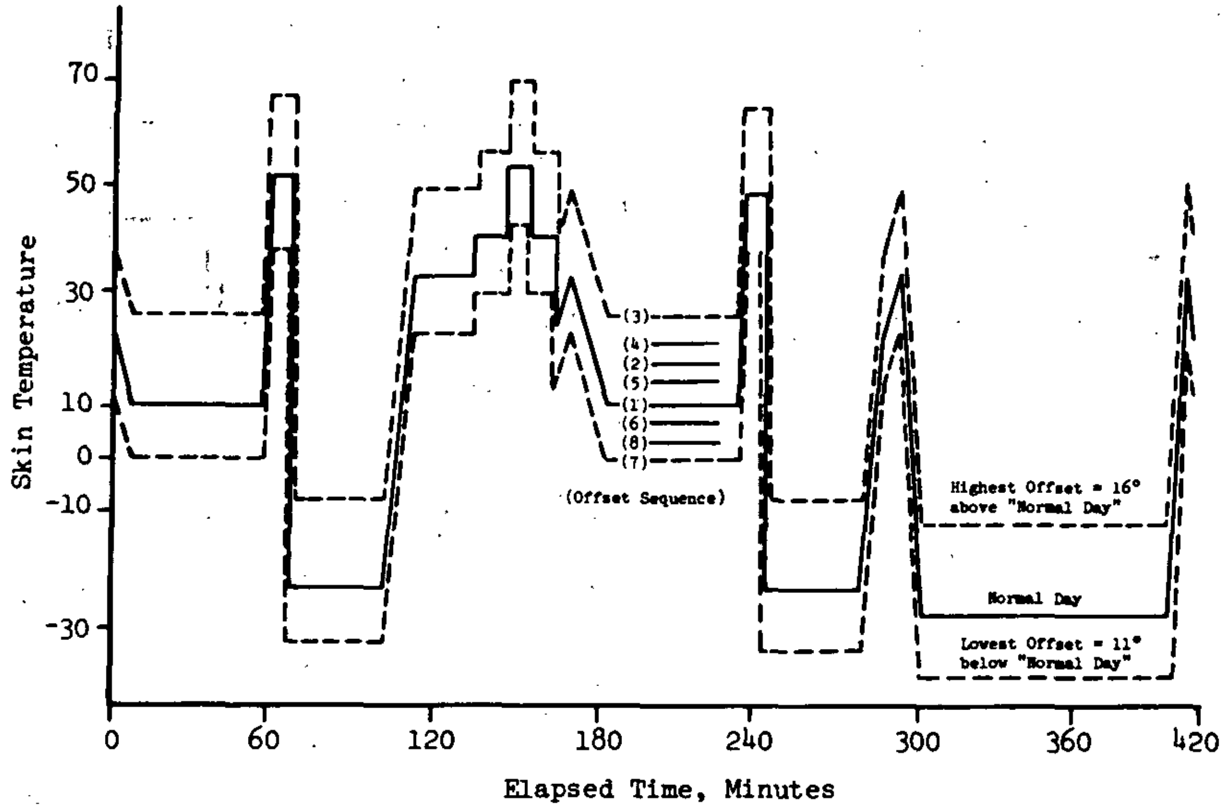

FIGURE 523.0-5. Climatic set plan showing offset sequence.

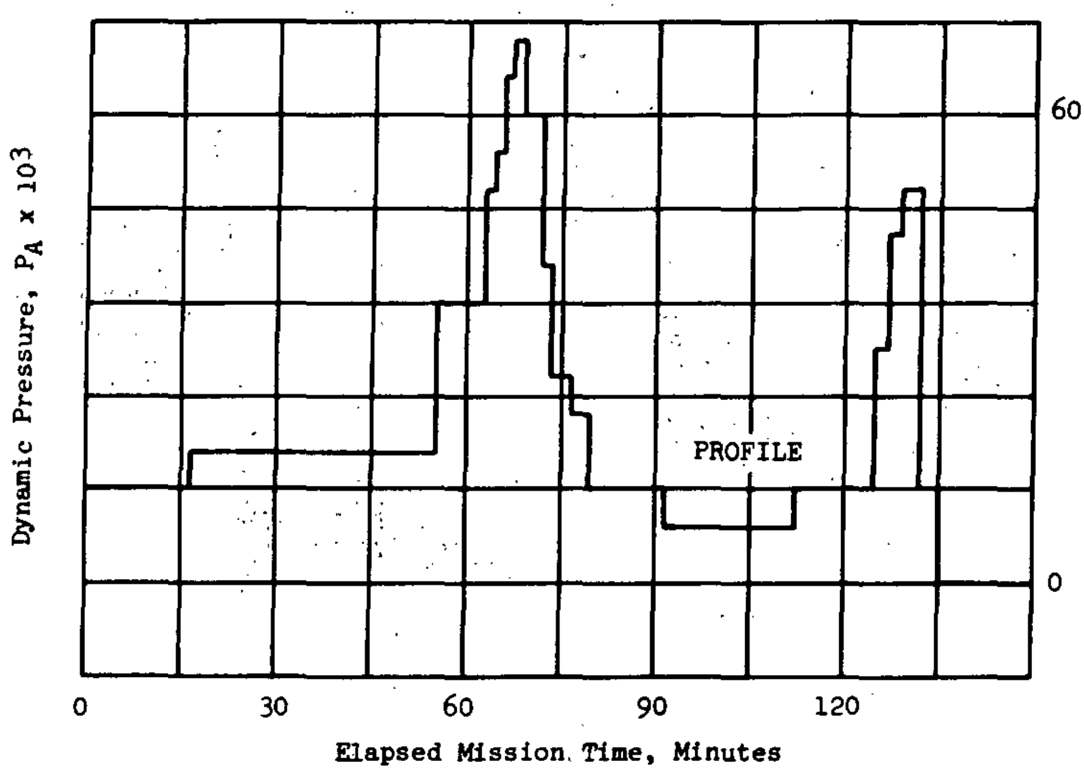

FIGURE 523.0-6. Dynamic pressure, q, profile for composite mission.

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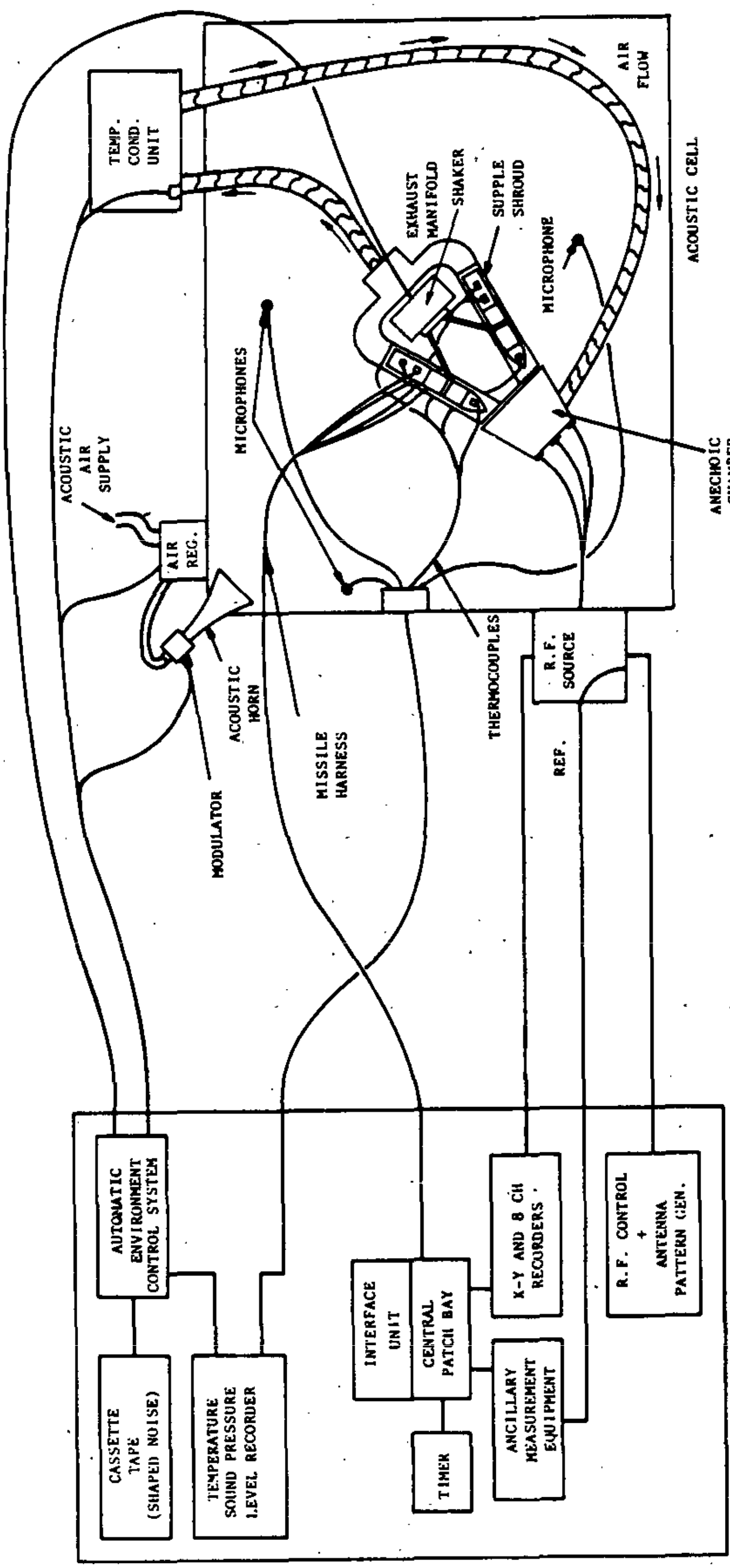

FIGURE 523.0-7. Typical arrangement of apparatus.

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METHOD 523.0

VIBRO-ACOUSTIC, TEMPERATURE

SECTION II

II-1 APPARATUS

II-1.1 General. The facility must include a large acoustical noise test chamber capable of approximately a 155 dB intensity level and associated air-conditioning equipment to provide controlled, fixed air temperatures and rapid temperature changes (4°C per minute) in the range -40°C to +85°C. Mechanical or hydraulic shakers capable of stressing the store(s) under test may also be required. Adequate instrumentation for controlling, monitoring, calibrating and recording the environment variables will be needed.

II-1.2 Test chamber. Chamber shape and dimensions shall provide for diffusion and uniform distribution of the acoustic field, and support reverberation of acoustic frequencies of 150 Hz and above. Ports must be provided for introduction of the acoustic energy, for pressure stabilization (exit of modulator air), for entry and exit of temperature-conditioned air and for access by multiple electrical cables and waveguides, light beams, anechoic ducting, etc. as applicable. Some stores may require specialized test apparatus such as artificial targets, r-f anechoic shrouds, or visible gages which must be incorporated without compromising the combined environments.

II-1.3 Vibration equipment. A suitable acoustic energy field shall be provided by an acoustic power source controlled to reproduce the acoustic mission profile. Typical apparatus consists of a constant-pressure compressed air source such as a reciprocating compressor with pressure regulator feeding an air modulator that is acoustically coupled to the chamber through an exponential horn. The air modulator is excited electrically by an amplified audio signal. Considerable acoustic power is needed to reach required levels, often 10 to 30 KW; multiple modulator-horn units may be necessary to reach desired intensities.

To provide low-frequency vibration below about 100 Hz, electrodynamic or hydraulic shakers may be used to augment the acoustic field. Such shakers may also be used to provide limited mechanical shock impulses. To maintain access to the stores by the conditioned air and acoustic energy, suspended stores can be vibrated at low levels using a rod and collar arrangement to conduct the vibration from the shaker(s). Procedure VI of method 514.3 will furnish some guidelines for this procedure. This arrangement is diagrammed in figure 523.0-7.

II-1.4 Temperature equipment. Temperature conditioning of the store(s) under test must be accomplished without adversely affecting the acoustic environment. One process for accomplishing this is to duct high velocity conditioned air across the stores by means of thin flexible shrouds that are acoustically transparent. They can be supported by light metal frameworks.

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Thin silicone rubber and rip-stop nylon sheetings have been found to be suitable shroud materials. To provide the rapid temperature changes required, one method uses insulated tanks or hot and cold fluids which are pumped through heat exchangers as required to temperature-condition the blower-driven air. By increasing the blower speed or by narrowing the circumferential gap between the surface of the test item and the shroud (usually between 2 and 4 cm), the boundary air velocity can be raised to provide the needed rapid heat transfer to or from the store to simulate the captive flight conditions. The arrangement is diagrammed in figure 523.0-7.

II-1.5 Electrical stress equipment. Basic electrical stresses always present in electrical or electronic circuits are produced by power on/off transients and resulting localized thermal shocks, and also by hot spots accompanying the full power condition. A switching system is normally used to form typical patterns of store operation during the composite mission test cycle. The use of equipment to modify the power source to the store(s), to simulate likely variations (voltage, frequency, transients, ripple, noise, etc.) met during mission operations, is optional.

II-1.6 Instrumentation and control

II-1.6.1 Functional monitoring of the store. The operating stores should be adequately monitored to indicate failures when they occur. Some form of manual or automatic test performed at intervals (at least once for each composite mission cycle) can be used. Failure criteria, based on equipment specifications and functional requirements, must be clearly defined. Functional monitoring must be accomplished without adversely affecting the environmental simulation. Functions which can only be measured outside the environmental chamber should be checked at intervals which are short compared to the equipment's mean-time-to-failure.

II-1.6.2 Vibration monitoring

II-1.6.2.1 Acoustic stimulus. The acoustic signal source is normally a pre-recorded tape or the shaped output of a noise generator. Filters are used as required to control spectral distribution. Intensity level is monitored by calibrated microphones. Microphone placement should conform with II-2, step 6, method 515.3 unless other placement can be justified by measurement and analysis.

II-1.6.2.2 Mechanical stimulus. The shaker input signal is normally a pre-recorded tape or the shaped output of a noise generator. Filters are used as required to control spectral distribution. Intensity level is monitored by calibrated accelerometers mounted on or in the store(s) which measure the vibration response (see II-1.6.2.3, next). The shaker frequency range is limited (typically <200 Hz) so that feedback control is unnecessary.

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II-1-6.2.3 Vibration response. Calibrated accelerometers mounted in and on the store(s), when used with appropriate analysis equipment, provide the needed response monitoring for both acoustic and mechanical stimuli. Accelerometer positions in and on the store, at least during setup, should be as close as possible to those used to obtain captive-flight data. Accelerometer placement should aim to provide coverage for possible directional variation (e.g., longitudinal, lateral and vertical axes) and for possible extension or radial variation (e.g., fore, mid, aft, external, internal). Power Spectral Density (PSD) measurement or display (g^2/Hz units) plus intensity readings (grms units) furnish the needed information for comparing test chamber and captive-flight vibration parameters (see II-2.4).

II-1.6.3 Temperature monitoring. Temperature sensors on the surface of the store(s) provide the best location for monitoring and feedback control. Refer to figure 523.0-7.

II-1.6.4 Humidity monitoring. Although humidity is not a controlled variable for procedure I, the ducted airstream may be continuously monitored for moisture content, either by dewpoint or relative humidity sensing. It should be noted that moisture can collect on a store's surface when it has reached and holds a cold temperature that is below the dewpoint of warmer air following in the mission cycle. This is a normal and expected condition.

II-1.6.5 Electrical input monitoring. All electrical inputs to the store(s) should be monitored whether or not they are modified to represent expected mission irregularities.

II-2 PREPARATION FOR TEST

II-2.1 Test plan. A test plan shall be prepared to document tests using this method. The following areas should be addressed in the test plan:

a. Scope and purpose. Test procedures differ with different test goals (see table 523.0-I). A design qualification test might require demonstration of a specific Mean-Time-To-Failure (MTTF), a quantitative value. A Test, Analyse, and Fix (TAAF) during development would be qualitative in nature since its primary purpose is the identification of failure modes to be expected in service.

b. Test items. The items to be tested must be clearly identified. Their service designation, source, and exact configuration should be recorded. Drawing numbers or other specific documentation should be referenced.

c. Performance parameters. List those to be used in the test.

d. Failure criteria. These must be clearly stated and be based on the performance monitoring system to be used.

e. Failure analysis. Indicate how failures are to be analyzed, classified and reported. For example, failures can be classified by cause (suspected stress), subsystem or unit involved, effect on store operation, or responsibility (i.e., bad component or material, poor workmanship, inadequate inspection, deficient design, etc.).

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f. Mission profile. Information must be supplied that will allow the mission profile to be properly charted for the particular test item. The needed information may be provided through the referencing of relevant documents or by inclusion in the test plan. The information should include:

(1) The particular environments that are to be controlled. Temperature and acoustic energy environments are always used. Shaker vibration and/or shock stresses are optional additions.

(2) Data on all operational missions using the the test item in the aircraft captive-carry mode. Needed information includes types of aircraft used, length of missions, aircraft flight paths and patterns, aircraft velocities in different operational modes, theaters of expected use and percent-of-time estimates for the various categories.

(3) Climatic and atmospheric data. World-wide seasonal altitude-versus-temperature tables or charts are needed.

g. Measured store responses to environments used in determining test stresses.

h. Test data. List specific performance and environmental parameters to be recorded before, during, or after a test cycle and whether recordings should be continuous or made at stated intervals. Explain how data is to be handled and specifiy recording methods. If analysis is required, methods should be referenced. All raw test data should be sorted, labeled and stored for possible later use in analyses or for graphic illustration (see II - 4).

i. Test reporting. State how results are to be reported and whether conclusions and recommendations are to be included.

j. Test procedures. Critical operations should be pointed out and requirements for step-by-step procedures stated (see II-3).

II-2.2 Safety program plan. A safety program plan shall be prepared which shall incorporate all safety policies, practices and regulations applicable to the preparation and conduct of the test. Safety policies and directives of the facility conducting the test, contractual safety requirements where applicable, safety precautions applying to the stores under test, and special hazards involved with the test apparatus shall be treated. The plan shall require that operating procedures prepared for this test method shall be event-sequenced and contain suitable warnings to , and precautions to be taken by, operators wherever and whenever potential hazards exist. MIL-STD-882, Requirements for System Safety Program for Systems and Associated Subsystems and Equipment, shall be used as a guide for preparation of the Safety Program Plan. After approval by proper authority, the Safety Program Plan shall be strictly followed during preparation and conduct of this test method.

II-2.3 Composite mission test cycle

II-2.3.1 Test cycle. A test cycle consists of a single simulated composite mission. A climatic set is a fixed number of test cycles (usually 6 to 15, as called out in the test plan) in which the temperature profile is offset by a fixed temperature difference predetermined for each test cycle of the set. A complete Composite Mission Combined Environments Test consists of a number (usually five or more) of repeated climatic sets of test cycles.

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II-2.3.2 Environment profile charts. For each of the controlled environments, prepare a chart plotting stimulus level versus time that best represents the composite mission. Each chart should be based on a standard atmosphere and the time period for the composite mission. These plots define the basic environment profiles that constitute a single test cycle and provide the patterns for controlling the environmental test apparatus. Methods for generating composite mission environmental profiles are discussed in I-2.3.

II-2.3.3 Climatic offset table. Prepare a table or chart indicating the temperature offsets applying to consecutive test cycles in a climatic set of about 6 to 15 cycles (refer to figure 523.0-5). The offsets are chosen so that one climatic set will represent the predicted mixture of climates expected in operational missions. This process is discussed in I-3.4.1.

II-2.3.4 Combined environments control directions. Provide directions for adjusting each of the controlled environments throughout each complete climatic set of test cycles. Levels are obtained from the composite mission environment profile with the temperature pattern for each cycle of the climatic set offset according to plan. These directions should not be finalized until test setup is completed (see II-2.4, next).

II-2.4 Test setup

II-2.4.1 General. Using instrumented (but not necessarily operable) stores, assemble test items and environmental apparatus, with accompanying instrumentation and controls, into the planned configuration. After sensor calibrations, test each environment separately to check ability to reach test levels and rate-of-change requirements. With individual environments checked out, run combined environments through a test cycle. Correct problems as necessary. The general accuracy and tolerance requirements of section 4 of this standard shall be followed where applicable.

II-2.4.2 Vibration checkout. Adjustment of the vibration sources to provide the best simulation of in-flight vibration response is an essential part of test setup. Vibration response simulation can involve the following types of error: spatial (relative distribution of levels among various locations and in different directions in or on the store), spectral (frequency spectrum shape at any location and direction in or on the store), and intensity (peak and rms values). An iterative process of adjusting vibration stimulus variables (intensity, spectral envelope, limited directivity/store positioning) and observing responses is conducted to minimize these errors. The goal is to find the stimulus adjustments for each test level which will optimize the correlation of test setup with corresponding captive-flight total vibration responses. Optimum values are noted and made part of the Combined Environments Control Directions (II-2.3.4).

II-2.5 Operational checkout. Replace instrumented stores with one or more operable "practice" stores. Provide input power as required and use performance monitoring system at room environment and then, if required, during one or more mission test cycles of combined environments. Debug as necessary.

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II-3 PROCEDURES

II-3.1 General. Written step-by-step procedures shall be prepared as called out in the test plan.

II-3.2 Specific procedures. The following operations should be considered as candidates for written procedures:

a. Pre-test visual inspection and checkout.

b. Mounting and connection of test units in the chamber.

c. Calibration of instruments and apparatus.

d. Functional testing of the store(s).

e. Controlling the test cycle environments.

f. Post-test operations.

II-4 INFORMATION TO BE RECORDED

II-4.1 General. The test information to be recorded shall be included in the test plan.

II-4.2 Examples of information to be recorded

II-4.2.1 Test operation information. For each test cycle, starting with number 1:

a. starting and ending times

b. any deviations from specified time limits or environmental patterns, or alternately, preservation of all continuous environment response records

c. operators on duty

d. pertinent comments

II-4.2.2 Test item information. For each item under test:

a. specific identification

b. results of pre-test inspection and checkout

c. position occupied in test chamber, if more than one used

d. time when item installed in chamber and number of the test cycle first encountered

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e. time when item removed from chamber and test cycle number last encountered

f. reason for removal

g. results of post-test inspection and checkout

h. disposition of item

II-4.2.3 Special information for non-conforming items

a. time non-conformance was noted and number of test cycle in or after which it was discovered

b. evidence indicating non-conformance

c. confirmation of failure if failure suspected and explanation of how it was confirmed

d. failure analysis and diagnosis

e. disposition of item

f. failure report number

g. names of operators providing the above information

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(See Instructions – Reverse Side)

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2. DOCUMENT TITLE

3a. NAME OF SUBMITTING ORGANIZATION

4. TYPE OF ORGANIZATION *(Mark one)*

- ☐ VENDOR
- ☐ USER
- ☐ MANUFACTURER
- ☐ OTHER *(Specify)*: ______

b. ADDRESS *(Street, City, State, ZIP Code)*

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional

b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional

c. MAILING ADDRESS *(Street, City, State, ZIP Code)* – Optional

8. DATE OF SUBMISSION *(YYMMDD)*