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MIL-STD-810E
NOTICE 2
1 September 1993

MILITARY STANDARD

ENVIRONMENTAL TEST METHODS

AND ENGINEERING GUIDELINES

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ENVIRONMENTAL TEST METHODS AND ENGINEERING GUIDELINES

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FOREWORD

This military standard is approved for use by all Departments and Agencies of the Department of Defense.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: ASC/ENOSD, Bldg 125, 2335 Seventh St Ste 6, Wright-Patterson AFB OH 45433-7809 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

MIL-STD-810E has been revised to require 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. Individual methods have been revised to encourage 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.

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5.1.1 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 ±2°C (±3.6°F) of the test temperature and shall not exceed 1°C per meter or a maximum of 2.2°C total (equipment nonoperating).

b. Pressure. ±5% (±200 Pa).

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

d. Vibration amplitude

Sinusoidal: ±10 percent
Random: See method 514.4

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

f. Acceleration.. Acceleration (g's) shall be measured to within ±10 percent.

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

h. Air velocity. Air velocity shall be within 10 percent of the specified value.

5.1.2 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.

5.1.3 Stabilization of test temperature

5.1.3.1 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.

5.1.3.2 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.

5.1.4 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 combination consistent with 1.2 and 4.2.1 of General Requirements may be used with the permission of the acquisition agency.

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

5.1.6 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.

5.2 General test performance guidance.

5.2.1 Pretest performance record. Before testing, the test item should be operated at standard ambient conditions (see 4.4) to obtain and record data determining compliance with the requirements document(s) and for comparison 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. 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 limited (with permissible degradation) when operation of the test item is required.

b. Additional evaluation criteria (in addition to 5.2.7).

5.2.2 Installation of test item in test facility. Unless otherwise specified, the test item shall be installed in the test facility in a manner that will simulate service usage, 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.

METHOD 500.3
LOW PRESSURE (ALTITUDE)

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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, and withstand rapid pressure changes.

I-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: The tailoring process as described in section 4 of this document should be used to determine the appropriate tests and test variables.

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.

c. Sequence. (See General Requirements, 5.1.4.) 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 the tests, determine any required variations of the test procedures(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 items. From the requirement 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.

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. Consideration should be given to temperature-altitude effects as appropriate.

(1) Procedure I - Storage. Procedure I is appropriate if the test item is to be stored at high ground elevations or transported 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, rapid 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 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 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 500.3-1 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.

Table 500.3-1. Minimum cargo compartment pressures.

Aircraft	Minimum Cargo Compartment Pressure (psia)	(kPa)	Equivalent Altitude (Reference c) (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
VC-10	11.49	79.2	6,492	1,980
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). The value of 10 m/s will also be used for ground deployment tests (for standardization proposes) 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.

Explosive decompression (c(1)) should be accomplished within 0.1 second. Rapid decompression (c(2)) and (c(3)) should not take more than 60 seconds.

d. Test duration. For procedure I, the test duration should be representative of the anticipated service environment, but a test duration of at least one 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 temperature. Although testing at standard ambient temperature is common, using low temperatures associated with various altitudes may provide more realistic results.

f. 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.

g. 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, 5.2.7. 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 test of section II:

a. Test procedure.

b. Test altitude(s).

c. Altitude change rates.

d. Test duration.

e. Test temperature (if other than standard ambient).

f. Test item configuration.

g. Additional guidelines used.

I-5 REFERENCES

a. MIL-STD-210, Climatic Information To Determine Design and Test Requirements For Military Systems and Equipment. 9 January 1987.

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.

METHOD 500.3
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 and temperature. 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 two percent of full scale.

II-1.3 Test interruption. (See General Requirements, 5.2.4). 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 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 and temperature 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:

Step 1. Prepare the test item in its operational configuration in accordance with General Requirements, 5.2.2.

Step 2. Record the standard ambient conditions.

Step 3. Conduct as complete of a visual examination of the test item as possible, and document the results.

Step 4. Conduct an operational checkout in accordance with the test plan.

Step 5. Record the results for compliance with General Requirements, 5.2.1.

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 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 temperature (if required) to that specified in the test plan. Adjust the air pressure (at the rate specified) to the required test altitude.

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

Step 4. Adjust the chamber air pressure and temperature 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 temperature as required and then adjust the air pressure to the required equivalent operational altitude at a rate not to exceed that specified in the test plan.

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 and temperature 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, 5.2, and shall include the following:

a. Test item identification (manufacturer, serial number, etc.)

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

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

(1) Pretest.

(2) During test.

(3) Post-test.

d. Time-versus-pressure data.

e. Test temperature and standard ambient conditions.

f. Initial failure analysis.

METHOD 501.3
HIGH TEMPERATURE

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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 as follow. The list is not intended to be all-inclusive.

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 distorting, 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.

k. Shortened operating lifetime.

l. Solid propellants or grains separating.

m. High pressures created within sealed cases (projectiles, bombs, etc.)

n. Accelerated burning of explosives or propellants.

o. Expansion of cast explosives within their cases.

p. Melting and exuding of explosives.

q. Discoloration, cracking or crazing of organic materials.

I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS

NOTE: The tailoring process as described in section 4 of this document should be used to determine the appropriate tests and test variables.

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 505.3.

(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.

d. <u>Sequence.</u> (See General Requirements, 5.1.4) The high-temperature test is usually scheduled early in the test sequence before initial dynamic transportation tests. Although not written for such, this test may be used in conjunction with shock and vibration tests to evaluate the effect of dynamic events (i.e., shipping, handling, shock) on hot materiels. This test may contribute significantly to the results of low pressure testing of seals.

e. <u>Test variations.</u> 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.

---

[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.

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

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-3.1.2 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.

c. Exposed to reflected solar radiation.

d. Stacked.

e. Wind ventilated.

f. Above or on the Earth's surface.

I-3.1.3 Selection of test procedures(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 regions (figure 5a, section 5) where high storage temperatures are typically encountered: Hot Dry and Basic Hot. In each of these climatic regions, 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 considered with respect to:

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

Table 501.3-I. High temperature cycles, climatic category - Hot[2]

Time of Day	Ambient Air Conditions			Induced Conditions		
	Temperature °C	Temperature °F	Relative Humidity (%)	Temperature °C	Temperature °F	Relative Humidity (%)
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	37	98	6	35	95	6

NOTE: Data originally recorded in °F and converted to °C. Hence, table data conversion may not be consistent.

[2] See reference a.

Table 501.3-II. High temperature cycles, climatic category - Basic Hot[3]

Time of Day	Ambient Air Conditions			Induced Conditions		
	Temperature °C	°F	Relative Humidity (%)	Temperature °C	°F	Relative Humidity (%)
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	107	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

NOTE: Data originally recorded in °F and converted to °C. Hence, table data conversion may not be consistent.

[3] See reference a.

Table 501.3-III. Summary of high temperature diurnal cycle ranges[4]

Category	Location	Ambient Air	Induced [5]
Hot (A1)	Northern Africa, Middle East, Pakistan and India, southwestern United States and northern Mexico	32°C - 49°C (90°F-120°F)	33°C - 71°C (91°F-160°F)
Basic Hot (A2)	Many parts of the world, extending outward from the hot category of the United States, Mexico, Africa, Asia, Australia, southern Africa, South America, southern Spain and southwest Asia	30°C - 43°C (86°F-110°F)	30°C - 63°C (86°F-145°F)

[4] The exact diurnal cycles for temperature and humidity are given in tables 501.3-I and 501.3-II.

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

(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 501.3-I and 501.3-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 one percent 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 5, 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 501.3-I and 501.3-II and in 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 501.3-I and 501.3-II and of 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 501.3-I and 501.3-II and from 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 501.3-I 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 one percent frequency of concurrence of the hours of extreme temperatures during the most severe month in an average year at the most severe location. (The maximum temperature occurs for approximately one 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:

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 Information to Determine Design and Test Requirements For Military Systems and Equipments. 9 January 1987.

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 2895, Extreme Climatic Conditions and Derived Conditions for Use in Defining Design/Test Criteria for NATO Forces Materiel.

METHOD 501.3

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, 5.1.1)

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 3°C (6°F) per minute.

II-1.3 Test interruption. (See General Requirements, 5.2.4)

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 restarted 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

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LOW TEMPERATURE

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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 materiel. 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.).

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.

f. 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: The tailoring process as described in section 4 of this document should be used to determine the appropriate tests and test variables.

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 a 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, 5.1.4) 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 500.3.

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.

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

(a) Operated[1] at low temperatures.

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

(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.

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 502.3: 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 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. Although the natural low temperature environment is normally cyclic, in most instances it is acceptable to use a constant low temperature test. Only in those instances where design assessment suggests that exposure to varying low temperatures may be important are the appropriate cold cycles from MIL-STD-210C recommended. 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 502.3-I and the map in General Requirements, figure 5b, 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 502.3-I are based on a one percent 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, during which the given temperature

[2]Extended storage is defined as storage for 2 years or longer.

Table 502.3-I. Summary of low temperature diurnal cycle ranges[3]

Climatic Region	Location	Temperature	
		Ambient Air	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] See reference a.

is equaled 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 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 four 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 following temperature stabilization of the test item is recommended, since extreme temperatures have existed for at least that length of time.

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[4] Corresponds to Severe Cold condition.

(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.

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 503.3-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 503.3-II and figure 5a (General Requirements) can be used to determine test temperatures for the anticipated deployment locations.

(2) Air delivery/air drop. 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. The high temperature surface extremes should be determined according to I-3.2a, from tables 503.3-I and 503.3-II, or from method 501.3.

(3) Ground transfer/air delivery - arctic. The conditions developed for heated enclosures 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 503.3-III.

TABLE 503.3-I. Diurnal cycle of temperature for high temperature climatic categories.

Time of Day	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

NOTE: Data originally recorded in °F and converted to °C. Hence, table data conversion may not be consistent.

Table 503.3-II. High temperature geographical climatic categories.

Category[1]	Location[2]	Climatic Conditions	
		Operational	Induced
Hot Dry (A1)	Northern Africa, Middle East, Pakistan, India, southwestern United States and northern Mexico.	32°C - 49°C (90°F - 120°F) 8 to 3% RH	33°C - 71°C (91°F - 160°F) 7 to 1% RH
Basic Hot (A2)	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°C - 43°C (86°F - 110°F) 44 to 14% RH	30°C - 63°C (86°F - 145°F) 44 to 5% RH

[1] See Table 503.3-1 for the diurnal temperature/humidity cycles of these climatic categories.

[2] See General Requirements, figure 5a, for locations.

TABLE 503.3-III. Low temperature geographical climatic categories.

Category	Location[3]	Climatic Conditions	
		Operational	Induced
Mild Cold (CO)	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 coats of Alaska High elevations in low altitudes	-21°C to -31°C (-6°F to -24°F)	-25°C to -33°C (-13°F to -27°F)
Cold (C2)	Norther 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, and 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] See General Requirements, figure 5b, for locations.

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

b. Test item temperatures. 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 501.3, 502.3, and 505.3) 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 503.3-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 electron 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.

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, 5.2.7, 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 501.3).

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 Information to Determine Design and Test Requirements for Military Systems and Equipment, dated 9 January 1987.

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 2895, Extreme Climatic Conditions and Derived Conditions for Use in Defining Design/Test Criteria for NATO Forces Materiel.

METHOD 503.3

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 five minutes. Materiel 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). (General Requirements, 5.1.1a.)

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 five minutes (unless the test item is large and requires handling equipment).

II-1.3 Test interruption (General Requirements, 5.2.4).

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.

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 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, 5.1a).

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, 5.2.2, 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, 5.2.1.

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.

II-3 PROCEDURE. The following procedure provides the basis for collecting the necessary information concerning the test item in a severe temperature shock environment: The procedure is written to start with the low temperature. (However, it is permissible to start with high temperature, and alternate between the two temperature extremes in sequence.)

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 one 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 five 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, 5.1.3)

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

NOTE: If the test procedure is interrupted due to 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, 5.1b) and stabilize.

Step 7. Operate and inspect the test item and obtain results in accordance with General Requirements, 5.2.6. Compare these data with the pretest data.

II-4 INFORMATION TO BE RECORDED

a. Test item identification (manufacturer, serial number, etc.).

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

(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:

(a) The anticipated areas of deployment.

(b) The test item configuration.

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 501.3) 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 501.3 (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 reproduce 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 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.

I-3.2 Choice of related test conditions. Having chosen the test procedure, it is necessary to choose the cycle, test duration, test item configuration, relative humidity, and any additional appropriate conditions.

a. Diurnal cycle. For Procedure I, two high temperature diurnal cycles are provided in table 505.3-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 $Btu/ft^2/hr$) and represents the hottest conditions exceeded not more than one percent of the hours in the most extreme month at the most severe locations in those portions of the earth under consideration. This cycle is used when there is a requirement for the test item to perform satisfactorily worldwide. The second cycle (Basic Hot) is less severe and peaks at an air temperature of 43°C (110°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 as described in Table 501.3-III of the High Temperature Method. 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. The test item shall be exposed to continuous 24-hour cycles of controlled simulated solar radiation and dry bulb temperature as indicated in table 505.3-I or as specified in the requirements documents. The number of cycles performed shall be either the minimum necessary to produce the peak response temperature of the test item's critical component(s) (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. It is suggested that, for most applications, the maximum test duration should be seven cycles. The data in Table 505.3-I should be applied directly if chamber control allows. Otherwise, a step approach as shown in Figure 505.3-1 may be used with no less than the number of increments shown, and the amount of radiation for each step shall be equally divided between zero and 1120 watts/m^2.

(2) Procedure II. 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.

TABLE 505.3-I. Temperature/solar radiation diurnal cycles[1]

Time	Hot-Dry		Basic Hot		Solar Radiation	
	°C	°F	°C	°F	W/m^2	Btu/ft^2/hr
0000	37	98	33	91	0	0
0300	34	93	32	90	0	0
0600	32	90	30	86	55	18
0900	38	101	37	99	730	231
1200	44	112	42	107	1120	355
1500	48	119	43	110	915	291
1600	49	120	43	110	730	231
1800	48	118	42	107	270	85
2100	41	105	36	97	0	0
2400	37	98	33	91	0	0
Max	49	120	43	110	1120	355
Min	32	90	30	86	0	0

NOTE: Data originally recorded in °F and converted to °C. Hence, table data conversion may not be consistent.

[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.

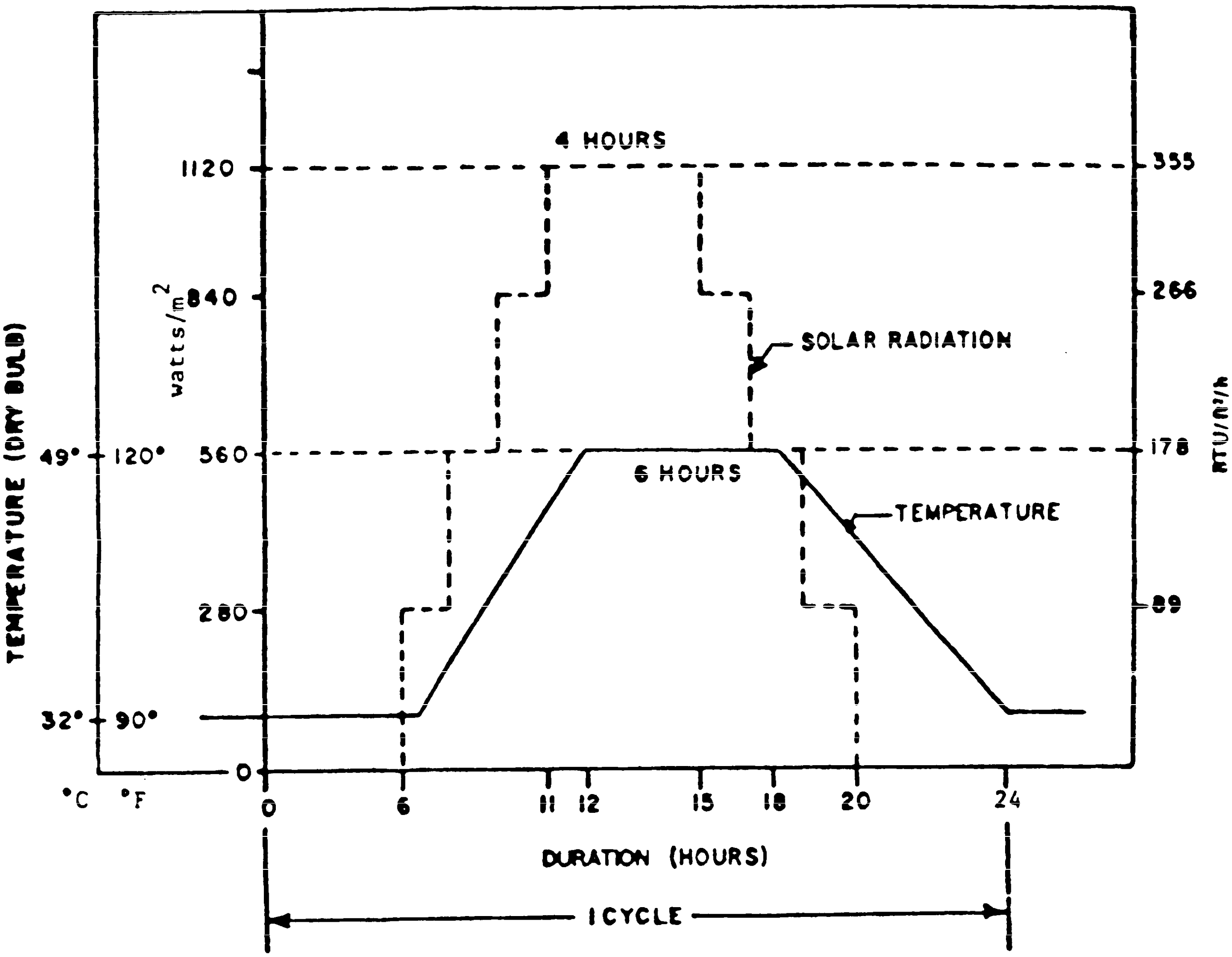

FIGURE 505.3-1 Simulated solar radiation cycle (Procedure I).

Figure 505.3-2 deleted.

c. Configuration. The test item configuration should be the same as its configuration during deployment 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 guidance. Review the requirements document(s). Apply any additional guidelines appropriate.

I-4 SPECIAL CONSIDERATIONS

I-4.1 Failure analysis (See General Requirements, 5.2.7.)

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. All actinic effects, regardless of whether or not they affect performance, durability, or required characteristics, will be recorded. 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.

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 ensure 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 ensure 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, 5.2.4.)

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 conditioning and continuation of the test from the point of the interruption.

(2) Procedure I. If an interruption occurs after 18 hours and 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. Place the test item in the chamber and stabilize it at standard ambient conditions (General Requirements, 5.1a).

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, 5.2.2, and required test item operational configuration (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, 5.2.6.

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 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 ensure that there is no mutual shading or blocking of airflow.

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

c. Sequence. (See General Requirements, 5.1.4.) 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 512.3) 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 506.3: 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.

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. Although various rainfall intensities have been measured in areas of heavy rainfall, a minimum rate of 10cm/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. Further information may be obtained from MIL-STD-210C.

Table 506.3-I Deleted.

c. Droplet size. Nominal drop-size spectra exist for instantaneous rainfall rates but, according to MIL-STD-210, 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 be predominantly in the range of approximately 0.5mm in diameter[1] (which is considered to be mist or drizzle rather than rain (reference e.)), to 4.5mm in diameter (reference i.).

d. Wind velocity. High rainfall intensities accompanied by winds of 18 m/s (40 mph) are not uncommon during storms. Unless otherwise specified or when steady state conditions are specified, this velocity is recommended. Gusts in excess of 18m/s may be required in the test plan. Where facility limitations preclude the use of wind, Procedure III may be used.

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 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.

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

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:

(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 507.3 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 results of a rain test. For nominally sealed items, increasing the test item temperature to about 10°C higher than the rain temperature at the beginning of each exposure period to produce subsequently a negative pressure inside the test item will provide a more reliable verification of its watertightness.

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.

Water temperature.

i. Additional guidelines.

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

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 Information to Determine Design and Test Requirements for Military Systems and Equipment, 9 January 1987.

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.

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.

i. Tattelman, P.I., and Sissenwine, N., Extremes of Hydrometeors at Altitude for MIL-STD-210B: Supplement Drop Size Distributions (1973), AFCRL-TR-73-0008, AFSG 253.

METHOD 506.3
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 2 and 4.5 millimeters (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 (40mi/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 28 (+3, -0) $L/m^2/h$ (0.7 $gal/ft^2/h$) dripping from a dispenser with drip holes on a 25.4 mm pattern (but without coalescence of the drips into a stream), as shown in figure 506.3-1. The drip area of the dispenser should be large enough to cover the entire top surface of the test item.

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 $\pm$1 in. from the test surface.[3]

II-1.2 Controls

a. For procedures I and II, verify the rainfall rate immediately before each test.

b. For procedure I, verify the air velocity immediately before each test.

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[3]From references f and g.

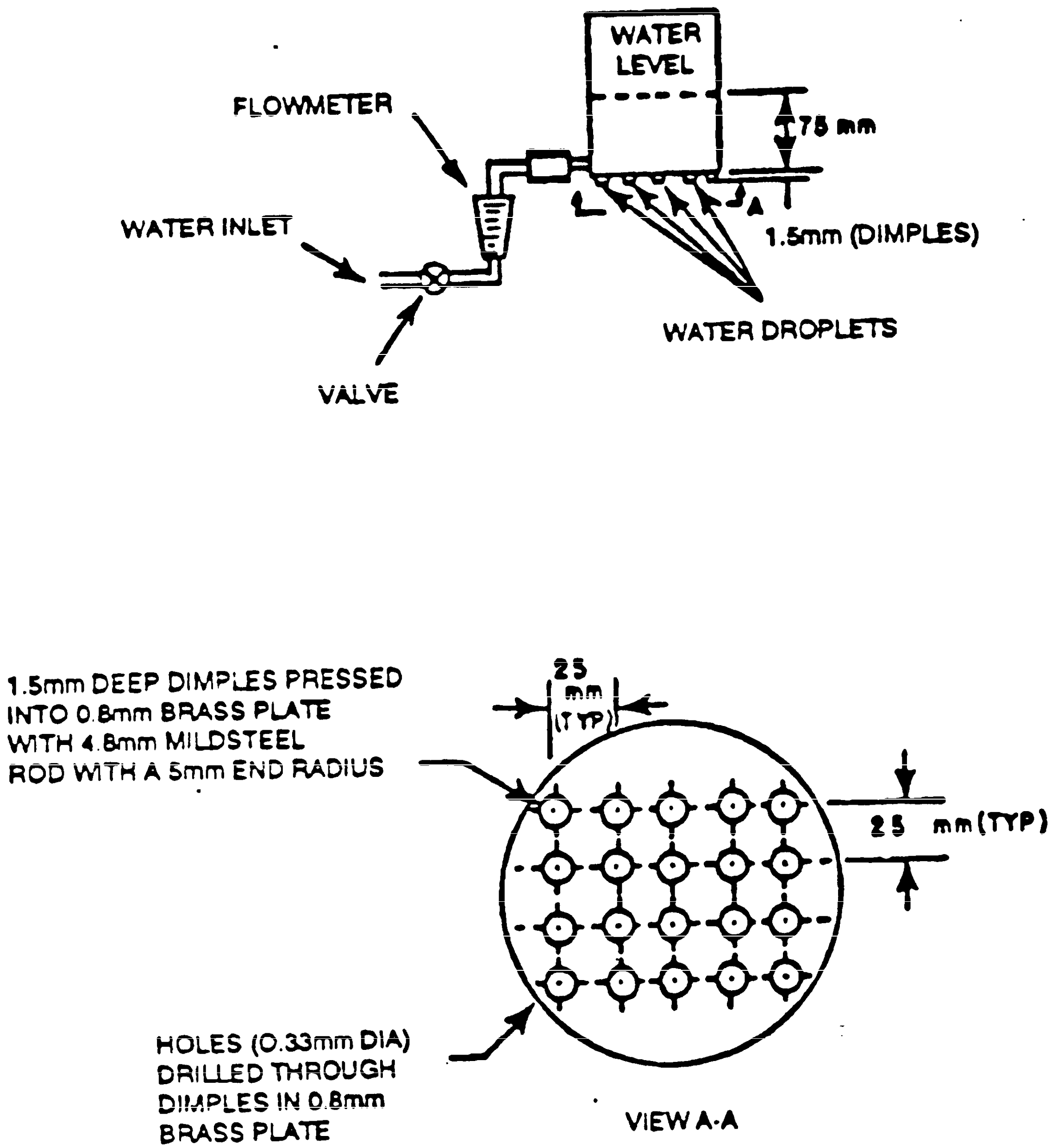

Figure 506.3-1. Details of Dispenser for Drip Test

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

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

II-1.3 Test interruption. (General Requirements, 5.2.4)

a. Undertest interruption. Interruption of a rain test is unlikely to generate any adverse effects. Normally continue the test from 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, 5.1a, 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, 5.2.2, and required test item configuration.

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

Step 6. Record the results for compliance with General Requirements, 5.2.6.

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.

METHOD 507.3
HUMIDITY

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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 to include surface effects such as corrosion, and biologic growth; changes in material properties due to moisture penetration, and electrical or mechanical performance effects due to condensation. Typical problems that can result from exposure to a warm, humid environment include:

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.

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: The tailoring process as described in section 4 of this document should be used to determine the appropriate tests and test variables.

a. Application. This method applies to equipment which is likely to be stored or deployed in a warm, humid environment, or an environment in which condensation is likely to occur, and exposure in the natural environment is not practical because of logistical, cost or schedule considerations. These conditions can occur year-round in tropical areas, and seasonally in mid-latitude areas, and in equipment subjected to combinations of changes in pressure, temperature and relative humidity.

b. Restrictions. This method may not reproduce all of the humidity effects associated with the natural environment. Therefore, it is preferable to test equipment at appropriate natural sites whenever practical. Specifically, this method does not address condensation resulting from changes of pressure and temperature for airborne or ground equipment; condensation resulting from black-body radiation (e.g., night sky effects); synergistic effects of humidity or condensation combined with biological and chemical contaminants, or liquid water trapped within equipment or packages and retained for significant periods.

c. Sequence. (See General Requirements, 5.1.4.) The test procedures of this method are potentially damaging. The position 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.

(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 combined high temperature and humidity levels more severe than those that occur in documented service scenarios. Its advantage is that it produces results quickly, i.e., it may generally exhibit humidity effects sooner than in either the natural or induced procedures; its disadvantage is that the effects may not accurately represent those that will be encountered in actual service. Care should be taken in interpreting the test results.

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 507.3-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 507.3-1 and 507.3-2 are approximations of cycles and are to be used if chamber control of table 507.3-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

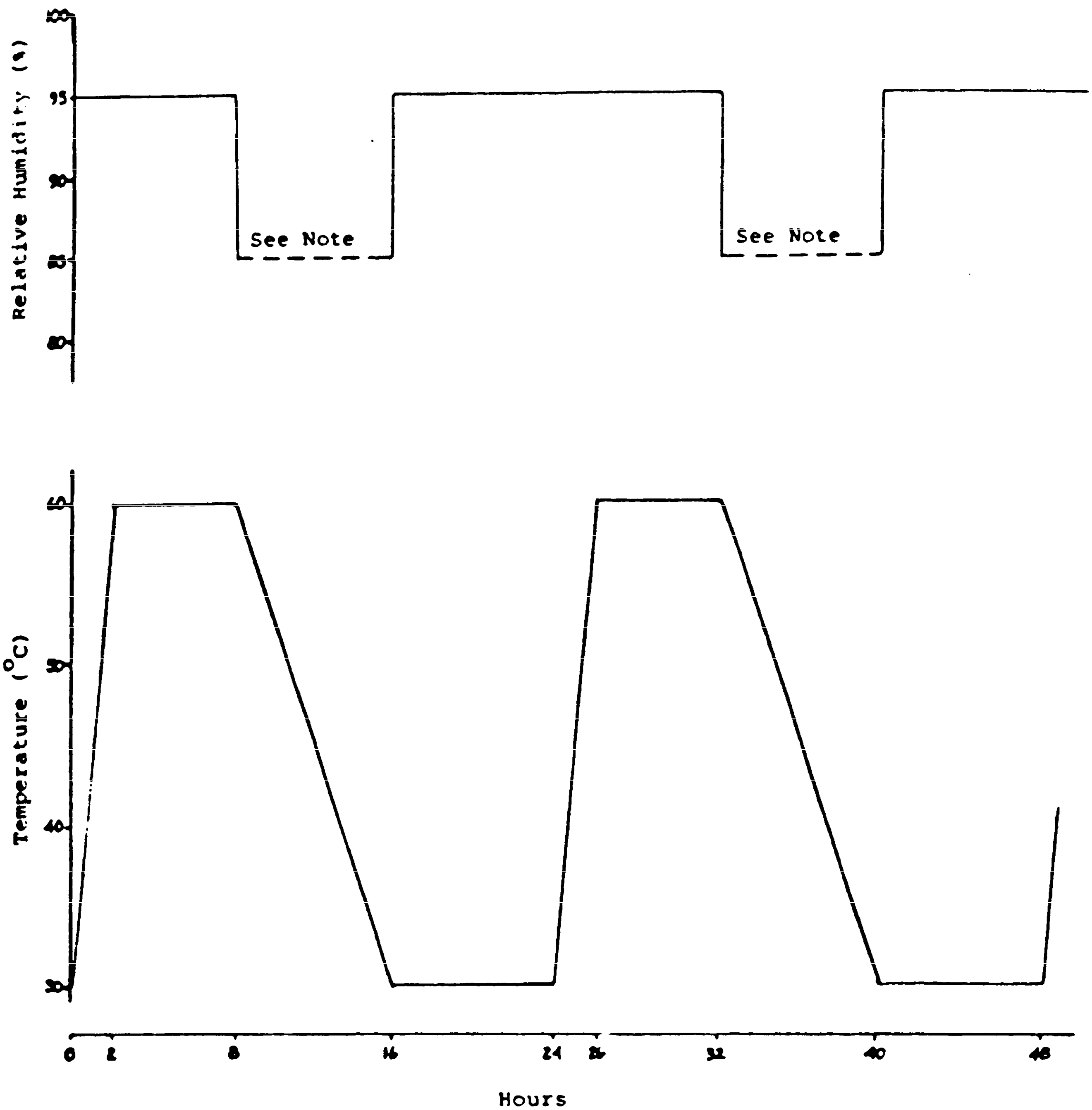
TABLE 507.3-I. High humidity diurnal categories. 1/

Time	Natural									Induced					
	Hot-Humid (Cycle 1)			High Humidity Constant (Cycle 2)			High Humidity Cyclic (Cycle 3)			Hot Humid (Cycle 4)			Cyclic High Humidity (Cycle 5)		
	Temp °F	Temp °C	RH %	Temp °F	Temp °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	33	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%.

NOTE: Data originally recorded in °F and converted to °C. Hence, table data conversion may not be consistent.



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

FIGURE 507.3-3. Aggravated temperature-humidity cycles.

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 monthly, year round. The frequency decreases as the distance from the equator increases. The midlatitudes can experience these conditions several days a month for two to three 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. The durations provided in Table 507.3-II are, in most cases, far less than necessary to provide an annual comparison.

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 507.3-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 507.3-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.

TABLE 507.3-II. Test Cycles (days).

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

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

(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 507.3-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 temperature/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 507.3-II, cycles 4 and 5, depending upon the geographical category to which the material 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) Tests 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 507.3-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 configurations. 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 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.

(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 Information to Determine Design and Test Requirements for Military Equipment, 9 January 1987.

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. STANAG 2895, Climatic Environmental Conditions Affecting the Design of Materiel for Use of NATO Forces.

METHOD 507.3
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, 5.1.1)

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 ±0.6°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, when physically possible, 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 4.6 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 1.7 meters per second (98 to 335 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 resistivity of not less than 250,000 ohm centimeters at 25°C. Its quality shall be determined at periodic intervals (not to exceed 15 days) to ensure 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.

Step 3. Conduct test item performance checks as required by the test plan and at the specified temperature-humidity conditions, and record the results.

Step 4. Repeat steps 2 and 3 for the number of cycles indicated in table 507.3-II unless otherwise directed by the requirements documents.

Step 5. At the end of the required number of cycles, adjust the temperature and humidity conditions to standard 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.

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 507.3-I for time 0000.

Step 4. Cycle the chamber air temperature and RH with time as shown in the appropriate cycle of table 507.3-I (or in the approximated curves of figure 507.3-2) through the 24-hour cycle.

Step 5. Repeat step 4 for the number of items indicated in table 507.3-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 507.3-3).

Step 1. Prepare the test item in accordance with General Requirements, 5.2.2, 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 two hours.

Step 3. Maintain the conditions of step 2 for not less than six hours.

Step 4. Maintain 85% or greater relative humidity and reduce the internal chamber temperature in eight hours to 30°C (86°F) and 95% ±5% relative humidity.

Step 5. Maintain the 30°C (86°F) and 95% ±5% relative humidity for an additional eight hours.

Step 6. Repeat steps 2,3,4, and 5 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. Test item identification (manufacturer, serial number, etc.).

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

c. Results of each performance check (pre-, during, and post-test) and visual examination (and photographs, if applicable).

d. Length of time required for each performance check.

e. Procedure and test levels used.

f. Exposure durations.

g. Time versus temperature and humidity.

a. Application. Since microbial deterioration is a function of temperature and humidity and is an inseparable condition of hot-humid tropics and 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.

NOTE: Although the basic (documented) resistance of materials to fungal growth is helpful in the design of new equipment, the combination of materials, the physical structure of combined materials, and the possible contamination of resistant materials during manufacture necessitate laboratory or 12-18 months of natural environment tests to verify the resistance of the assembled materiel to fungal growth.

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, 5.1.4.) This method should not be conducted after a salt fog test (method 509.3) or a sand and dust test (method 510.3). 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 biosusceptiblity 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 fungus 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

:ffects and physical interference are not likely to occur in the relatively short time 'rame of the fungus test, extension of the exposure period up to 84 days should be :onsidered if a greater degree of certainty (less risk) is required in determining the :xistence or effect of fungal growth.

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

(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 locuments. Apply any additional guidelines necessary.

.-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 listribution, and their stability. They must be used in all Method 508.4 tests. Other .pecies that can be used to supplement the basic five species may be found in STANAG .370[c], Allied Environmental Conditions and Test Publications 300, Method 308, Mould ;rowth.

a. Because the test item is not sterile before testing, other microorganisms will e present on the surfaces. When the test item is inoculated with the five test fungi, oth these and the other organisms will compete for available nutrients. It is not urprising to see organisms other than the test fungi growing on the test item at the end f the test.

b. Additional species of fungi may be added to those required in this test method. lowever, if additional fungi are used, their selection shall be based on prior knowledge f specific material deterioration. For example, Aureobasidium pullulans can be employed ecause of its known specificity for degrading paints.

-4 SPECIAL CONSIDERATIONS

-4.1 Failure analysis

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

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

(1) The extent of growth on the component(s) supporting growth. Table 508.4-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.

TABLE 508.4-1. Evaluation scheme for visible effects.[1]

Amount of Growth	Grade	Organic Substrates
None	0	Substrate is devoid of microbial growth.
Trace	1	Scattered, sparse or very restricted microbial growth.
Slight	2	Intermittent infestations or loosely spread microbial colonies on substrate surface. Includes continuous filament growth extending over the entire surface, but the underlying surfaces are still visible.
Moderate	3	Substantial amount of microbial growth. Substrate may exhibit visible structural change.
Severe	4	Massive microbial growth. Substrate decomposed or rapidly deteriorating.

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

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

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

[1]This scheme should be used as a guide, but exceptions may occur that require a more specific description.

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 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.

d. 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. 1 August 1979.

b. MIL-STD-210, Climatic Information to Determine Design and Test Requirements for Military Equipment. 9 January 1987.

c. NATO STANAG 4370, Environmental Testing, 1991.

METHOD 508.4

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 General Requirements, 5.1.1 and 5.1.2.

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.

II1.2 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 1.7 meters per second (98 to 335 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, 5.2.2)

d. Unless otherwise specified, the test chamber temperature and relative humidity shall be recorded continuously.

e. Readout charts shall be readable to within ±0.6°C (±1°F).

f. The desired humidity shall be generated by using steam or water having a resistivity of not less than 250,000 ohm centimeters at 25°C.

(1) 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, 5.2.4. 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 to ensure a "standard test" is conducted.

b. If the interruption occurs late in the test, 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 four hours or more, or

(c) There is evidence of deterioration of the fungal colonies on the control strips.

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 four hours or more, or

(c) There is evidence of deterioration 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 as 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, 5.2.2, 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.

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 1000ml

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.

a. Using aseptic techniques, prepare the spore suspension containing at least the following test fungi:

TABLE 508.4-II. Test fungi.

Fungi	Fungus Sources Identified No.	
	USDA[2]	ATCC[3]
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

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 four months at $6° \pm 4°C$ ($43° \pm 7°F$) after that time prepare subcultures and use them for the new stocks.

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[2] US Department of Agriculture (SEA/FR)
Northern Regional Research Center
ARS Culture Collection
1815 North University Street
Peoria, Illinois 61604

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

[3] American Type Culture Collection
12301 Parklawn Drive
Rockville, Maryland 20852

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.

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 though a 6 mm layer of glass wool contained in a glass funnel.

NOTE: This process should remove large mycelial fragments and clumps of agar.

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

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

m. Dilute the final washed residue with mineral-salts solution in such a manner that the resultant spore suspension shall contain 1,000,000 ±200,000 spores per 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° ±4°C (43° ±7°F) for not more than seven 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 specifies.

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

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

(4) After the incubation period, check the fungal growth.

NOTE: The absence of copious growth of any of the test organisms over the entire surface in each container will invalidate the results of any tests using these spores.

b. Test chamber environment

(1) 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 NATO STANAG 4370, AECTP 300, Method 308, 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 ensure 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.

c. Hold the test item in the operating chamber (at 24° to 31°C (75° to 88°F) and 95 ±5% RH) for at least four 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 for the duration specified at a relative humidity of 95 ±5% and an air temperature of 30° ±1°C (86° ±2°F).

b. After seven 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.

c. If the cotton strips show satisfactory fungal growth after seven 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.

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 eight 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. Test item identification (manufacturer, serial number, etc.).

b. Presence of evidence of fungal growth at the 7-day check and at the end of the test.

c. Location of fungi.

d. Narrative description of growth, including colors, areas covered, growth patterns, density of growth, and thickness of growth (and photographs, if necessary).

e. Test period.

f. Effect of fungi on performance or use:

(1) As received from chamber.

(2) After removal of fungus, if appropriate.

g. Test conditions.

h. Condition of test item at time of test.

i. All deviations from specified test conditions:

(1) Temperature.

(2) Humidity.

(3) Time.

(4) Air velocity.

(5) Other.

j. Whether the test items arrive directly from the manufacturer.

k. Test item history (previous tests).

l. Physiological or aesthetic considerations.

m. Types of fungi used.

n. Results of performance checks:

(1) Pretest.

(2) Post-test.

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. Experience has shown that alternating 24-hour periods of salt fog exposure and standard ambient (drying) conditions for a minimum of four 24-hour periods (2 wet and 2 dry), provides a more realistic exposure and a higher damage potential than does continuous exposure to a salt atmosphere. The number of cycles may be increased to provide a higher degree of confidence in the ability of the materials involved to withstand a corrosive environment.

I-4 SPECIAL CONSIDERATIONS

I-4.1 Failure criteria. In addition to the failure criteria of General Requirements, 5.2.7, 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, 1 August 1979.

b. MIL-STD-210, Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment. 9 January 1987.

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

METHOD 509.3
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 $.34m^3$ (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 $0.28m^3$ (10 ft^3) of chamber volume per 24 hours.

When chambers with a volume considerably in excess of $0.34m^3$ (12 ft^3), are used the conditions specified may require modification.

NOTE: A filter fabricated of noncorrosive materials similar to that shown in figure

509.3-1 shall be provided in the supply line and immersed in the salt solution reservoir as illustrated in figure 509.3-2.

d. A minimum of 2 salt fog collection receptacles. One is to be at the perimeter of the test item nearest to the nozzle, and the other also at the perimeter of the test item but at the farthest point from the nozzle. If multiple nozzles are used, the same principles apply. Receptacles shall be placed so that they are not shielded by the test item and will not collect drops of solution from the test item or other sources.

II-1.2 Controls

a. Before injection into the test section, the salt solution shall be heated to within ±6°C (±10°F) of the test section temperature at the time of injection.

b. All water used during the salt fog tests shall be from steam or distilled, demineralized, or deionized water, and have a pH between 6.5 and 7.2 at 25°C, or have a resistivity of not less than 250,000 ohm centimeters at 25°C.

c. Test section air circulation: Air velocity in test chambers shall be minimal (essentially zero).

d. The oil and dirt-free compressed air used to produce the atomized solution shall be preheated (to offset the cooling effects of expansion to atmospheric pressure) and pre-humidified such that the temperature is 35 ± 1°C and the relative humidity is in excess of 85% at the nozzle (see table 1).

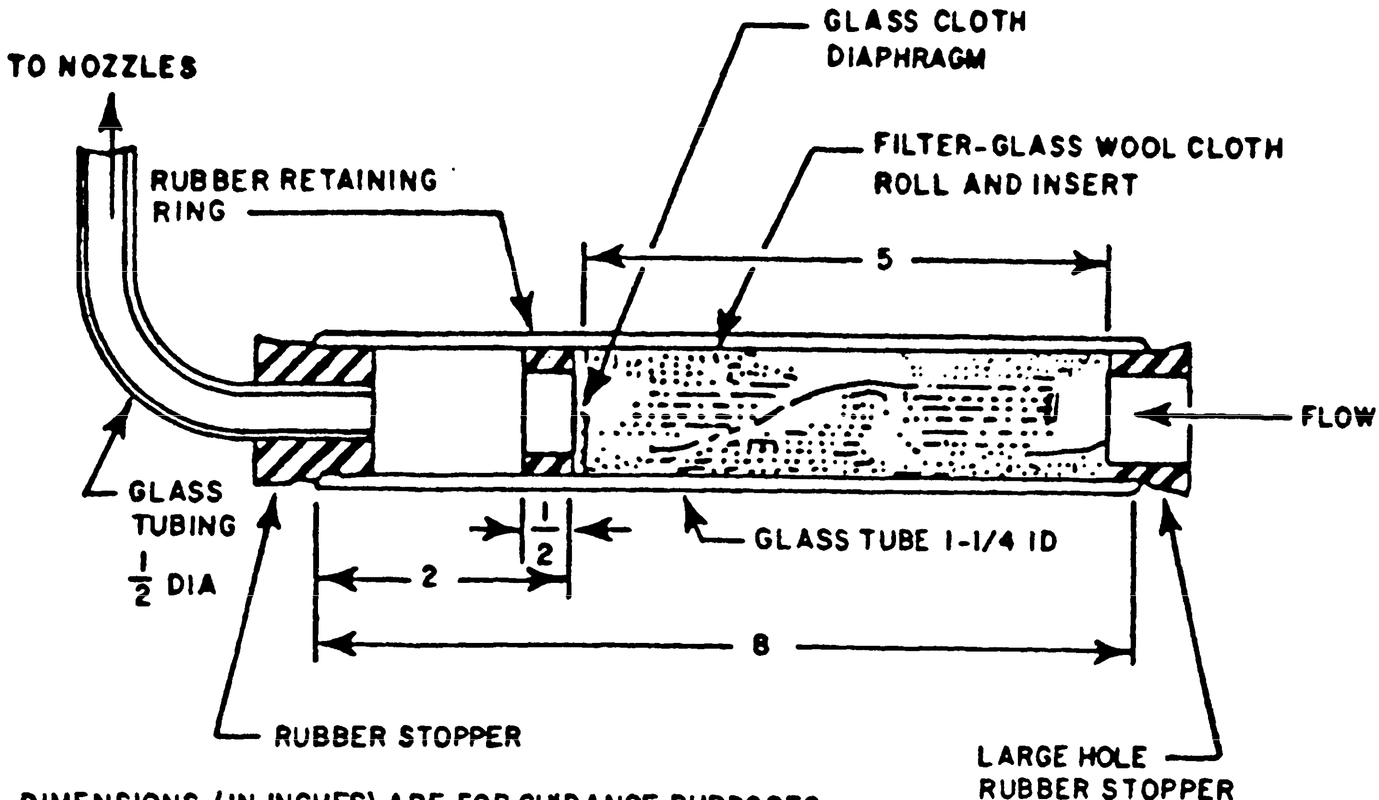
Table 509.3-I. Temperature and pressure requirements for operation at 35°C

Air Pressure (kPa)	83	96	110	124
Preheat temperature (°C) (before atomizing)	46	47	48	49

II-1.3 Test interruptions. (See General Requirements, 5.2.4)

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 · exceed allowable tolerances away from standard ambient conditions, the test condition: ould be stabilized to within tolerances and held at that level until a complete visual examination and technical evaluation can be made to determine the



DIMENSIONS (IN INCHES) ARE FOR GUIDANCE PURPOSES.

FIGURE 509.3-1. SALT SOLUTION FILTER.

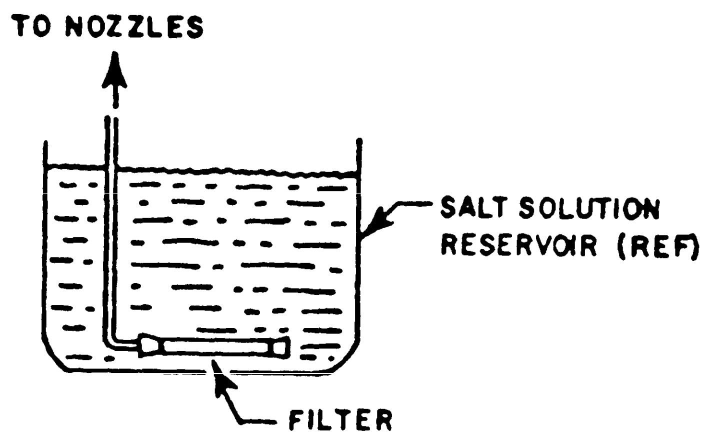


FIGURE 509.3-2. LOCATION OF SALT SOLUTION FILTER.

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 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-2.1 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 509.3-3) 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 five 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 at least one 24-hour period or until proper operation and salt fog collection can be verified. 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, 5.2.2.

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.

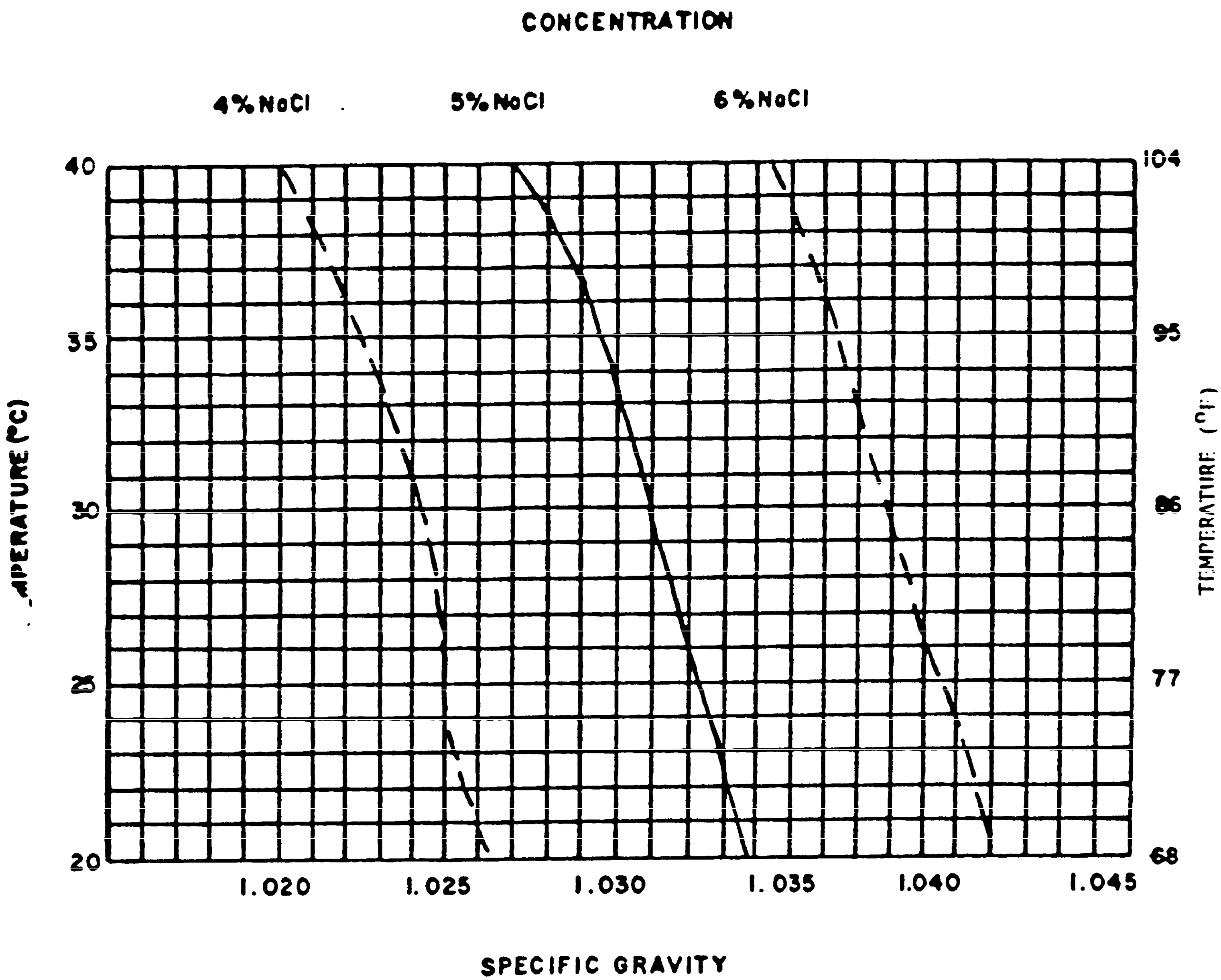


FIGURE 509.3-3. VARIATIONS OF SPECIFIC GRAVITY OF SALT (NaCl) SOLUTION WITH TEMPERATURE.

d. Metallic surfaces.

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 Requirement, 5.2.1.

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.

b. Configure the test item as specified in the test plan.

c. Insert the test item into the test chamber (General Requirements, 5.2.2).

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 two hours before introducing the salt fog.

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 the 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. Test item identification (manufacturer, serial number, etc.).

b. Previous test methods to which the test item was subjected.

c. Results of each visual examination and performance checkout performed on the test item.

d. Areas of the test item visually and functionally examined and an explanation of their inclusion.

e. Areas of the test item not visually and functionally examined and an explanation of their exclusion.

f. Test chamber operational information (interruptions, time schedule, etc.).

g. Test variables:

(1) Salt solution pH.

(2) Salt solution fallout rate ($ml/cm^2/hr$).

(3) Resistivity of initial water and type of water.

h. Preliminary failure analysis.

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[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.

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 501.3

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:

Solubilities < 2%, PH between 6 and 8	5%
Ferric oxide (Fe_2O_3)	10 ±5%
Aluminum oxide (Al_2O_3)	20 ±10%
Silicon dioxide (SiO_2)	Silicon dioxide and remaining impurities

[1] From MIL-STD-210

(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 and (at least 95% by weight SiO_2). The amount 1.0% ±0.5% of the sand shall be retained by a 20 mesh screen (850μm), 1.7% ±0.5% by a 30 mesh screen (590μm), 14.8% ±1% by a 40 mesh screen (420μm), 37.0% ±1% by a 50 mesh screen (297μm), 28.6% ±1% by a 70 mesh screen (210μm), 12.7% ±1% by a 100 mesh screen (149μm), 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 ±7g/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[2] shall be as follows unless otherwise specified.

(a) For materiel likely to be used close to aircraft (such as helicopters) operating over unpaved surfaces: 2.2 to ±0.5g/m^3 (0.0623 ±0.015 g/ft^3).

(b) For materiel never used or never exposed in close to operating aircraft, but which may be found near operating surface vehicles: 1.1 ±0.25g/m^3 (0.033 ±0.0075 g/ft^3).

(c) For materiel that will be subjected only to natural conditions: 0.177g/m^3 (0.0050 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:

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[2] See reference a.

(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. Durations

(1) For blowing sand tests, 90 minutes per face is considered to be a minimum (see I-3.2g).

(2) For blowing dust tests, six hours at 23°C (73°F) and six 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 ensure 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 other test items, 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:

(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 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. Duration.

k. Additional guidelines.

I-5 REFERENCES

a. MIL-STD-210, Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment, 9 January 1987.

b. 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.

c. Industrial Ventilation, A Manual of Recommended Practice, Committee on Industrial Ventilation, Box 16153, Lansing, MI 48901.

METHOD 510.3
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, 5.1.1.) Figures 510.3-1 and 510.3-2 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).

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, dust 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 ensure 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 510.3-1.

(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 conditioning 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 Controls

a. Test parameters. 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, 5.1.1 and 5.1.2. 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. Relative humidity. Relative humidity in the test section shall be less than 30 percent throughout the conduct of the test.

c. Test variables. 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 Test interruption. (See General Requirements, 5.2.4).

a. Undertest interruption. 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.

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 sections 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, 5.2.2.

Step 3. Stabilize the test item at standard ambient conditions (General Requirements, 5.1a).

Step 4. Conduct a complete visual examination of the test item with special attention to sealed areas and minute openings.

METHOD 511.3
EXPLOSIVE ATMOSPHERE

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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: The tailoring process as described in section 4 of this document should be used to determine the appropriate tests and test variables.

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.

(1) This test utilizes an explosive mixture that has a relatively low flash point which may not be indicative of some actual fuel-air mixtures.

(2) 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.

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.

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 that may be used as an indicator of a potential problem. 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 for 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.

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 511.3-1).

(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) =

$$(2.74 x\ 10^{-4}) \left[\frac{(net\ chamber\ vol\ (liters))\ x\ (chamber\ pressure\ (pascals))}{(chamber\ temp\ (K))\ x\ (specific\ gravity\ of\ n\text{-}hexane)} \right]$$

(2) In English units:

Volume of 95 percent n-hexane (ml) =

$$(96.38) \left[\frac{(net\ chamber\ vol\ (ft^3))\ x\ (chamber\ pressure\ (psia))}{(chamber\ temp\ (R))\ x\ (specific\ gravity\ of\ n\text{-}hexane)} \right]$$

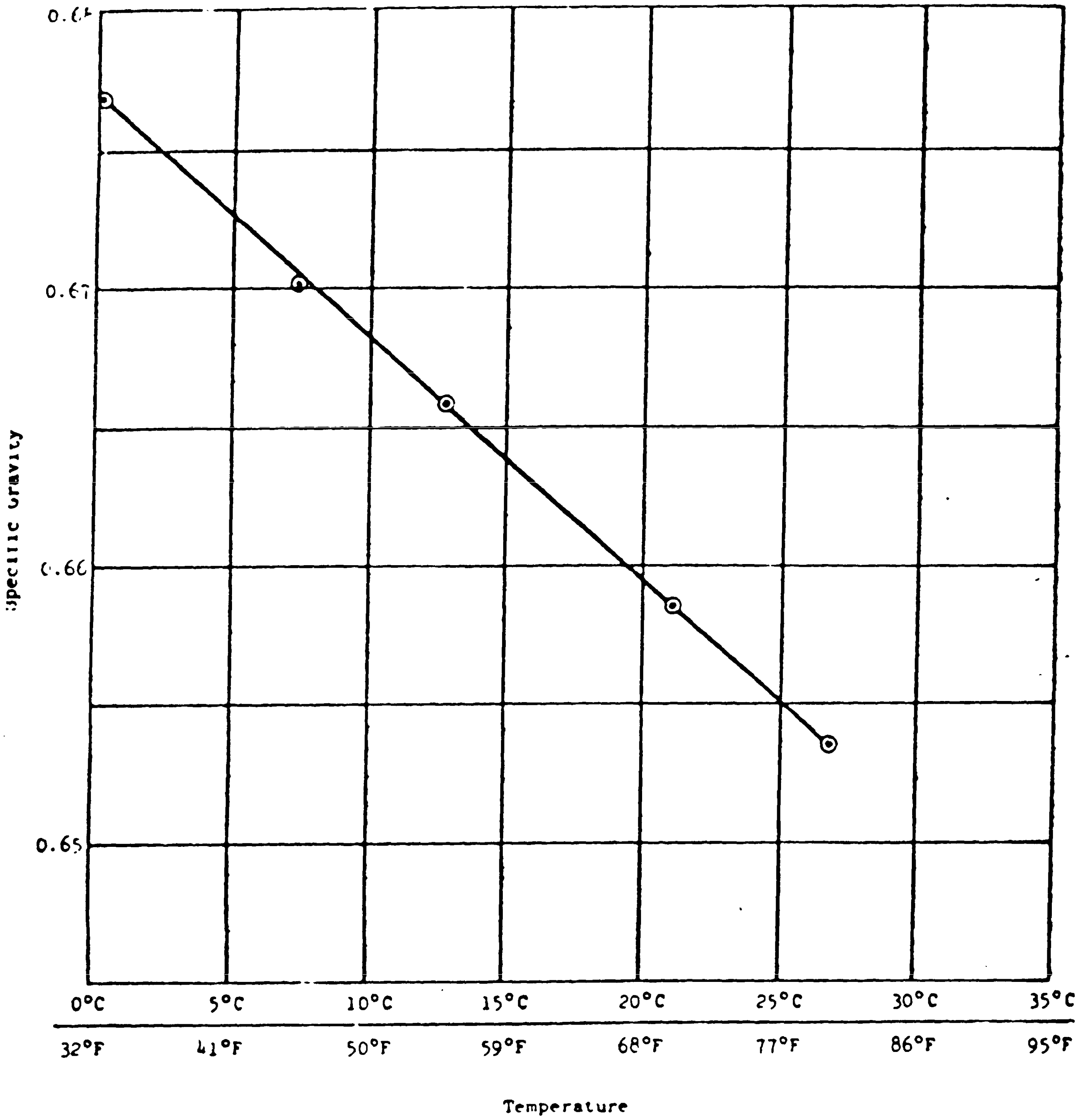


FIGURE 511.3-1. Specific gravity of n-hexane.

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 34percent 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 item is intended for use at or within 1000m of sea level (e.g., shipboard), testing at a facility within 1000m of sea level is recommended.

I-3.2.7 Definitions. For the purpose of this document, the following definitions apply:

a. Test altitude. The nominal simulated height(s) above sea level at which the test item will be tested, i.e., the maximum altitude identified in paragraph 2.3.6, and all altitudes below it in increments of 3000m.

b. Simulated altitude. Any height other than the test altitude that is produced in the test chamber.

I-4 SPECIAL CONSIDERATION

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 atmosphere. 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 constitutes 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, pp27-29.

d. Kuchta, J.M. Summary of Ignition Properties of Jet Fuels and Other Aircraft Combustible Fluids. 1975. AFAPL-TR-75-70, pp9-14. DTIC number AD-A021-320.

e. ASTM E 380-79. Standard for Metric Practice.

METHOD 511.3
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, 5.2.2.

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 if 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.

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 internal volume by more than ±5%.

Step 3. Provide a 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. Ensure 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 633mm Hg, make provisions to pressurize the test chamber to at least 633mm Hg. Ground level pressures referred to in II-3.2 step 5 shall consist of pressures from 633 to 800mm Hg, inclusive.

Step 7. Perform steps 4 and 5 of II-2.1.

II-3 PROCEDURES

II-3.1 Procedure I - Operation in explosive atmosphere

Step 1. Perform the preparation for test.

Step 2. Seal the chamber with the test item mounted inside.

Step 3. Raise the ambient temperature of air inside the chamber to that determined in I-3.2.3. Wait until the temperatures of the test item and test chamber inner walls come to within 11°C of the chamber ambient air temperature.

Step 4. Adjust the chamber air pressure to simulate the test altitude plus 2000 meters, as given in I-3.2.6, to allow for introducing, vaporizing and mixing the fuel with the air.

Step 5. Slowly introduce the required quantity of n-hexane into the test chamber as determined by I-3.2.4.

Step 6. Circulate the test atmosphere and continue to reduce the simulated chamber altitude for at least three minutes to allow for complete vaporization of fuel and the development of a homogeneous mixture.

Step 7. At 1000m above the test altitude, operate the test item. Operation shall be continuous from step 7 through step 9. Make and break electrical contacts as frequently as reasonably possible.

Step 8. Slowly decrease the simulated chamber altitude by bleeding air into the chamber. Change the simulated altitude at a rate no faster than 100 meters per minute.

Step 9. Stop the altitude change at 1000 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.

a. If the simulated altitude reached in Step 9 is 3000 meters or greater above site level, continue testing at the next test altitude which is defined as 3000 meters below the just-completed test altitude. Repeat Steps 5-11 using the new test altitude.

b. If the simulated altitude reached in Step 9 is below 3000m, repeat Steps 5-10[1] using site level as the last test altitude, and then go to Step 12.

Step 12. Document test results per 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 the test item inside.

Step 3. Raise the ambient air temperature inside the chamber.

Step 4. Wait until the temperatures of the test item and test chamber inner walls come to within 11°C (20°F) of the chamber ambient air temperature.

Step 5. Change the chamber air pressure to 2000 meters of simulated altitude above the site ambient pressure (i.e., ground level).

Step 6. Slowly introduce the required quantity of n-hexane into the test chamber to obtain optimum fuel-vapor/air mixture at site ambient pressure or as given in I-3.2.4b for n-hexane.

Step 7. Circulate the test atmosphere and continue to reduce the simulated chamber altitude for at least three minutes to allow for complete vaporization of fuel and the development of a homogeneous mixture within the test item and within the test chamber.

[1]It may be necessary to perform Step 4 first if insufficient altitude remains for fuel introduction.

Step 8. Slowly decrease the simulated chamber altitude to return the pressure altitude to site ambient pressure (i.e., ground level).

Step 9. Energize the internal case ignition source and 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 10. If the explosion inside the test item's case did not propagate to the fuel/air mixture outside the test item:

a. Repeat steps 5 through 10 four times if the test item's case is not in excess of 0.02 times the chamber volume;

b. If the test item volume is equal to or greater than 0.02 times the chamber volume, purge the chamber and test item of air/fuel vapor and repeat steps 2 through 10 four times.

Step 11. 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 12. Document the test results.

II-4 INFORMATION TO BE RECORDED

a. Test item identification (manufacturer, serial number, etc.).

b. Test procedure number.

c. Chamber pressure and temperatures at each test point (simulated altitude).

d. For Procedure II, the locations of glow plugs or spark gaps installed inside test items.

e. For Procedure II, the energy requirement for the glow plug or spark gaps for operation.

f. The quantity of fuel required at each test point.

g. The off/on cycling rate for the test equipment.

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.

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 REFERENCES

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

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

METHOD 512.3
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° ±10°C (64° ±18°F).

b. The temperature of the test item shall be 27° +2°C (49° ±4°F) above the temperature of the water.

c. The temperature of the water shall not change more than 3°C (5°F) throughout the duration of the test.

II-1.3 Test interruption (See General Requirements, 5.2.4)

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.

TABLE 513.4-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 513.4-1					
			Fore	Aft	Up	Down	Lateral: Left	Lateral: 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	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/	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.

TABLE 513.4-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 513.4-1)					
			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	5.0	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.

I-3.7 Fighter and attack aircraft. The test levels as determined from tables 513.4- I and 513.4-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.

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 513.4-I. ΔN_z, the additional load induced by roll, is computed as follows:

$$\Delta N_z = \frac{d}{g}\ddot{\phi}$$

Where: d = lateral distance of equipment from aircraft CG in meters
$\ddot{\phi}$ = absolute value of maximum roll acceleration in rad/s^2 (if unknown, use $\ddot{\phi}$ = 20 rad/s^2)
g = 9.80 m/s^2

For structural test levels, multiply the accelerations by a factor of 1.5.

For Procedure II (Operational Test), the test levels are the up and down levels as determined in table 513.4-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 513.4-I. ΔN_y, the load induced by roll, is computed as follows:

$$\Delta N_y = \frac{d}{g}(\dot{\phi})^2$$

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/s^2

For structural test levels, multiply the accelerations by a factor of 1.5.

For Procedure II (Operational Test), the test levels are the lateral left and lateral right test levels as determined in table 513.4-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 513.4-I. ΔN_z, the additional load induced by pitch change, is computed as follows:

$$\Delta N_z = \frac{d}{g}\ddot{\phi}$$

Where: d = fore or aft distance of equipment from CG in meters
$\ddot{\phi}$ = maximum pitch acceleration in rad/s^2 (if unknown, use $\ddot{\phi}$ = 5 rad/s^2)
g = 9.80 m/s^2

For structural test levels, multiply the accelerations by a factor of 1.5. For Procedure II (Operational test), the test levels are the up and down levels as determined in table 513.4-II plus ΔN_z.

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 513.4-I. ΔN_x, the load induced by pitch change, is computed as follows:

$$\Delta N_x = \frac{d}{g}(\dot{\phi})^2$$

Where: d = fore or aft distance of equipment from the aircraft CG in meters
$\dot{\phi}$ = maximum pitch velocity in rad/s (if unknown, use $\dot{\phi}$ = 2.5 rad/s)
g = 9.80 m/s^2

For structural test levels, multiply the accelerations by a factor of 1.5. For Procedure II (Operational Test), the test levels are the fore and aft test levels as determined from table 513.4-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 513.4-I. ΔN_y, the load induced by yaw, is computed as follows:

$$\Delta N_y = \frac{d}{g}(\ddot{\psi})$$

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 structural test levels, multiply the accelerations by a factor of 1.5. For Procedure II (Operational Test), the test levels are lateral right test levels as determined in table 513.4-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 513.4-I. ΔN_x, the load induced by yaw change, is computed as follows:

$$\Delta N_x = \frac{d}{g}(\dot{\psi})^2$$

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 structural test levels, multiply the accelerations by a factor of 1.5. For Procedure II (Operation Test), the test levels are fore and aft test levels as determined from table 513.4-II or ΔN_x, whichever is higher.

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 that test level. The total test duration 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 functionally 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 with 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 determine 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 than the normal service use environment. 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 1965. AFFDL-TR-65-197. DITC number AD-625-543.

TABLE 514.4-I. Vibration environment categories. 1/

Division	Category	Description	Test Procedure	Test Conditions 2/
Transportation/ Cargo-Induced Vibration	1. Basic Transportation	Equipment carried as secured cargo. 3/	I	I-3.3.1
	2. Large Assembly Transport	Very large shelters, van, and trailer systems as an alternative to shaker testing.	II	I-3.3.2
	3. Loose Cargo Transport 4/	Equipment carried on ground vehicles as unrestrained cargo. 5/	III	I-3.3.3
Application-Induced Vibration	4. Propeller Aircraft and turbine engines	Equipment installed in propeller aircraft and on turbine engines manned and unmanned.	I	I-3.4.1
	5. Jet Aircraft	Equipment installed in jet aircraft, manned and unmanned.	I	I-3.4.2
	6. Helicopter	Equipment installed in helicopters.	I	I-3.4.3
	7A. External Stores	Assembled stores externally carried on jet aircraft (including captive missile flight).	IV	I-3.4.4
	7B. External Stores	Equipment installed in stores externally carried on jet aircraft.	I	I-3.4.5
	7C. External Stores	Assembled stores externally carried on helicopters.	I	I-3.4.6
	8. Ground Mobile	Equipment installed in wheeled vehicles, trailers, and tracked vehicles.	I	I-3.4.7
	9. Marine	Equipment installed in ships or other naval watercraft.	I	I-3.4.8
	10. Minimum Integrity Test	a. All other. b. Vibration-isolated equipment.	I	I-3.4.9

1/ Also referred to as "equipment categories".
2/ The provisions of section I-4 apply to all vibration tests.
3/ Secured cargo. Cargo which is securely tied or blocked in all three axes with respect to the bed of the transport vehicle.
4/ Loose cargo. Cargo which is not tied, blocked, or restrained when placed on the bed of the transport vehicle.
5/ Restrained cargo. Cargo which is blocked or tied in the two horizontal axes with respect to the bed of the transport vehicle.

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 operating.

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.

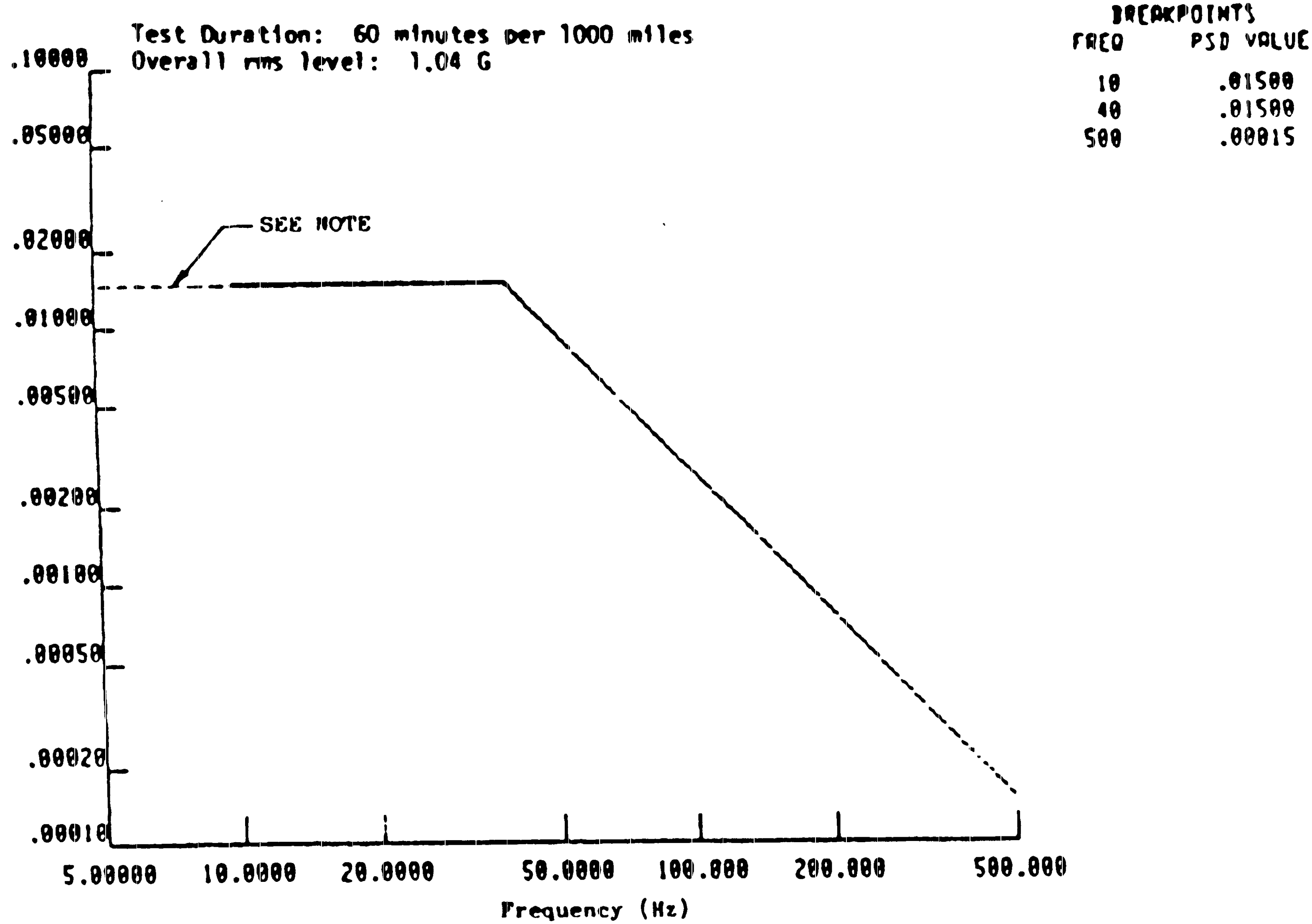
I-3.2 Choice of related test conditions. Guidance for setting test values is given below with the discussion of each vibration environment category. The provisions of section I-4 apply for each test designated under this method.

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.

I-3.3 TRANSPORTATION VIBRATION

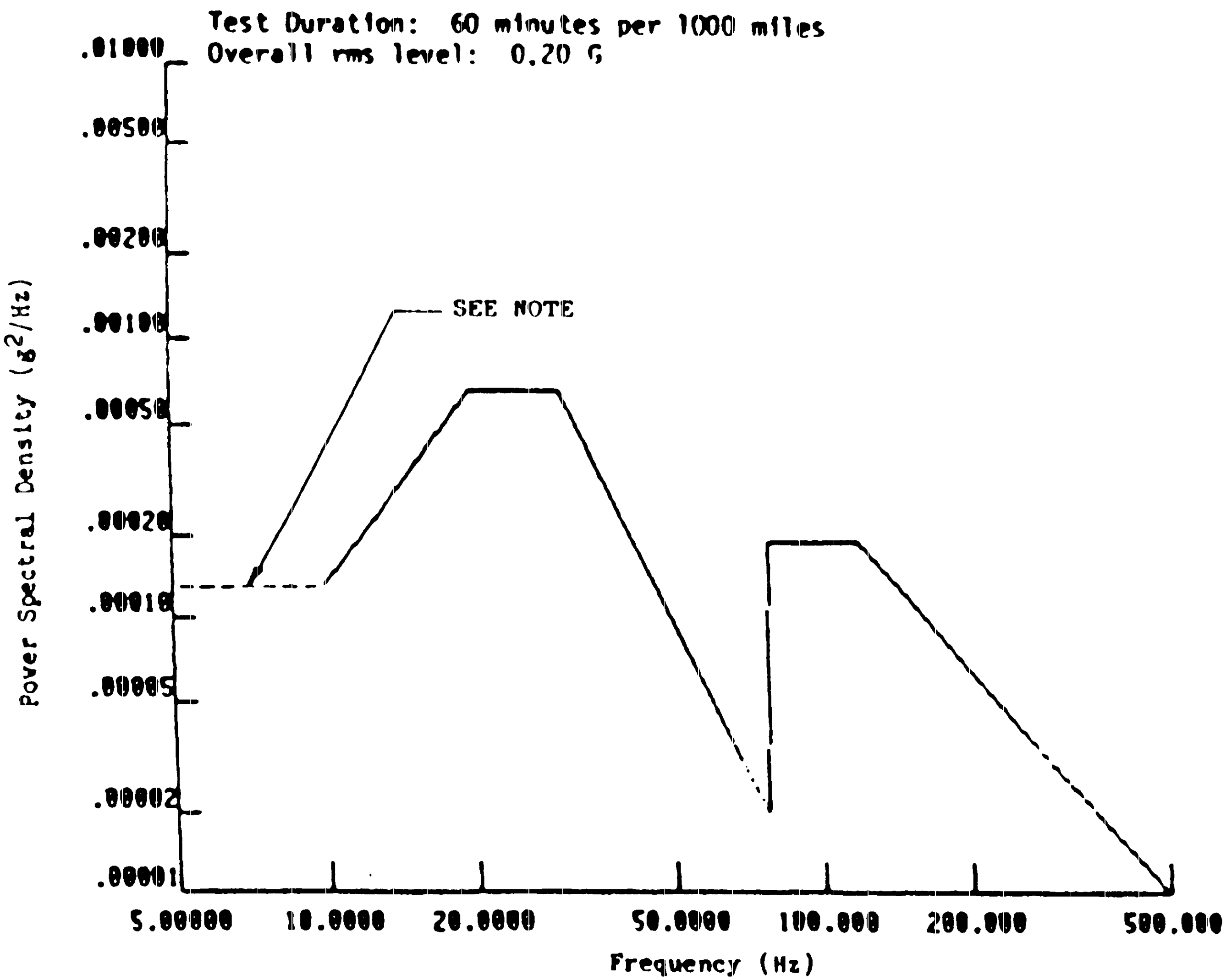
I-3.3.1 Category I - Basic transportation

I-3.3.1.1 Application. All equipment shipped as secured cargo by land, sea or air will encounter this environment.



NOTE: If the test item is resonant below 10 Hz extend the curve to the lowest resonant frequency.

Figure 514.4-1. Basic transportation, common carrier environment, vertical axis.



BREAKPOINTS

FREQ	PSD VALUE
10	.00013
20	.00065
30	.00065
78	.00002
79	.00019
120	.00019
500	.00001

NOTE: If the test item is resonant below 10 Hz extend the curve to the lowest resonant frequency.

FIGURE 514.4-2. Basic transportation, common carrier environment, transverse axis.

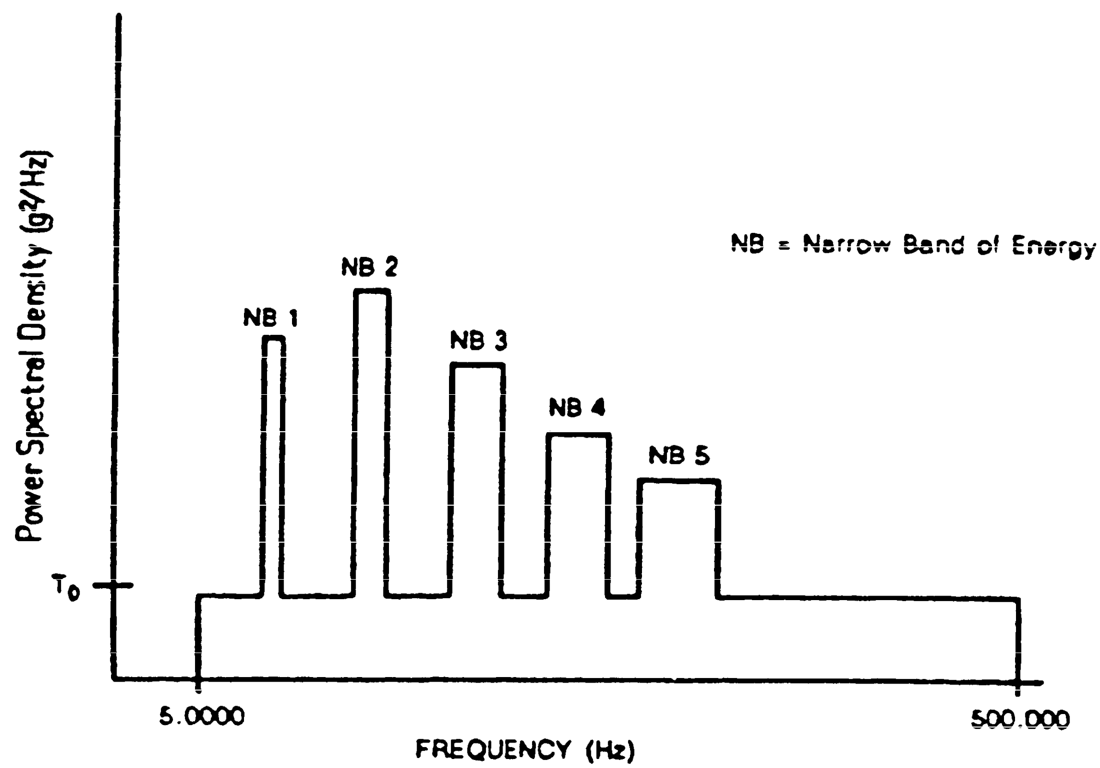


FIGURE 514.4-5. Representative spectral shape, tracked vehicle.

```
Port                        Corps                   Forward                Using
Staging    375 miles        Storage   125 miles     Supply    16 miles     Unit    16 miles
Area       (---------->     Area      (------->     Point     (--------->  (---------------->
(PSA)                       (CSA)                   (FSP)                  :
  :                                                   :                    :
  :                                                   :                    :
  :            Trucks, Semitrailers                   :    Two-Wheeled     :  Two-Wheeled
  :   (------------------------------------>          :    Trailers        :  Trailers or
  :                                                   : (------------->    :  M548 Cargo
  :                                                   :                    :  Carrier
```

FIGURE 514.4-6. Typical mission/field transportation scenario.

I-3.3.2 Category 2 - Large assembly transport.

I-3.3.2.1 Application. 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 consist 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.

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 installed 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. Provide instrumentation to measure the vertical axis acceleration time history on the shelter floor and at any other locations of concern.

paper overlaid on the surface of mineral salts agar

I-3.3.2.2 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 II. 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.

I-3.3.2.3 Test duration. The test duration shall be as specified in procedure II or until the test item has received the exposure representative of the anticipated deployment scenarios, whichever is longer.

I-3.3.3 Category 3 - Loose cargo transport.

I-3.3.3.1 Application. This 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. 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 with 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 as described in procedure III. This test has few tailoring options and the selection of the test equipment must be based upon the desired end result.

I-3.3.3.2 Test levels. The basic movement of the bed of the test equipment where the test item is placed is a 2.54-cm diameter 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.)

I-3.3.3.3 Test conditions. The test conditions for this procedure are based on the results of two methodology studies (References 56 and 57). The former study determined that testing of packaged items on a package tester in a circular synchronous mode with a plywood-covered bed at 300 rpm provides a reasonable simulation of the loose cargo transportation environment. A test duration of 20 minutes represents a scenario of 240 km (all three axes simultaneously) of truck transportation (which encompasses the severity and duration of the two-wheeled trailer and tracked vehicle environments), over the various road profiles found in the transport scenario from the Corps storage area to a using unit (see figure 514.4-6). The latter study determined that testing of circular cross-section items and unpackaged equipment on a package tester with a steel-covered bed and in the same mode and speed as for packaged items, provides a reasonable simulation of the loose cargo transportation environment for those items. The test duration of 20 minutes again represents 240km as for the packaged items.

I-3.4 Operational environments

I-3.4.1 Category 4 - Propeller aircraft and turbine engines.

I-3.4.1.1 Background information. Service vibration frequency spectra for equipment installed in propeller aircraft consist of a broadband background with superimposed narrow band spikes. The background spectrum results from various random sources (see I-3.4.2) with many periodic (not pure sinusoidal) components due to the rotating elements (engines, gearboxes, shafts, etc.) associated with turboprops. The spikes are produced by the passage of pressure fields rotating with the propeller blades. These occur in relatively narrow bands 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).

Most current propeller 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 514.4-7. These spikes have an associated bandwidth because there is minor rpm drift and because the vibration is not pure sinusoidal (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 514.4-7 must be modified if used for these.

These vibration environments can be 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 coincidence 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.

I-3.4.1.2 Test level. Whenever possible, flight vibration measurements should be used to develop vibration criteria for laboratory tests. In the absence of flight measurements, the test levels of table 514.4-II can be used with the spectra of figure 514.4-7. 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.

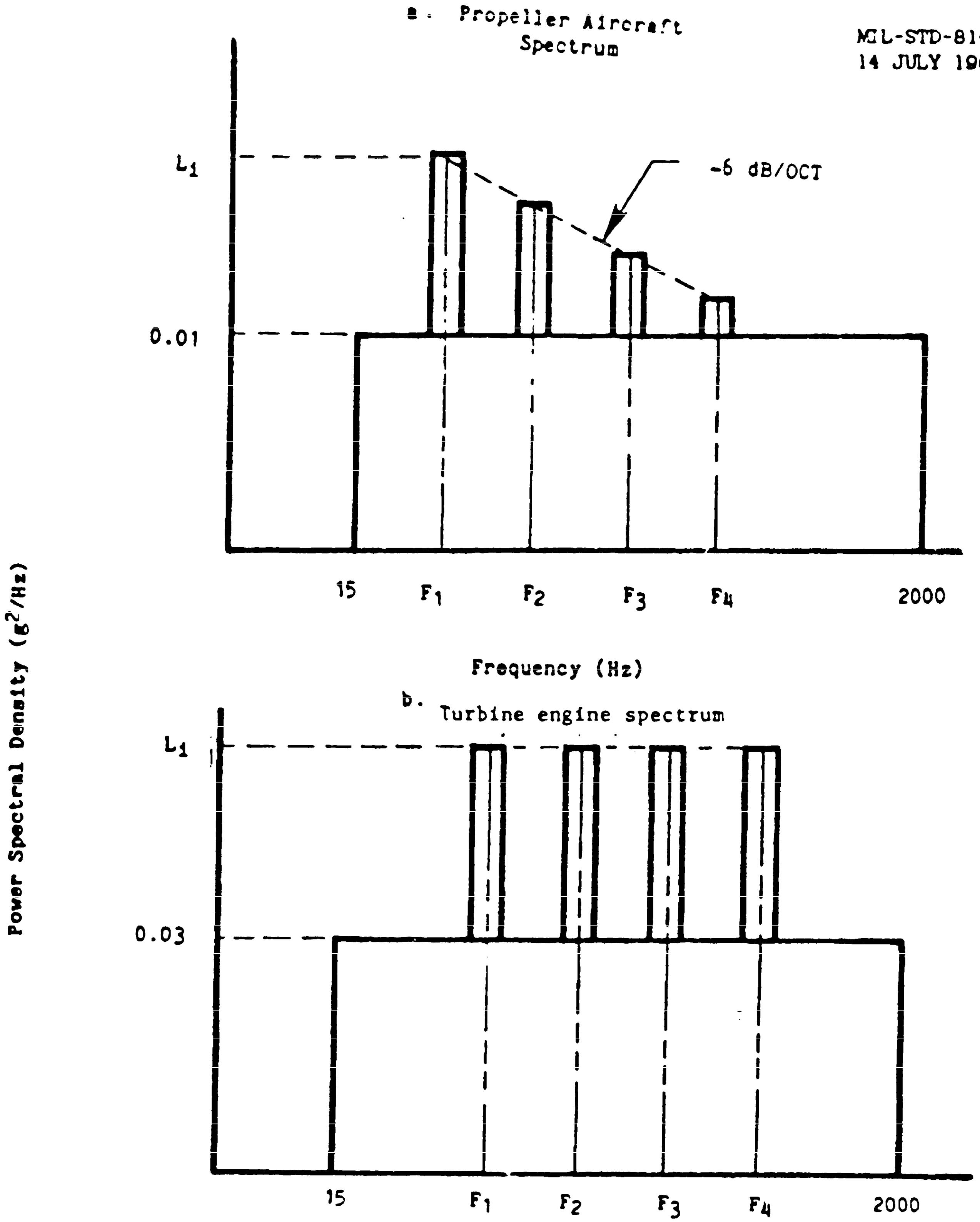


FIGURE 514.4-7. Suggested vibration spectra for propeller aircraft and equipment on turbine engines.

I-3.4.2.2 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 514.4-III and figure 514.4-8. Use the envelope of the worst case aerodynamic and worst case jet noise induced vibrations.

I-3.4.2.3 Test duration. Test durations should be developed from field data and/or intended usage. The guidance of I-3.4.9, I-4.3, I-4.6, and I-4.7 applies.

I-3.4.3 Category 6 - Helicopter installed.

I-3.4.3.1 Background information. Helicopter vibration is characterized by dominant sinusoids superimposed on a broadband random background as depicted in figure 514.4-9. These sinusoids are generated by the rotating components of the helicopter, primarily the main rotor, but which also include the tail rotor, engine(s), drive shafts and gear meshing. The normal operating speeds of these components are generally constant, varying less than five percent. However, recent designs have taken advantage of variable rotor speed control which generates a pseudo steady state rotor speed at values between 95% to 110% of the nominal 100% rotor speed, thus complicating the component design and test process as all steady state rotor speeds, pseudo or otherwise, must be accounted for. The broadband random background is attributed to fuselage aerodynamics.

The relative amplitudes of the sinusoids differ throughout the helicopter structure. The vibration environment at the location of the test item is dependent on its proximity to the vibration excitation source, as well as on the structure and geometry of the helicopter. Thus, the need for measured data is especially acute. A clear requirement for helicopter component design is the avoidance of coincidence of the installed components' resonant frequencies with the helicopter excitation frequencies at the installed component aircraft location. It is important to note that, in general, helicopter excitation frequencies and amplitudes are different for each helicopter type. A typical laboratory vibration will include four (4) sinusoids superimposed on a broadband random background. For fuselage-mounted components, refer to I-3.4.3.2 through I-3.4.3.4. For components mounted on engines, refer to I-3.4.1. For components exposed to gunfire vibration, the requirements of Method 519 shall be additionally imposed.

TABLE 514.4-III. Broadband Vibration test values for jet aircraft equipment.

Criteria

Aerodynamically induced vibration (figure 514.4-8) 1/

Functional test level 3/

$$W_o = K(q)^2$$

Jet engine noise induced vibration (figure 514.4-8) 1/

Functional test level 2/, 3/, 4/, 5, 6/

$$W_o = (0.48\ (\cos^2\theta)/R)[D_c\ (V_c/A)^3 + D_f(V_f/A)^3]$$

K -	1.18×10^{-11} for cockpit panel equipment and equipment attached to structure in compartments adjacent to external surfaces that are smooth, free from discontinuities. ($K = 2.7 \times 10^{-8}$ if q is in lb/ft^2)
K -	6.11×10^{-11} 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. ($K = 14 \times 10^{-8}$ if q is in lb/ft^2)
q -	$57.46\ kN/m^2$ ($1200\ lb/ft^2$) or maximum aircraft q, whichever is less.
D_c -	engine core exhaust diameter, meters (feet). (For engines without fans, use maximum exhaust diameter).
D_f -	engine fan exhaust diameter, meters (feet).
R -	minimum distance between center of engine aft exhaust plane and the center of gravity of installed equipment, meters (feet).
V_c -	engine core exhaust velocity, meters per sec (feet per sec). (For engines without fans, use maximum exhaust velocity without afterburner).
V_f -	engine fan exhaust velocity, meters per second (feet per sec).
θ -	angle between R line and engine exhaust axis, aft-vectored, degrees.
A -	1850 if engine exhaust velocities are in feet/sec.
A -	564 if engine velocities are in meters/sec.

TABLE 514.4-III. Broadband Vibration test values for jet aircraft equipment. Continued

NOTES

1/ Worst case aerodynamic and jet engine induced vibration should be identified and enveloped.

2/ If the aircraft has more than one engine, W_o shall be the sum of the individually computed values for each engine.

3/ To account for the effect of equipment inertia on vibration levels, W_o may be multiplied by a mass loading factor, M, based on equipment weight in kilograms (pounds). This does not apply to equipment which is on isolators.

$$M_f = 10^{(0.6 - Kg/60)};$$

$$M_f = 10^{(0.6 - 0.0075\ lb)}$$

Values of M_f are restricted to the range 0.25 to 1.0.

4/ For $70° < \theta \leq 180°$, use $\theta = 70°$ to compute W_o.

5/ For engines with afterburner, use W_o, which is four times larger than W_o computes using maximum V_c and V_f without afterburner.

6/ For instrument panel equipment, reduce the 0.04 G^2/Hz value of figure 514.4-8 by 3 dB and reduce the calculated value W_o by 6 dB for functional testing. Endurance is 0.04 g^2/Hz.

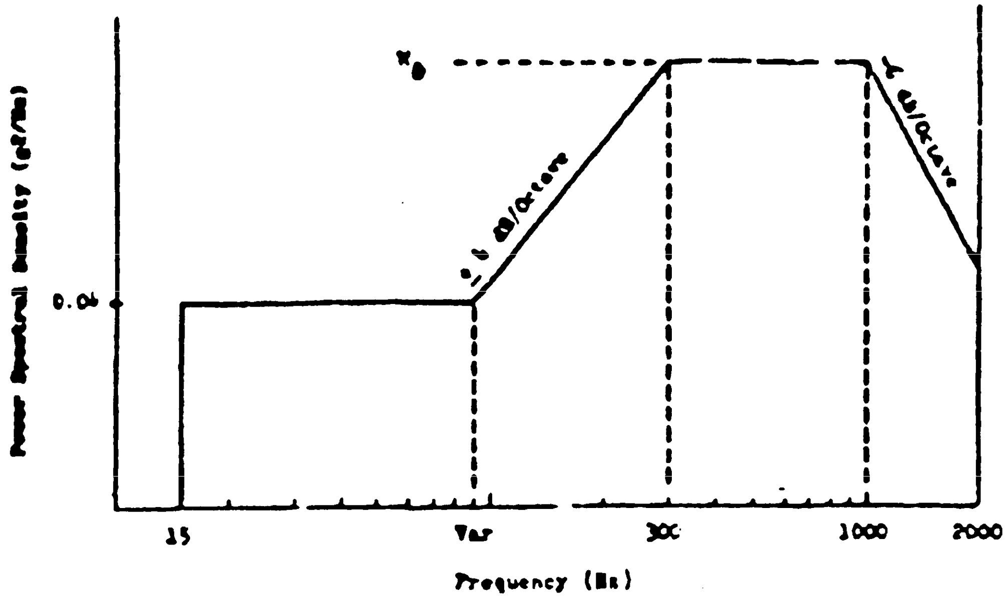


Figure 514.4-8. Vibration test spectrum for jet aircraft.

EQUIPMENT LOCATION	W_o	W_1	F_t
General	.001	.01	500
Instrument Panel	.001	.01	500
External Stores	.002	.02	500
On/Near Drive Train Elements	.002	.02	2000

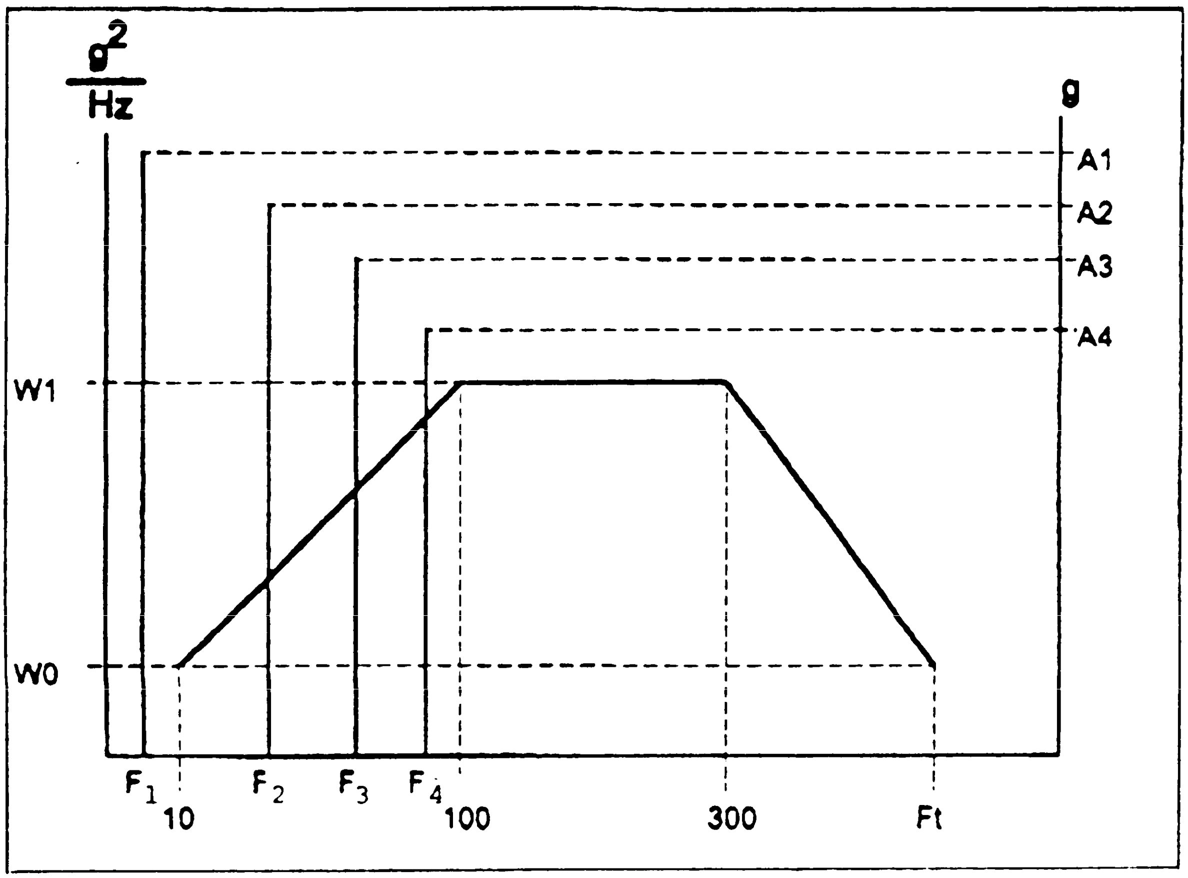


Figure 514.4-9. Vibration spectrum for equipment mounted on helicopters.

I-3.4.3.2 Test frequencies. For laboratory test purposes, the aircraft can be divided into three zones as depicted in Figure 514.4-10. For components located in the vertical projection of the main rotor, the laboratory test frequencies are the fundamental rotational frequency of the main rotor (1P), and the harmonics of 1P multiplied by the number of blades in the main rotor system (n). For components located in the horizontal projection of the tail rotor, the laboratory test frequencies are the fundamental rotational frequency of the tail rotor (1T), and the harmonics of 1T multiplied by the number of blades in the tail rotor system (m). Thus, laboratory test frequencies (labeled F_1, F_2, F_3 and F_4) for a component located in the vertical projection of the main rotor are determined as:

$$F_1 = 1P$$
$$F_2 = nP$$
$$F_3 = 2nP$$
$$F_4 = 3nP$$

A similar calculation is made for components located in the horizontal projection of the tail rotor. The fundamental main and tail rotor frequencies and the number of rotor blades are defined for various helicopter types in Table 514.4-V. All equipment located on or in close proximity to the drive train 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, etc.). These drive train source frequencies are also aircraft-specific.

I-3.4.3.3 Test amplitudes. The test amplitudes are labeled A_1, A_2, A_3 and A_4 and are associated with excitation frequencies F_1, F_2, F_3 and F_4. Whenever possible, the test amplitudes for equipment installed on helicopters should be derived from aircraft measured values at the component installation location. These measured amplitudes are then amplified to derive a component test duration equivalent to the life of the component. The time-scaling is delineated in I-3.4.3.4. However, when measured data are not available, the frequency-dependent amplitudes can be determined from Figures 514.4-9 and 514.4-10, and from Tables 514.4-IV and 514.4-V. These default amplitudes are an attempt at enveloping potential worst-case environments; they do not represent environments under which vibration sensitive equipment should be expected to perform. However, the components are expected to survive and function to specification at the completion of the test. Consequently, performance vibration amplitudes should be tailored to particular applications.

I-3.4.3.4 Test duration. Utilizing the default test amplitudes delineated in I-3.4.3.3, the test duration shall be four (4) hours of excitation for each of three (3) mutually perpendicular axes for a total test time of twelve (12) hours per component. If a test amplitude other than the default amplitude is used, the test

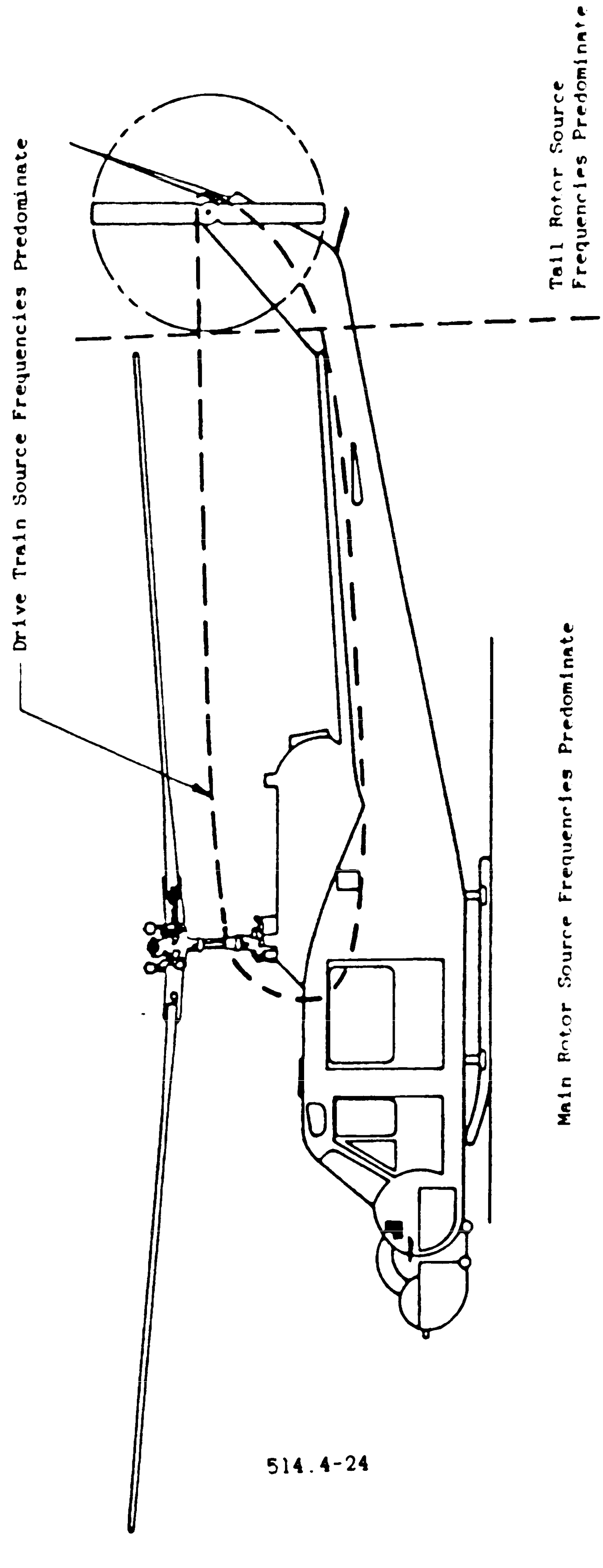


FIGURE 514.4-10. Zones for rotary wing aircraft.

duration shall be scaled as follows:

$$t_f = 4.0 \left(\frac{A_T}{A_D}\right)^{-6}$$

where t_f = actual test time per axis
A_D = default test amplitude
A_T = actual test amplitude

The longest resultant t_f determined from the various combinations of the frequency-dependent A_T/A_D ratios shall be utilized.

TABLE 514.4-IV. Default test peak amplitudes for equipment on helicopters.

Equipment Location	Source Frequency (F_x) Range (Hz)	Peak Amplitude (A_x) at F_x (g's)
General (1)	3-10 10-25 25-40 40-50 50-500	$0.7/(10.7-F_x)$ $0.1 * F_x$ 2.5 $6.5-0.1 * F_x$ 1.5
Instrument Panel (1)	3-10 10-25 25-40 40-50 50-500	$0.7/(10.7-F_x)$ $0.07 * F_x$ 1.75 $4.55-0.07 * F_x$ 1.05
External Stores (1)	3-10 10-25 25-40 40-50 50-500	$0.7/(10.7-F_x)$ $0.15 * F_x$ 3.75 $9.75-0.15 * F_x$ 2.25
On/Near Drive Systems' Elements (2)	5-50 50-2000	$0.1 * F_x$ $5.0 + 0.01 * F_x$

NOTES:

(1) F_x = Excitation frequency, x = 1, 2, 3 or 4
F_1 = Fundamental excitation frequency (Rotor rotational speed)
$F_2 = nF_1$ or mF_1 (Blade passage frequency)
$F_3 = 2nF_1$ or $2mF_1$ (Blade passage frequency)
$F_4 = 3nF_1$ or $3mF_1$ (Blade passage frequency)
where n (or m) = number of main (or tail) rotor blades (Table 514.4-V)

Upon determining values of F_1, through F_4 (Figure 514.4-9), select the appropriate excitation frequency range for each to determine the peak amplitudes.

(2) F_1, F_2, F_3, F_4 must be determined from drive train areas for the particular helicopter. NOTE (1) is then applicable.

I-3.4.4 Category 7A - Assembled external stores, jet aircraft. Assembled jet aircraft stores will encounter three distinct vibration environments: captive flight, buffet maneuver, and free flight.

I-3.4.4.1 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:

a. Aerodynamic boundary layer turbulence.

b. Buffet maneuvers.

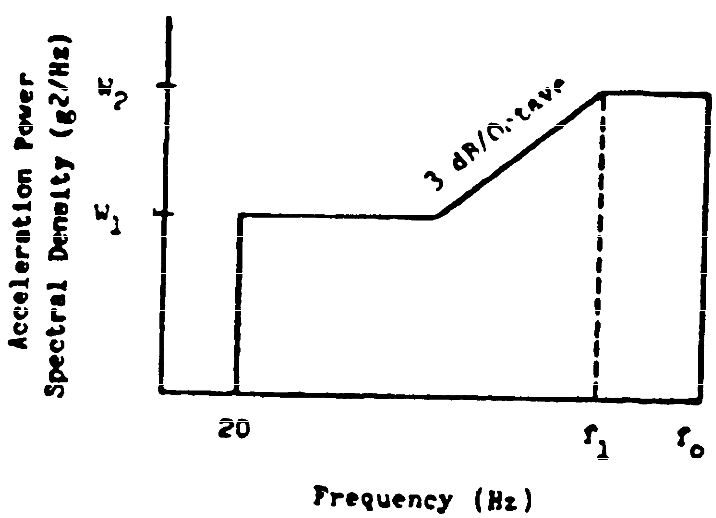
c. Aircraft-induced vibration.

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.

TABLE 514.4-V. Fundamental source frequencies (F_1).

HELICOPTER	MAIN ROTOR 1P (Hz)	TAIL ROTOR 1T (Hz)	n (Blades)	m (Blades)
AH-1	5.4	27.7	2	2
AH-6J	7.8	47.5	5	2
AH-64	4.8	23.4	4	4
CH-47D	3.75	1/	3	
MH-6H	7.8	47.5	5	2
OH-6A	8.1	51.8	4	2
OH-58A/C	5.9	43.8	2	2
OH-58D	6.6	39.7	4	2
UH-1	5.4	27.7	2	2
UH-60	4.3	19.8	4	4

1/ The CH-47D has two (2) main rotors and no tail rotor.



NOTE: Use table 514.4-VI to define W_1 and W_2

FIGURE 514.4-11. Response threshold spectrum for assembled external stores carried on jet aircraft in the absence of flight measurements.

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 514.4-11.

I-3.4.4.2 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.

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 compliance of the pylon interface. 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 if necessary to duplicate both rigid body and bending modes.

I-3.4.4.3 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 do not exist, the factors A_1 and A_2 from table 514.4-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.

I-3.4.4.4 Test levels. The test levels and spectra for the three vibration environments, captive flight, free flight and buffet, can be selected from table 514.4-VI and figures 514.4-11, 12, and 13. The use of these tables and figures is suggested only when there is an absence of satisfactory flight measurements. Due to normal mounting orientation of external stores and the corresponding low vibration levels in the longitudinal axis, the store excitation shall be applied only in the vertical and lateral axes.

TABLE 514.4-VI. Vibration criteria for external stores carried on airplanes.

Parametric Equations for Figures 514.4-11 and 514.4-14

Eq (1) 1/, 9/, 10/: $W_1 = (5)(10)^{-3}(N/3T)^{1/4}(A_1)(B_1)(C_1)(D_1)(E_1)g^2/Hz$

Eq (2) 1/, 4/, 8/, 9/, 10/: $W_2 = (H)(q/\rho)^2(N/3T)^{1/4}(A_2)(B_2)(C_2)(D_2)(E_2)g^2/Hz$

Eq (3) 2/, 3/, 6/: $f_1 = (C)10^5(t/R^2)Hz$

Eq (4) 2/, 3/: $f_2 = f_1 + 1000$ Hz

Eq (5) 5/, 7/: $f_o = f_1 + 100$ Hz

Location, Configuration, Special Adjustments

	Factor	
	A_1	A_2
Single stores	1	1
Stores carried side by side	1	2
Stores carried behind other stores	2	4
	B_1	B_2
Aft half of air fired missiles	1	4
Aft half of air other stores	1	2
Forward half of all stores	1	1
	C_1	C_2
Blunt nosed stores, 11/		
Single and side by side	2	4
Behind other stores	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 stores	1	1

TABLE 514.4-VI (Continued)

Representative parameter values to be used for captive flight when specific parameters are not available.

Representative Parameter Values								
Store Type	Max q kN/M^2 (lb/ft^2)		ρ kg/m^3 (lb/ft^3)		N[9/] Endurance	T[10/] Endurance	f_1 (Hz)	f_2 (Hz)
Missile, air to ground	76.61	(1600)	1602	(100)	3	None	500	1500
Missile, air to air	76.61	(1600)	1602	(100)	100	1	500	1500
Instrument pod	86.18	(1800)	801	(50)	500	1	500	1500
Dispenser (reusable)	57.46	(1200)	801	(50)	50	1	200	1200
Demolition bomb	57.46	(1200)	1922	(120)	3	None	125	2000
Fire bomb	57.46	(1200)	641	(40)	3	None	100	1100

DEFINITIONS

q - maximum captive flight dynamic pressure in kN/m^2 (lbs/ft^2). (Note 1)

μ - average store weight density in kg/m^3 (lbs/ft^3)(total weight / total volume)

t - local store average skin thickness where R is measured - meter (inches)

R - one-half the average of the major and minor diameters - meter (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 - 57.46 kN/m^2 (1200 lb/ft^2) or maximum q, whichever is less.

2. Free fall stores with tail fins, use f_1 - 125 Hz: $f_2 - Cx(t/R^2)x10^5 +$ 1000 Hz.

3. For general-use fuzes which can be used in several stores: use W_1 - $0.04g^2/Hz$: W_2 - 0.15 g^2/Hz; f_1 - 100 Hz: f_2 - 1000 Hz.

4. Acceptance range for parameter values: $641 \leq \rho \leq 2403 kg/m^3$ ($40 \leq \rho \leq 150 lb/ft^3$)
$0.001 \leq C(t/R)^2 \leq 0.02$
or if calculated values fall outside these limits, use these limit values.

5. For circular and elliptical cross-sections, f_o - 500 Hz for all other cross-sections.

TABLE 514.4-VI (Continued)

6. C = 1 where t&R are in inches
C = 2.54 x 10^{-2} where t&R are in meters

7. If $f_o \geq 1200$ Hz is calculated, use 2000 Hz.

8. H = 5.597 if q is in kN/m^2; H = 5 x 10^{-5} if q is in lb/ft^2

9. N = Maximum number of anticipated service missions for store or equipment. ($N \geq 3$)

10. T = Test time per axis, hours ($T \geq 1$)

11. Blunt nosed refers to configurations with separated aerodynamic flow at or just aft of the store nose. Optical flats, corners, sharp edges, bluffs, and open cavities are potential sources of separation. Any nose other than smooth, rounded and gently tapered is suspect. The engineers responsible for store aerodynamics design and performance should make this determination.

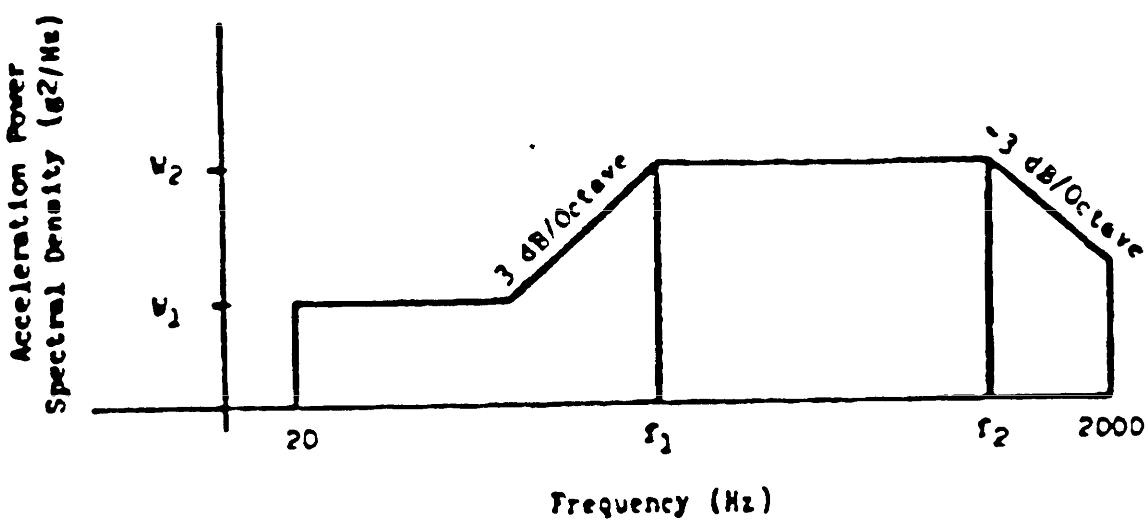


FIGURE 514.4-14 Suggested vibration test levels for equipment installed in external stores carried on jet aircraft.

I-3.4.4.5 Test duration. The test duration should be developed from flight measurements, flight characteristics, and flight durations. If these data are not available, then test durations can be obtained from the information given in I-4.3, I-4.6 and I-4.7.

I-3.4.5 Category 7B - Equipment installed in externally carried stores.

I-3.4.5.1 Background information. Equipment installed within an externally carried store will experience a broad-band 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 514.4-14 and table 514.4-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-maneuver 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.

I-3.4.5.2 Test levels. If sufficient measured data do not exist, use figure 514.4-14 and refer to I-3.4.4. Vibration testing of equipment to be installed in externally carried jet aircraft stores should be input-controlled testing (see I-4.2.6).

I-3.4.5.3 Test duration. Refer to I-4.3, I-4.6, and I-4.7 for test duration and endurance test criteria.

I-3.4.6 Category 7C - Assembled external stores, helicopters.

I-3.4.6.1 Background information. 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 I-4.2.2).

I-3.4.6.2 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 514.4-IV and figure 514.4-9 can be used for initial testing prior to acquisition of field data.

I-3.4.6.3 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, test durations can be selected from information provided in I-4.2.7, I-4.3, I-4.6 and I-4.7.

I-3.4.7 Category 8 - Ground mobile.

I-3.4.7.1 Background information. 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.

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. There is presently no analytical model of this environment suitable for generalized test application. This environment can be simulated by a wide-band random vibration test similar to the minimum integrity spectrum for aircraft as given in I-3.4.9. The use of a smooth spectrum similar to figure 514.4-16 generally will produce an overtest at some parts of the frequency spectrum. The spectra of I-3.3.1 and figure 514.4-4 are typical of 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 (figure 514.4-5) 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.

I-3.4.7.2 Test levels. As discussed above, generalized test levels for wheeled vehicles and two-wheeled tracks have not been developed which would be applicable to a specific case. The information, levels and curves presented in I-3.3.1 and I-3.4.9 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.

Numerous test levels have been developed for tracked vehicles. The spectra given in table 514.4-AIV represent the environment for ammunition in the Wegmann hull rack for the M1A1 main battle tank. This rack was found to produce the most severe vibration environment of any of the racks in that tank. Similarly, table 514.4-AV is the spectrum for the hull rack of the M1 tank which produces the most severe vibration environment of any of the 105-mm racks in the M1 or M60 series of tanks.

Tables 514.4-AVI through AXI are the spectra for ammunition and various other items of installed equipment at various locations in the M109 self-propelled howitzer. Similarly, tables 514.4-AXII through 514.5-AXV present the spectra for items of installed equipment at various locations on the M110 self-propelled howitzer. Vibration spectra for various locations on the M113 armored personnel carrier are given in tables 514.4-AXVI and 414.4-AXX. For installed equipment in the turret and hull areas of the M60A3 tank, the vibration test levels are presented in tables 514.4-AXXI and 514.4-AXXII respectively. The simulated transport distances are presented in Table 514.4-AXXIII, Annex A, page 514.4-A88.

I-3.4.7.3 Test duration. The test duration must be related to the test item's service scenario. Appropriate test durations are given in I-3.3.1 and I-3.3.2; the test durations for the various tracked vehicle spectra are presented on the respective tables.

I-3.4.8 Category 9 - Shipboard vibration.

I-3.4.8.1 Background information. 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 speeds, sea states, maneuvers, etc., and a periodic component imposed by propeller shaft rotation and hull resonance. Equipment mounted on masts (such as antennas) can be expected to receive higher input than equipment mounted on the hull or deck.

I-3.4.8.2 Test level. Whenever possible, measurements should be used to develop the test criteria. In the absence of shipboard measurements, levels found in figure 514.4-15 should be used. The random vibration test of shipboard equipment should follow either the Basic Transportation Test (I-3.3.1) or the Bench Handling Shock Test (Method 516.4, Procedure VI).

In order to verify structural integrity and the compatibility or 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.

I-3.4.8.3 Test duration. The test durations for shipboard applications should be based upon the anticipated deployment scenarios. For tests which utilize the test levels from figure 514.4-15, the test duration should be two hours along each of three orthogonal axes.

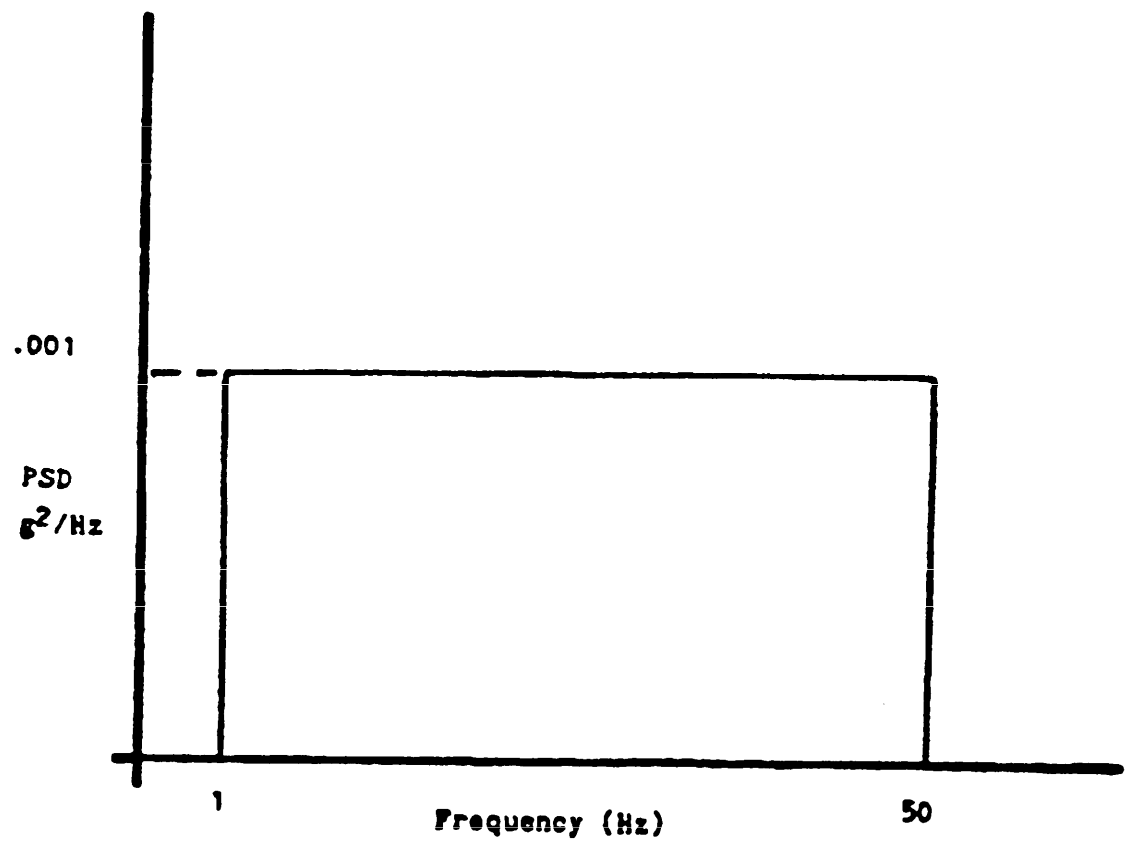


FIGURE 514.4-15. Threshold performance random vibration spectrum for equipment installed in ships (non-combat).

I-3.4.9 Category 10 - Minimum integrity test.

I-3.4.9.1 Background information. Vibration levels of Figures 514.4-16 and 514.4-17 and the durations of Table 514.4-VII are not based on application environments. Rather, experience has shown that equipment which withstands these exposures functions satisfactorily in general field use and that equipment tested to lower levels does not. These exposures are sometimes called "junk" tests and provide reasonable assurance that equipment can withstand operations and handling during field installation, removal and repair. Note that these exposures are to be applied directly to the equipment (hard mounted) and not through vibration isolation devices. Minimum integrity tests generally should be applied to the following equipment in addition to other applicable vibration tests (Table 514.4-I):

a. Items tested on vibration isolation devices (I-4.8).

b. Items tested hard-mounted to levels and durations less stringent than the applicable minimum integrity test (I-4.7).

c. Items not tested to any of the other vibration environments of Table 514.4-I. A secured cargo test (I-3.3.1) may also be prudent since all equipment is subject to transportation environments.

These exposures are based on "typical" electronic boxes. When boxes or assemblies are too large, unnecessarily high loads are induced in mounting and chassis structures while higher frequency vibrations experienced at subassemblies are too low. In these cases the minimum integrity test should be applied to subassemblies. The maximum weight of an item or subassembly should be approximately 36 kilograms (80 pounds).

Care should be used with delicate equipment. This test should not be applied when the levels are felt to be too high for the equipment. Rather, provisions should be made to ensure the equipment is adequately protected from vibration and shock during all phases of the environmental life cycle.

I-3.4.9.2 Test level. The test levels shown in Figures 514.4-16 and 514.4-17 are for general use and for helicopter equipment, respectively.

I-3.4.9.3 Test duration. The suggested test durations are provided in table 514.4-VII.

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, I-4.3, and I-4.6.

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 (See I-4.6.3.1) 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 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 (See I-4.6.3.2) 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.

Endurance testing does not establish fatigue life (See I-4.6.3.2). 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 requires a combined environments test (method 520.1) where all relevant environments are varied realistically and a sufficient number of samples are 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 <u>Mechanical impedance effects</u>. 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 <u>Determination of bandwidth for source dwell testing</u>. Test spectra representative of this type of testing are presented in figures 514.4-7 and 514.4-9. Test bandwidths should be based on measured data if possible.

I-4.6 Test phases.

I-4.6.1 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 item's structural integrity, or raised in steps to evaluate performance variations and obtain failure data.

I-4.6.2 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 failsafe 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-4.6.3 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 functional tests to accomplish the first goal and endurance tests for the second.

I-4.6.3.1 Functional tests. 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 function 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.

I-4.6.3.2 Endurance tests. In the past, endurance test duration was normally set at one hour per axis. Test levels were established by raising functional levels to account for equivalent fatigue damage (see I.4-7). Another approach was to assume that if enough stress cycles were accumulated without failure, that this demonstrated the stresses were below the material endurance level. The necessary number of stress cycles was usually assumed to be $1*10^6$. The test was run at the maximum vibration level (functional level) for a time equivalent to 10^6 cycles at the lowest natural frequency of the equipment.

Each of these approaches has serious shortcomings. The first requires testing at vibration levels well above those seen in service. This ignores nonlinearity with vibration amplitude of material properties, joint friction, isolator performance, heat buildup, etc. The second ignores the fact that many materials (particularly those typical of electrical/electronic devices) do not exhibit endurance limits and that 10^6 stress cycles may not be sufficient for those that do.

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 vary throughout each mission). 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 these cases, use as long a test duration as is practical and use the fatigue relationship to define the test level.

In all cases, the combined functional and endurance test severity should be equivalent to (by I-4.7 relationship) or exceed the applicable minimum integrity test severity across the test frequency range.

I-4.7 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:

$$\left(\frac{W_o}{W_1}\right) = \left(\frac{T_1}{T_o}\right)^{\frac{1}{M}}$$

where W - Vibration levels (acceleration spectral density)
T - Time (hours)
M - Material constant (slope of log/log random s/N curve)

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. A value of 4.0 for M is commonly used; other values may be appropriate. (Note: If this equation is used for sine calculation, W represents peak g and M = 6 in general case.)

I-4.8 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.

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. These parameters should be measured at each test level. This is necessary because isolation devices are nonlinear. This is also true when sub-elements are isolated within equipment items. Further, all isolated equipment should pass the Minimum Integrity Test (I.3.4.9).

I-4.9 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-3.4.9 with the test item hard-mounted to the fixture.

I-4.10 Equipment operation. During all platform-induced vibration simulations, the test item should be functioning and its performance should be measured and recorded, if it would normally be operating under these conditions in service. 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-4.6.3).

I-4.11 Failure definition. During qualification testing, the equipment shall not suffer permanent deformation or fracture, no fixed part or assembly shall loosen, no moving or movable part of an assembly shall become free or sluggish in operation, no movable part or control shall shift in setting, position, or adjustment, and equipment performance shall meet specification requirements while exposed to functional levels and following endurance tests. Any deviation from the above shall constitute a failure.

For tests other than qualification tests, success and/or failure criteria shall be prepared which reflects the purpose of the tests. For example, a step stress test might be conducted to find the level at which a mechanism fails to operate properly. The test would be deemed successful when this level is found.

I-4.12 Qualification test completion. A qualification test is complete when all elements of the test item pass a complete test. When a failure occurs the test shall be stopped. The failure shall be analyzed and repaired. The test shall then continue until all fixes have been exposed to a complete test. Each element is considered qualified when it has been exposed to a complete test. Qualified elements which fail prior to test completion are not considered failures but will be repaired to allow test completion.

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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II-1.1.2.2 Swept frequency systems. Swept frequency analysis systems must have the following characteristics:

a. Constant bandwidth

(1) 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

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

(3) Analysis sweep rate (linear) = $R = \frac{B}{4RC}$ or

$\frac{B^2}{8}$ (Hz/second) maximum, whichever is smaller.

b. Constant percentage bandwidth analyzer

(1) Filter bandwidth = pf_c = one-tenth of center

frequency maximum ($0.1f_c$), where p = percentage and f_c = analyzer center frequency.

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

(3) Analysis sweep rate (logarithmic) = $R = \frac{pf_c}{4RC}$

or $\frac{(pf_c)^2}{8}$ (Hz/second) maximum, whichever is smaller.

II-1.2 Test set up

II-1.2.1 Procedure 1

II-1.2.1.1 Category 1 - Basic transportation. Mount the test item on the vibration equipment using restraints and tie downs typical of those used in actual transport.

II-1.2.1.2 Category 4 - Propeller Aircraft 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 installation provisions from the carrying aircraft. Fixture designs which utilize the maximum amount of platform structure possible will allow the best item to respond to the laboratory excitation in a manner more closely duplicating its response in the actual field environment.

II-1.2.1.3 Category 5 - Jet aircraft. (See II-1.2.1.2)

II-1.2.1.4 Category 6 - Helicopter. 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.

II-1.2.1.5 Category 7A - Assembled external stores, jet aircraft.

II-1.2.1.5.1 Fixtures. Suspend the store from a structural support by means of its normal mounting lugs, hooks and sway braces simulating the operational mounting configuration. Include launcher or mounting rails where applicable. Rigid body store suspension modes shall be between 5 and 20 Hz except that the highest rigid body mode shall be no higher than one half the lowest test frequency. In some instances in the past stores have been hard mounted to large shakers. This has proven to be inadequate and should not be attempted.

Vibration shall be transmitted to the store by means of a rod or other suitable mounting devices running from vibration shakers to the surface of the store. The tie points on the store surface shall be relatively hard and structurally supported by the store internal structure or supported by an external fixture (usually a ring around the local store diameter) attached to the store. Separate driving points will be required to drive the verical and lateral axes. Separate driving points at each end in each axis are also recommended although aligning a single driving point in each axis with the store aerodynamic center has also been successful.

II-1.2.1.5.2 Accelerometers. 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).

II-1.2.1.6 Category 7B - Equipment installed in externally carried stores. (See II.1.2.1.2)

II-1.2.1.7 Category 7C - Assembled external stores, helicopters. 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 the 2.75 inch FFAR launcher). The vibration fixture shall utilize, if feasible, actual aircraft components for accomplishing this test attachment.

II-1.2.1.8 Category 8 - Ground mobile. 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.

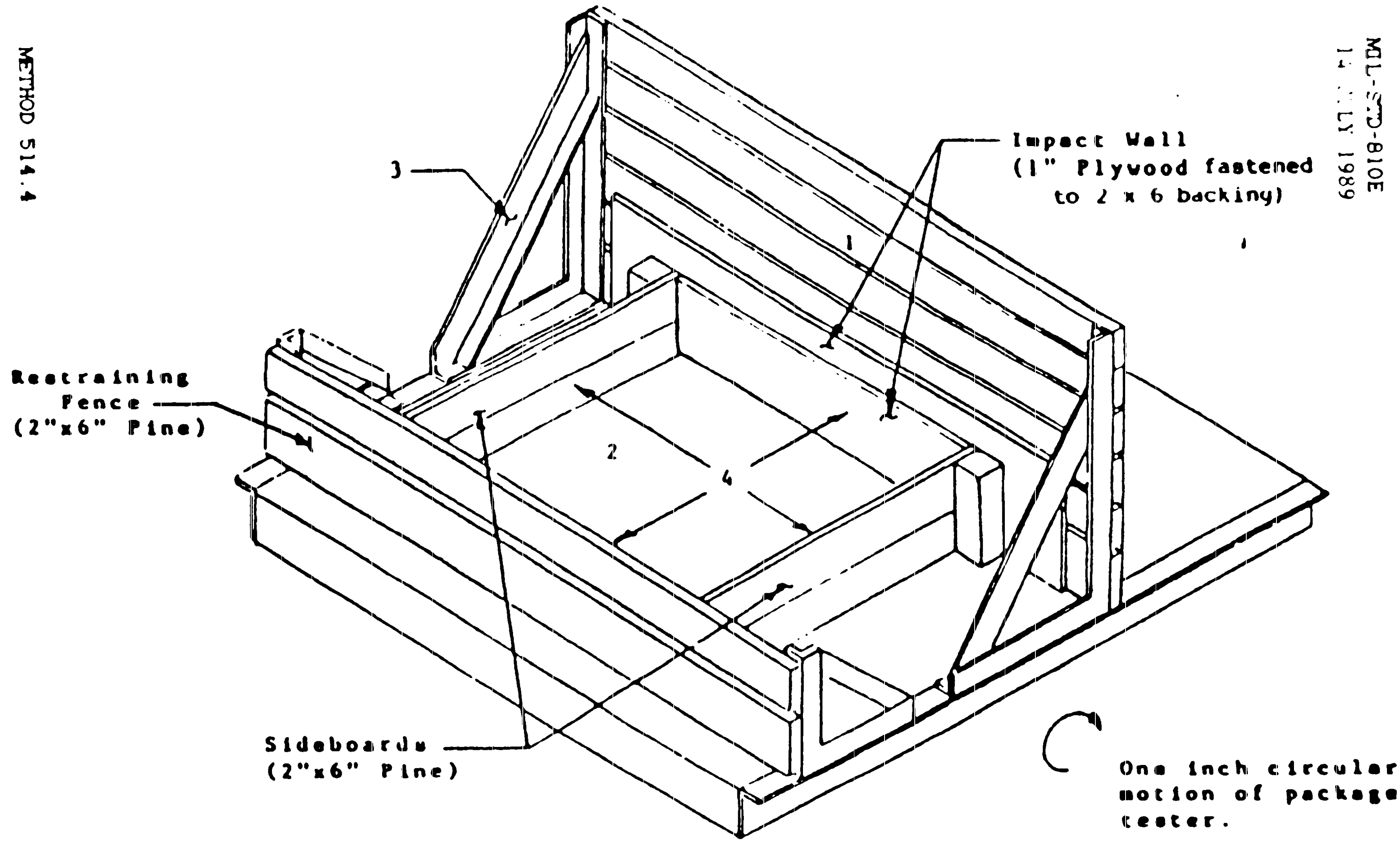
II-1.2.1.9 Category 9 - Shipboard. Equipment should be mounted in its normal configuration with normal shock/vibration isolator mounts used throughout the test.

II-1.2.1.10 Category 10 - Minimum integrity. The secured cargo transportation test phase shall be accomplished as indicated in I-3.3.1. The additional vibration exposure shall be accomplished with the test item secured to the fixture/exciter. Items which are mounted on vibration isolators should be tested with the isolation removed. The items shall be tested in each of three orthogonal axes.

II-1.2.2 Procedure II - Category 2 - Large assembly transport. The test setup uses the actual transport vehicle and test track to simulate service conditions. Secure the test item on the transport vehicle for normal transportation.

II-1.2.3 Procedure III - Category 3 -Loose cargo transport

II-1.2.3.1 Package test. The test setup uses a package tester as depicted in figure 514.4-19. 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 514.4-19 shall be installed to contain the test items on the bed of the package tester. The fence opposite the vertical impact wall is not intended as an impact surface, but is used to restrain the test item from leaving the tester. The distance to this restraining fence should be sufficient to prevent constant impact, but still prevent one or more of multiple test items from "walking" away from the others. The height of the test enclosure (sideboards, impact wall and restraining force) should be at least 5 cm higher than the height of the test item to prevent unrealistic impacting of the test item on the top of the enclosure.



1. 2" x 6" Pine
2. 1/2" Plywood Floor
3. Angle Iron Structure
4. Test Area

FIGURE 514.4-19. Typical package tester.

II-1.2.3.2 Test bed. For testing packaged items, the test bed of the package tester shall be covered with a panel of 1/2-inch plywood, with the finished side up and the grain parallel to the drive chain. (Marine plywood is recommended because it is generally more durable.) The plywood shall be secured with bolts or six penny nails, with tops of heads slightly below the surface. The bolts or nails shall be spaced at sufficient intervals around all four edges and through the center area to prevent "oilcanning" of the plywood.

For testing of unpackaged items, the test bed of the package tester shall be covered with a steel plate, 5 to 10mm thick. The plate shall be secured to the bed of the package tester with bolts having the heads slightly below the surface. The bolts shall be spaced at sufficient intervals around all four edges and through the center area to prevent "oil canning" of the plate.

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.

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, 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-2.2 Procedure III - Loose cargo transport.

a. Packaged items. Using suitable wooden sideboards, the test item shall be constrained to a horizontal motion of 5cm (free space) in a direction parallel to the axes of the shafts - a distance more than sufficient to ensure the test item(s) will not rebound from sideboard to sideboard (i.e., the distance between sideboards shall be equal to the width of the test item plus 5cm). Initial positioning of the test item will be such that there are 2.5cm of space on either side. If more than one similar item is tested simultaneously, 2.5cm of additional free space per additional item should be used between sideboards; the initial spacing should have 2.5cm between test items and 2.5cm to each sideboard. The total free space should not exceed the length of the longest horizontal axis of the test item (to prevent test item rotation). Multiple similar test items shall not be separated by sideboards unless specified in the requirements documents.

b. Circular cross-section items. The test area on the package tester (see Figure 514.4-19) shall be square in shape. The following formula shall be used to determine the test area dimensions:

$$x = 0.767 * L * (N)^{1/2}$$

where:

x = length of each side of the test area
L = length of the test item
N = number of test items if N>3
For values of N $\leq$3, x $\geq$1.5 L

c. Other unpackaged test items. If the packaged item is square or rectangular in shape, use the fencing arrangement for packaged items as detailed above.

II-3 PROCEDURES

II-3.1 Procedure I

II-3.1.1 General procedure

Step 1. Complete steps 1 through 8, paragraph II-2.1.

Step 2. Inspect the test item to establish pretest criteria and physical condition.

Step 3. Verify the test item's functionality.

Step 4. Mount the test item on the vibration equipment as required by the applicable paragraph of II-1.2.1.

Step 5. Expose the test item to the test level and duration as determined from I-3.3 or I-3.4 and II-3.1.2. The test item shall be operated as if it were in operational usage. (See I-4.10, 1-4.11 and I-4.12.)

Step 6. Inspect the test item and compare it to pre-test data and physical condition. Verify the test item functionality and record the results. (See I-4.11)

Step 7. Repeat steps 2 through 6 (see I-4.6) for each axis (see I-4.2.5) and each test.

Step 8. Document the test results in accordance with II-4.

II-3.1.2 Special considerations

II-3.1.2.1 Category 7A Assembled external stores, jet aircraft

Step 1. Apply broadband vibration to the store using an input spectrum shape of the store-mounted forward accelerometer response spectrum from I-3.4.4. The input level should be 6 dB down from the calculated response level of the forward accelerometer.

Step 2. Identify those frequencies at which the store-mounted accelerometers, in the direction of applied vibration, exceed the applied input vibration by 6 dB or greater. There may be different frequencies for the forward and aft accelerometers.

Step 3. 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 I-3.4.4. 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.

NOTE: The off-axis accelerometer response (those accelerometers 90 degrees to the applied vibration) should be examined. For each frequency where the response of a 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.

II-3.2 Procedure II - Large assembly transport.

Step 1. Complete steps 1 through 5, II-2.1.

Step 2. Inspect test item to establish pretest criteria and physical condition.

Step 3. Verify the test item's functionality.

Step 4. Place the shelter on the transport vehicle(s) that is normally used to transport vehicle.

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 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:

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. (see I-4.11, I-4.12)

Step 10. Verify the test item's functionality. (see I-4.11, I-4.12)

Step 11. Document the test in accordance with II-4.

II-3.3 Procedure III - Loose cargo transport.

II-3.3.1 General information

a. Configuration. The test item(s) is placed on the appropriately-covered bed of the package tester in the required configuration or as otherwise prepared for loose-cargo field transportation. The test item shall not be operated during this test unless specified in the requirements document.

b. Orientation. The orientation of the packaged test item should represent its most likely shipping orientation. If this cannot be determined, place the test item on the test bed with the longest axis of the test item parallel to the long axis (throw axis) of the package tester. Any changes to the orientation of the test item due to the movement of the package tester shall not be corrected. Circular cross-sectioned items shall be placed on the package tester in a random manner. Unpackaged, non-circular cross-sectioned items shall follow the placement guidelines for packaged items.

c. Cautions. Since proper rotation of the table should cause the test item to rebound against the impact wall, any item not doing so should be rotated 180° in the horizontal plane in an attempt to change any movement caused by test item weight distribution. There is no need to alter the initial placement of circular cross-sectioned items because they will roll and spin. No test will be started on an area of plywood on which the top ply is damaged or worn through, or on steel plate which is severely damaged or worn through.

II-3.3.2 Detailed procedure

Step 1. Complete steps 1 through 5, II-2.1.

Step 2. Inspect test item to establish pre-test criteria and physical condition.

APPENDIX A

GROUND VEHICLE RESPONSE VIBRATION DATA

Appendix A provides measured vibration data from military vehicles as indicated on the individual tables.

Table 514.4-AI represents the cargo environment at the floor of a composite of two-wheeled trailers, the 1/4-ton, M416 and the 1-1/2 ton, M105A2. 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, in figure 514.4-IV the spectrum is characterized by 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 given in table 514.4-AI and spectra should be adjusted accordingly.

Table 514.4-AII represents the cargo environment at the cargo bed of a composite of tactical wheeled vehicles, the 5-ton M813 and M814 trucks, M36 2-1/2 ton truck, CUCV M1009 1-1/4 ton 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 provide substantially different input to the cargo loaded on the bed than given in table 514.4-AII and spectra should be adjusted accordingly.

Table 514.4-AIII represents 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 design courses ranging from paved highway to offroad conditions. This environment contains a low level of broadband random upon which is superimposed narrowband random 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.

Tables 514.4-AIV through 514.4-AXXII represent the environments of several combat vehicles (M1A1 tank, M1 tank, M109 self propelled howitzer, M110 self propelled howitzer, M113 armored personnel carrier and M60A3 tank).

In Tables 514.4-AIII through 514.4-AXXII, the term "test phase" is defined as the vibration environment at one or more vehicle speeds. The test phases are used to insure that there is no overlap of vehicle speeds within a given phase.

TABLE 514.4-AI. Random vibration program data for secured cargo transportation, composite two-wheeled trailer.

Test duration per axis: 32 minutes per 32 miles

Vertical Axis FREQ	Vertical Axis PSD VALUE	Transverse Axis FREQ	Transverse Axis PSD VALUE	Longitudinal Axis FREQ	Longitudinal Axis PSD VALUE
5	0.2252	5	0.0474	5	0.0536
8	0.5508	6	0.0303	6	0.0536
10	0.0437	7	0.0761	8	0.1102
13	0.0253	13	0.0130	13	0.0140
15	0.0735	15	0.0335	16	0.0303
19	0.0143	16	0.0137	20	0.0130
23	0.0358	21	0.0120	23	0.0378
27	0.0123	23	0.0268	27	0.0079
30	0.0286	25	0.0090	30	0.0200
34	0.0133	28	0.0090	33	0.0068
36	0.0416	30	0.0137	95	0.0019
41	0.0103	34	0.0055	121	0.0214
45	0.0241	37	0.0081	146	0.0450
51	0.0114	46	0.0039	153	0.0236
95	0.0266	51	0.0068	158	0.0549
111	0.0166	55	0.0042	164	0.0261
136	0.0683	158	0.0029	185	0.0577
147	0.0266	235	0.0013	314	0.0015
185	0.0603	257	0.0027	353	0.0096
262	0.0634	317	0.0016	398	0.0009
330	0.0083	326	0.0057	444	0.0027
360	0.0253	343	0.0009	500	0.0014
500	0.0017	384	0.0018		
		410	0.0008		
		462	0.0020		
		500	0.0007		
RMS = 3.86		RMS = 1.27		RMS = 2.41	

TABLE 514.4-AII. Random vibration program data for secured cargo transportation, composite wheeled vehicle.

Test duration per axis: 40 minutes per 500 miles

Vertical Axis

FREQ	PSD VALUE
5	0.2308
8	0.7041
12	0.0527
16	0.0300
20	0.0235
22	0.0109
24	0.0109
26	0.0154
69	0.0018
79	0.0048
87	0.0028
123	0.0063
161	0.0043
209	0.0057
224	0.0150
247	0.0031
278	0.0139
293	0.0037
357	0.0028
375	0.0052
500	0.0011

RMS - 2.21

Transverse Axis

FREQ	PSD VALUE
5	0.1373
9	0.0900
12	0.0902
14	0.0427
16	0.0496
18	0.0229
119	0.0008
146	0.0013
166	0.0009
201	0.0009
273	0.0053
298	0.0021
371	0.0104
382	0.0019
402	0.0077
422	0.0027
500	0.0016

RMS - 1.61

Longitudinal Axis

FREQ	PSD VALUE
5	0.0605
6	0.0577
8	0.0455
12	0.0351
15	0.0241
16	0.0350
19	0.0092
25	0.0159
37	0.0041
41	0.0060
49	0.0017
105	0.0006
125	0.0004
143	0.0013
187	0.0013
219	0.0028
221	0.0068
247	0.0325
249	0.0098
270	0.0026
293	0.0094
336	0.0120
353	0.0247
379	0.0085
431	0.0224
433	0.0092
500	0.0014

RMS - 1.96

TABLE 514.4-AIII. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR SECURED CARGO TRANSPORTATION, TRACKED VEHICLE

	5-500 Hz				Overall		NARROWBAND 1			NARROWBAND 2			NARROWBAND 3			NARROWBAND 4			NARROWBAND 5		
Test Phase	Floor g2/Hz	No. Sweeps	AV	AWF	RMS g	Time min	BW Hz	Ampl g2/Hz	Sweep BW Hz	BW Hz	Ampl g2/Hz	Sweep BW Hz	BW Hz	Ampl g2/Hz	Sweep BW Hz	BW Hz	Ampl g2/Hz	Sweep BW Hz	BW Hz	Ampl g2/Hz	Sweep BW Hz
VERTICAL AXIS																					
V1	.0041	1	17	2	1.70	12.0	30- 35	.0876	2	60- 70	.0405	5	90-105	.0319	7	120-140	.0131	10	150-175	.0173	12
V2	.0024	1	14	3	1.47	12.0	41- 47	.0686	3	82- 94	.0759	6	123-141	.0073	9	164-188	.0090	12	205-235	.0173	15
V3	.0059	1	4	4	2.74	12.0	53- 65	.1480	6	106-130	.0090	12	159-195	.0717	18	212-260	.0363	24	265-325	.0655	30
V4	.0043	1	1	4	2.86	12.0	71- 88	.1389	8	142-176	.0942	17	213-264	.0873	25	284-352	.0378	34	355-440	.0078	42
V5	.0068	1	3	4	5.85	12.0	94-112	1.6288	9	188-224	.7682	18	282-336	.0787	27	376-448	.0228	36			
TRANSVERSE AXIS																					
T1	.0020	1	17	2	1.17	12.0	30- 35	.0220	2	60- 70	.0300	5	90-105	.0151	7	120-140	.0073	10	150-175	.0050	12
T2	.0016	1	14	3	1.17	12.0	41- 47	.0223	3	82- 94	.0212	6	123-141	.0105	9	164-188	.0089	12	205-235	.0174	15
T3	.0054	1	4	4	2.05	12.0	53- 65	.0716	6	106-130	.0325	12	159-195	.0238	18	212-260	.0123	24	265-325	.0153	30
T4	.0039	1	3	4	2.51	12.0	71- 88	.0722	8	142-176	.1480	17	213-264	.0483	25	284-352	.0097	34			
T5	.0032	1	3	4	2.90	12.0	94-112	.2826	9	188-224	.1750	18	282-336	.0360	27	376-448	.0127	36			
LONGITUDINAL AXIS																					
L1	.0031	1	17	2	1.36	12.0	30- 35	.0257	2	60- 70	.0182	5	90-105	.0074	7	120-140	.0116	10	150-175	.0084	12
L2	.0016	3	11	3	.95	12.0	41- 47	.0100	3	82- 94	.0155	6									
L3	.0051	1	4	4	2.06	12.0	53- 65	.0559	6	106-130	.0306	12	159-195	.0177	18	212-260	.0223	24	265-325	.0204	30
L4	.0038	1	1	4	2.28	12.0	71- 88	.1196	8	142-176	.0128	17	213-264	.0400	25	284-352	.0284	34	355-440	.0132	42
L5	.0047	1	3	4	2.85	12.0	94-112	.1330	9	188-224	.1501	18	282-336	.0582	27	376-448	.0208	36			

AV = Number of Spectral Averages per Loop AWF = Averaging Weighting Factor

Exaggeration Factor = .69

TABLE 514.4-AIV. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR 120-MM AMMUNITION TRANSPORTED IN M1A1 TANK WEGMANN HULL RACK

Test Phase	5-500 Hz Floor g2/Hz	No. Sweeps	AV	AWF	Overall RMS g	Time min	Narrowband 1 BW Hz	Narrowband 1 Ampl g2/Hz	Narrowband 1 Sweep BW Hz	Narrowband 2 BW Hz	Narrowband 2 Ampl g2/Hz	Narrowband 2 Sweep BW Hz	Narrowband 3 BW Hz	Narrowband 3 Ampl g2/Hz	Narrowband 3 Sweep BW Hz	Narrowband 4 BW Hz	Narrowband 4 Ampl g2/Hz	Narrowband 4 Sweep BW Hz	Narrowband 5 BW Hz	Narrowband 5 Ampl g2/Hz	Narrowband 5 Sweep BW Hz
VERTICAL AXIS																					
V1	.0021	4	11	3	1.16	56.3	33- 41	.0037	4	66- 82	.0098	8	99-123	.0044	12	132-164	.0084	16	165-205	.0072	20
V2	.0028	3	12	3	1.76	56.3	46- 56	.0219	5	92-112	.0091	10	138-168	.0779	15	184-224	.0173	20	230-280	.0081	25
V3	.0029	2	14	3	1.72	56.3	60- 74	.0340	7	120-148	.0217	14	180-222	.0364	21	240-296	.0111	28	300-370	.0058	35
V4	.0034	1	20	2	2.56	56.3	80-100	.0550	10	160-200	.1093	20	240-300	.0413	30	320-400	.0150	40	400-500	.0163	50
TRANSVERSE AXIS																					
T1	.0024	4	11	3	1.23	56.3	33- 41	.0179	4	66- 82	.0050	8	99-123	.0024	12	132-164	.0052	16	165-205	.0118	20
T2	.0028	4	11	3	1.86	56.3	46- 56	.0246	5	92-112	.0106	10	138-168	.0917	15	184-224	.0300	20			
T3	.0029	2	14	3	1.81	56.3	60- 74	.0239	7	120-148	.0312	14	180-222	.0531	21	240-296	.0088	28	300-370	.0050	35
T4	.0031	1	20	2	2.64	56.3	80-100	.0671	10	160-200	.1627	20	240-300	.0310	30	320-400	.0163	40	400-500	.0081	50
LONGITUDINAL AXIS																					
L1	.0020	4	11	3	1.09	56.3	33- 41	.0106	4	66- 82	.0032	8	99-123	.0020	12	132-164	.0037	16	165-205	.0086	20
L2	.0021	4	11	3	1.56	56.3	46- 56	.0223	5	92-112	.0066	10	138-168	.0575	15	184-224	.0223	20			
L3	.0024	2	14	3	1.58	56.3	60- 74	.0195	7	120-148	.0235	14	180-222	.0396	21	240-296	.0056	28	300-370	.0034	35
L4	.0026	1	20	2	2.42	56.3	80-100	.0444	10	160-200	.1546	20	240-300	.0245	30	320-400	.0091	40	400-500	.0069	50

AV = Number of Spectral Averages per Loop AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AV. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR 105-MM AMMUNITION TRANSPORTED IN M1 TANK HULL RACK

	5-500 Hz				Overall		NARROWBAND 1			NARROWBAND 2			NARROWBAND 3			NARROWBAND 4			NARROWBAND 5		
Test Phase	Floor g2/Hz	No. Sweeps	AV	AWF	RMS g	Time min	BW Hz	Ampl g2/Hz	Sweep BW Hz	BW Hz	Ampl g2/Hz	Sweep BW Hz	BW Hz	Ampl g2/Hz	Sweep BW Hz	BW Hz	Ampl g2/Hz	Sweep BW Hz	BW Hz	Ampl g2/Hz	Sweep BW Hz
VERTICAL AXIS																					
V1	.0014	5	11	3	1.03	45.0	23- 28	.0058	2	46- 56	.0143	5	69- 84	.0066	7	92-112	.0050	10	115-140	.0183	12
V2	.0020	3	12	3	1.27	45.0	33- 41	.0400	4	66- 82	.0172	8	99-123	.0084	12	132-164	.0103	16	165-205	.0091	20
V3	.0018	2	16	3	1.54	45.0	46- 56	.0349	5	92-112	.0257	10	138-168	.0371	15	184-224	.0182	20	230-280	.0111	25
V4	.0026	2	10	4	3.00	45.0	60- 74	.2218	7	120-148	.2574	14	180-222	.0894	21	240-296	.0257	28	300-370	.0062	35
V5	.0037	1	18	2	3.78	45.0	79- 97	.3746	9	158-194	.3076	18	237-291	.0743	27	316-388	.0492	36	395-485	.0052	45
TRANSVERSE AXIS																					
T1	.0009	5	10	4	.76	45.0	14- 28	.0103	7	28- 56	.0059	14									
T2	.0012	3	12	3	.95	45.0	33- 41	.0337	4	66- 82	.0050	8	99-123	.0030	12	132-164	.0050	16	165-205	.0046	20
T3	.0013	2	16	3	1.12	45.0	46- 56	.0299	5	92-112	.0175	10	138-168	.0101	15	184-224	.0086	20	230-280	.0028	25
T4	.0020	2	10	4	2.04	45.0	60- 74	.0701	7	120-148	.0956	14	180-222	.0349	21	240-296	.0224	28	300-370	.0056	35
T5	.0039	1	18	2	2.96	45.0	79- 97	.1227	9	158-194	.1330	18	237-291	.0457	27	316-388	.0625	36	395-485	.0081	45
LONGITUDINAL AXIS																					
L1	.0015	5	10	4	.92	45.0	14- 28	.0101	7	28- 56	.0042	14									
L2	.0019	3	12	3	1.16	45.0	33- 41	.0278	4	66- 82	.0046	8	99-123	.0036	12	132-164	.0076	16	165-205	.0100	20
L3	.0020	2	16	3	1.47	45.0	46- 56	.0278	5	92-112	.0217	10	138-168	.0131	15	184-224	.0275	20	230-280	.0088	25
L4	.0031	2	10	4	2.75	45.0	60- 74	.0558	7	120-148	.1020	14	180-222	.0432	21	240-296	.0520	28	300-370	.0617	35
L5	.0045	1	18	2	3.98	45.0	79- 97	.2687	9	158-194	.1249	18	237-291	.0862	27	316-388	.1426	36	395-485	.0466	45

AV = Number of Spectral Averages per Loop   AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AVI. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR 155-MM PROJECTILE TRANSPORTED IN THE BUSTLE RACK OF THE M109A3 SELF-PROPELLED HOWITZER

Test Phase	5-500 Hz Floor g2/Hz	No. Sweeps	AV	AWF	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NARROWBAND 1 Ampl g2/Hz	NARROWBAND 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NARROWBAND 2 Ampl g2/Hz	NARROWBAND 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NARROWBAND 3 Ampl g2/Hz	NARROWBAND 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NARROWBAND 4 Ampl g2/Hz	NARROWBAND 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NARROWBAND 5 Ampl g2/Hz	NARROWBAND 5 Sweep BW Hz
										VERTICAL AXIS											
V1	.0030	4	10	4	1.71	47.8	24- 42	.0976	9	48- 84	.0361	18									
V2	.0069	3	10	4	3.23	47.8	48- 60	.5202	6	96-120	.2647	12	144-180	.0334	18	192-240	.0219	24			
V3	.0157	2	10	4	4.61	47.8	66- 84	.3852	9	132-168	.4237	18	198-252	.1074	27	264-336	.0249	36			
V4	.0131	2	16	3	3.07	47.8	90-108	.1846	9	180-216	.0669	18	270-324	.0300	27						
										TRANSVERSE AXIS											
T1	.0020	8	10	4	1.35	47.8	18- 36	.0948	9												
T2	.0044	6	10	4	1.96	47.8	42- 54	.2153	6	84-108	.0366	12									
T3	.0074	2	10	4	2.45	47.8	63- 78	.1563	7.5	126-156	.0300	15	189-234	.0241	22.5	252-312	.0118	30	315-390	.0169	37.5
T4	.0106	1	18	2	2.95	47.8	84-108	.1175	12	168-216	.0239	24	252-324	.0290	36	336-432	.0349	48			
										LONGITUDINAL AXIS											
L1	.0051	10	14	3	2.00	47.8	18- 24	.0843	3	36- 48	.2108	6									
L2	.0027	3	10	4	1.77	47.8	36- 48	.1764	6	72- 96	.0420	12	108-144	.0103	18	144-192	.0091	24			
L3	.0042	2	11	3	2.45	47.8	58- 72	.1605	7	116-144	.0152	14	174-216	.0474	21	232-288	.0239	28	290-360	.0386	35
L4	.0047	1	16	3	2.73	47.8	80-106	.1001	13	160-212	.0468	26	240-318	.0534	39	320-424	.0217	52			

AV = Number of Spectral Averages per Loop AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AVII. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR 155-MM PROJECTILE TRANSPORTED IN THE DECK RACKS OF THE M109A3 SELF-PROPELLED HOWITZER

	5-500 Hz				Overall		NARROWBAND 1			NARROWBAND 2			NARROWBAND 3			NARROWBAND 4			NARROWBAND 5		
Test Phase	Floor g2/Hz	No. Sweeps	AV	AWF	RMS g	Time min	BW Hz	Ampl g2/Hz	Sweep BW Hz	BW Hz	Ampl g2/Hz	Sweep BW Hz	BW Hz	Ampl g2/Hz	Sweep BW Hz	BW Hz	Ampl g2/Hz	Sweep BW Hz	BW Hz	Ampl g2/Hz	Sweep BW Hz
VERTICAL AXIS																					
V1	.0032	6	12	3	1.32	38.3	18- 24	.0194	3	36- 48	.0100	6	54- 72	.0103	9						
V2	.0096	4	10	4	3.02	38.3	36- 42	.1262	3	72- 84	.2353	6	108-126	.0876	9	144-168	.0910	12	180-210	.0733	15
V3	.0089	2	10	4	4.54	38.3	48- 60	.5794	6	96-120	.2855	12	144-180	.2445	18	192-240	.1067	24	240-300	.1037	30
V4	.0096	1	17	2	4.35	38.3	68- 84	.4641	8	136-168	.2240	16	204-252	.1133	24	272-336	.0833	32	340-420	.0663	40
V5	.0098	2	14	3	3.36	38.3	90-102	.2038	6	180-204	.2218	12	270-306	.1197	18	360-408	.0418	24			
TRANSVERSE AXIS																					
T1	.0052	10	20	2	1.62	38.3	18- 24	.0173	3												
T2	.0052	4	10	4	1.89	38.3	36- 42	.0632	3	72- 84	.0991	6	108-126	.0094	9	144-168	.0052	12	180-210	.0209	15
T3	.0046	2	10	4	2.24	38.3	48- 60	.0853	6	96-120	.0986	12	144-180	.0312	18	192-240	.0101	24	240-300	.0223	30
T4	.0052	1	17	2	2.54	38.3	68- 84	.0991	8	136-168	.0317	16	204-252	.0603	24	272-336	.0249	32	340-420	.0235	40
T5	.0052	2	10	4	3.25	38.3	90-102	1.0552	6	180-204	.0538	12	270-306	.0349	18	360-408	.0120	24	450-500	.0187	25
LONGITUDINAL AXIS																					
L1	.0018	6	12	3	1.03	38.3	18- 24	.0194	3	36- 48	.0100	6	54- 72	.0098	9						
L2	.0032	4	10	4	1.67	38.3	36- 42	.0032	3	72- 84	.0482	6	108-126	.0215	9	144-168	.0153	12	180-210	.0446	15
L3	.0046	2	10	4	2.41	38.3	48- 60	.0281	6	96-120	.0538	12	144-180	.0496	18	192-240	.0275	24	240-300	.0528	30
L4	.0052	1	17	2	2.64	38.3	68- 84	.0613	8	136-168	.0424	16	204-252	.0295	24	272-336	.0649	32	340-420	.0273	40
L5	.0052	6	12	3	1.84	38.3	90- 96	.0645	3	180-192	.0595	6	270-288	.0404	9						

AV = Number of Spectral Averages per Loop AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AVIII. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR 155-MM PROJECTILE TRANSPORTED ON THE SPONSON OF THE M109A3 SELF-PROPELLED HOWITZER

Test Phase	5-500 Hz Floor g2/Hz	No. Sweeps	AV	AWF	Overall RMS g	Time min	Narrowband 1 BW Hz	Narrowband 1 Ampl g2/Hz	Narrowband 1 Sweep BW Hz	Narrowband 2 BW Hz	Narrowband 2 Ampl g2/Hz	Narrowband 2 Sweep BW Hz	Narrowband 3 BW Hz	Narrowband 3 Ampl g2/Hz	Narrowband 3 Sweep BW Hz	Narrowband 4 BW Hz	Narrowband 4 Ampl g2/Hz	Narrowband 4 Sweep BW Hz	Narrowband 5 BW Hz	Narrowband 5 Ampl g2/Hz	Narrowband 5 Sweep BW Hz
VERTICAL AXIS																					
V1	.0022	5	10	4	1.22	38.3	36- 48	.0420	6	72- 96	.0155	12									
V2	.0067	4	10	4	3.38	38.3	36- 42	1.0916	3	72- 84	.2673	6	108-126	.2593	9	144-168	.0334	12	180-210	.0524	15
V3	.0096	2	10	4	5.54	38.3	48- 60	2.2084	6	96-120	.8362	12	144-180	.0416	18	192-240	.0597	24	240-300	.0460	30
V4	.0111	1	20	2	7.32	38.3	66- 82	1.1492	8	132-164	2.0115	16	198-246	.0777	24	264-328	.1774	32			
V5	.0118	1	20	2	5.82	38.3	90-108	2.1947	9	180-216	.1052	18	270-324	.1334	27	360-432	.1078	36			
TRANSVERSE AXIS																					
T1	.0018	10	10	4	.98	38.3	18- 24	.0100	3	36- 48	.0088	6									
T2	.0052	4	10	4	2.19	38.3	36- 42	.1318	3	72- 84	.1507	6	108-126	.0382	9	144-168	.0352	12	180-210	.0253	15
T3	.0074	2	10	4	4.02	38.3	48- 60	.6917	6	96-120	.1720	12	144-180	.1021	18	192-240	.1563	24	240-300	.0457	30
T4	.0072	2	10	4	3.56	38.3	66- 78	.4766	6	132-156	.1241	12	198-234	.0792	18	264-312	.0934	24	330-390	.0575	30
T5	.0076	1	14	3	5.18	38.3	84-108	.9133	12	168-216	.1748	24	252-324	.1324	36	336-432	.0838	48			
LONGITUDINAL AXIS																					
L1	.0012	10	10	4	.82	38.3	24- 36	.0155	6												
L2	.0022	4	10	4	1.17	38.3	42- 48	.0094	3	84- 96	.0251	6	126-144	.0067	9	168-192	.0040	12	210-240	.0058	15
L3	.0026	2	10	4	1.56	38.3	54- 66	.0460	6	108-132	.0172	12	162-198	.0067	18	216-264	.0098	24	270-330	.0179	30
L4	.0047	1	15	3	2.99	38.3	72- 90	.0364	9	144-180	.0207	18	216-270	.0179	27	288-360	.1603	36	360-450	.0064	45
L5	.0032	2	14	3	1.69	38.3	96-108	.0490	6	192-216	.0310	12	288-324	.0121	18	384-432	.0245	24			

AV = Number of Spectral Averages per Loop   AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AIX. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR 155-MM PROPELLING CHARGES TRANSPORTED IN THE M109A3 SELF-PROPELLED HOWITZER

Test Phase	5-500 Hz Floor g2/Hz	No. Sweeps	AV	AWF	Overall RMS g	Time min	NARROWBAND 1 BW Hz	Ampl g2/Hz	Sweep BW Hz	NARROWBAND 2 BW Hz	Ampl g2/Hz	Sweep BW Hz	NARROWBAND 3 BW Hz	Ampl g2/Hz	Sweep BW Hz	NARROWBAND 4 BW Hz	Ampl g2/Hz	Sweep BW Hz	NARROWBAND 5 BW Hz	Ampl g2/Hz	Sweep BW Hz
VERTICAL AXIS																					
V1	.0037	3	12	3	1.83	38.3	24- 36	.1613	6	48- 72	.0495	12	72-108	.0047	18						
V2	.0053	4	10	4	2.74	38.3	42- 48	1.0751	3	84- 96	.1382	6	126-144	.0120	9	168-192	.0201	12	210-240	.0480	15
V3	.0085	4	10	4	3.10	38.3	54- 60	.8679	3	108-120	.0374	6	162-180	.0312	9	216-240	.1583	12	270-300	.0528	15
V4	.0103	2	14	3	3.17	38.3	66- 78	.5529	6	132-156	.0464	12	198-234	.0529	18	264-312	.0317	24			
V5	.0103	1	20	2	3.44	38.3	84-108	.2031	12	168-216	.0818	24	252-324	.0846	36						
TRANSVERSE AXIS																					
T1	.0047	3	12	3	2.37	38.3	29- 36	.1556	3.5	58- 72	.0605	7	87-108	.1356	10.5	116-144	.0309	14	145-180	.0398	17.5
T2	.0066	4	10	4	3.43	38.3	42- 48	.5715	3	84- 96	.1398	6	126-144	.1504	9	168-192	.2819	12	210-240	.0988	15
T3	.0100	2	10	4	5.36	38.3	54- 66	.7530	6	108-132	.2294	12	162-198	.7143	18	216-264	.0993	24	270-330	.0740	30
T4	.0113	2	10	4	6.41	38.3	72- 84	1.7997	6	144-168	1.1840	12	216-252	.2055	18	288-336	.2092	24	360-420	.0920	30
T5	.0121	2	14	3	5.06	38.3	90-102	1.1329	6	180-204	.6302	12	270-306	.2222	18	360-408	.0821	24			
LONGITUDINAL AXIS																					
L1	.0056	5	10	4	3.04	47.8	36- 42	.7202	3	72- 84	.1161	6	108-126	.1504	9	144-168	.0870	12	180-210	.0988	15
L2	.0074	2	14	3	5.25	47.8	48- 60	.6747	6	96-120	.1352	12	144-180	.5833	18	192-240	.2660	24	240-300	.0677	30
L3	.0111	2	14	3	6.16	47.8	66- 78	1.4765	6	132-156	.6035	12	198-234	.5570	18	264-312	.2119	24	330-390	.0727	30
L4	.0121	2	10	4	7.05	47.8	84-102	1.6440	9	168-204	1.1807	18	252-306	.2158	27	336-408	.0821	36			

AV = Number of Spectral Averages per Loop AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AX. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR INSTALLED EQUIPMENT IN THE TURRET OF THE M109A3 SELF-PROPELLED HOWITZER

Test Phase	5-500 Hz Floor g2/Hz	No. Sweeps	AV	AWF	Overall RMS g	Time min	Narrowband 1 BW Hz	Narrowband 1 Ampl g2/Hz	Narrowband 1 Sweep BW Hz	Narrowband 2 BW Hz	Narrowband 2 Ampl g2/Hz	Narrowband 2 Sweep BW Hz	Narrowband 3 BW Hz	Narrowband 3 Ampl g2/Hz	Narrowband 3 Sweep BW Hz	Narrowband 4 BW Hz	Narrowband 4 Ampl g2/Hz	Narrowband 4 Sweep BW Hz	Narrowband 5 BW Hz	Narrowband 5 Ampl g2/Hz	Narrowband 5 Sweep BW Hz
VERTICAL AXIS																					
V1	.0010	7	10	4	1.05	54.0	18- 30	.0882	6	36- 60	.0081	12									
V2	.0024	7	10	4	1.80	54.0	36- 42	.4914	3	72- 84	.0391	6	108-126	.0076	9	144-168	.0275	12			
V3	.0026	3	12	3	1.85	54.0	48- 60	.2467	6	96-120	.0319	12	144-180	.0062	18	192-240	.0135	24			
V4	.0034	1	20	2	2.07	54.0	66- 96	.1227	15	132-192	.0249	30	198-288	.0074	45						
V5	.0024	2	12	3	1.40	54.0	102-126	.0307	12	204-252	.0120	24	306-378	.0024	36	408-500	.0079	48			
TRANSVERSE AXIS																					
T1	.0022	4	12	3	1.29	54.0	18- 36	.0585	9	36- 72	.0064	18									
T2	.0034	5	12	3	1.71	54.0	42- 48	.1639	3	84- 96	.0435	6	126-144	.0128	9	168-192	.0130	12	210-240	.0239	15
T3	.0032	2	16	3	1.71	54.0	54- 66	.0332	6	108-132	.0223	12	162-198	.0150	18	216-264	.0179	24	270-330	.0152	30
T4	.0040	1	20	2	2.31	54.0	72- 96	.0457	12	144-192	.0221	24	216-288	.0660	36	288-384	.0076	48			
T5	.0030	1	20	2	1.82	54.0	102-126	.0024	12	204-252	.0647	24	306-378	.0072	36	408-504	.0074	48			
LONGITUDINAL AXIS																					
L1	.0012	4	12	3	.84	54.0	18- 36	.0069	9	36- 72	.0046	18									
L2	.0017	5	12	3	1.15	54.0	42- 48	.0305	3	84- 96	.0143	6	126-144	.0040	9	168-192	.0246	12	210-240	.0037	15
L3	.0022	3	12	3	1.27	54.0	54- 66	.0679	6	108-132	.0034	12	162-198	.0067	18	216-264	.0032	24			
L4	.0030	1	20	2	1.56	54.0	72- 90	.0369	9	144-180	.0229	18	216-270	.0040	27	288-360	.0052	36	360-450	.0069	45
L5	.0022	1	16	3	1.43	54.0	96-126	.0157	15	192-252	.0091	30	288-378	.0076	45	384-504	.0072	60			

AV = Number of Spectral Averages per Loop   AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AXI. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR INSTALLED EQUIPMENT ON THE HULL WALLS OF THE M109A3 SELF-PROPELLED HOWITZER

Test Phase	5-500 Hz Floor g2/Hz	No. Sweeps	AV	AWF	Overall RMS g	Time min	NARROWBAND 1 BW Hz	Ampl g2/Hz	Sweep BW Hz	NARROWBAND 2 BW Hz	Ampl g2/Hz	Sweep BW Hz	NARROWBAND 3 BW Hz	Ampl g2/Hz	Sweep BW Hz	NARROWBAND 4 BW Hz	Ampl g2/Hz	Sweep BW Hz	NARROWBAND 5 BW Hz	Ampl g2/Hz	Sweep BW Hz
VERTICAL AXIS																					
V1	.0044	6	10	4	1.61	45.0	18- 24	.0444	3	36- 48	.0044	6	54- 72	.0204	9	72- 96	.0162	12			
V2	.0074	4	12	3	2.32	45.0	30- 36	.0806	3	60- 72	.0410	6	90-108	.0657	9	120-144	.0219	12	150-180	.0480	15
V3	.0086	3	10	4	3.77	45.0	84- 96	.8127	6	168-192	.0121	12	252-288	.2471	18	336-384	.0420	24			
V4	.0084	2	12	3	4.67	45.0	54- 66	.3652	6	108-132	.0661	12	162-198	.2657	18	216-264	.2075	24	270-330	.1895	30
V5	.0089	2	10	4	5.03	45.0	72- 90	.8138	9	144-180	.2323	18	216-270	.2549	27	288-360	.0924	36			
V6	.0089	1	12	3	6.17	45.0	96-126	.8320	15	192-252	.5561	30	288-378	.0969	45	384-500	.0251	58			
TRANSVERSE AXIS																					
T1	.0120	4	11	3	3.71	54.0	34- 42	.0223	4	68- 84	.1398	8	102-126	.0147	12	136-168	.3751	16	170-210	.0573	20
T2	.0110	2	16	3	5.56	54.0	48- 60	.2264	6	96-120	.4127	12	144-180	.1834	18	192-240	.5275	24	240-300	.1401	30
T3	.0116	2	16	3	4.66	54.0	66- 78	.2519	6	132-156	.5437	12	198-234	.1939	18	264-312	.1158	24	330-390	.0904	30
T4	.0113	1	20	2	5.35	54.0	84-102	.2394	9	168-204	.4815	18	252-306	.1971	27	336-408	.1249	36	420-500	.0876	40
T5	.0121	2	12	3	5.59	54.0	108-126	.5563	9	216-252	.4211	18	324-378	.2959	27	432-500	.1593	34			
LONGITUDINAL AXIS																					
L1	.0014	10	20	2	.86	45.0	24- 30	.0169	3												
L2	.0034	7	10	4	1.41	54.0	36- 42	.0081	3	72- 84	.0307	6	108-126	.0034	9	144-168	.0135	12			
L3	.0032	2	12	3	1.53	45.0	48- 60	.0207	6	96-120	.0100	12	144-180	.0221	18	192-240	.0100	24	240-300	.0054	30
L4	.0032	2	12	3	1.69	45.0	66- 78	.0490	6	132-156	.0131	12	198-234	.0315	18	264-312	.0128	24	330-390	.0076	30
L5	.0032	1	18	2	1.68	45.0	84-102	.0199	9	168-204	.0169	18	252-306	.0110	27	336-408	.0084	36	420-500	.0130	40
L6	.0037	2	10	4	2.10	45.0	108-126	.0572	9	216-252	.0466	18	324-378	.0255	27	432-500	.0246	34			

AV = Number of Spectral Averages per Loop   AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AXII. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR INSTALLED EQUIPMENT ON THE TRUNNION OF THE M110A2 SELF-PROPELLED HOWITZER

Test Phase	5-500 Hz Floor g2/Hz	No. Sweeps	AV	AWF	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NB 1 Ampl g2/Hz	NB 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NB 2 Ampl g2/Hz	NB 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NB 3 Ampl g2/Hz	NB 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NB 4 Ampl g2/Hz	NB 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NB 5 Ampl g2/Hz	NB 5 Sweep BW Hz
VERTICAL AXIS																					
V1	.0032	7	10	4	1.51	54.0	24- 36	.0717	6	48- 72	.0263	12									
V2	.0299	5	12	3	7.31	54.0	42- 48	2.4285	3	84- 96	1.8373	6	126-144	.9756	9	168-192	.5968	12	210-240	.3829	15
V3	.0221	2	16	3	7.65	54.0	54- 66	.7512	6	108-132	1.7157	12	162-198	.6355	18	216-264	.2226	24	270-330	.2563	30
V4	.0275	2	12	3	10.44	54.0	72- 90	2.8300	9	144-180	1.9544	18	216-270	1.0022	27	288-360	.2827	36			
V5	.0050	4	12	3	2.22	54.0	96-114	.2151	9	192-228	.0369	18									
TRANSVERSE AXIS																					
T1	.0246	7	10	4	4.94	67.5	42- 48	.4085	3	84- 96	.3341	6	126-144	.4016	9	168-192	.3159	12	210-240	.1822	15
T2	.0191	3	12	3	6.05	67.5	54- 66	.4884	6	108-132	.5501	12	162-198	.3505	18	216-264	.1285	24	270-330	.3323	30
T3	.0241	2	12	3	7.76	67.5	72- 90	1.0480	9	144-180	.9808	18	216-270	.3409	27	288-360	.1933	36	360-450	.1854	45
T4	.0044	6	10	4	1.85	67.5	96-114	.1077	9	192-228	.0221	18									
LONGITUDINAL AXIS																					
L1	.0293	7	10	4	7.45	67.5	36- 42	1.7113	3	72- 84	1.1814	6	108-126	.4711	9	144-168	1.2878	12	180-210	.6981	15
L2	.0032	9	10	4	1.39	67.5	48- 60	.0293	6	96-120	.0183	12									
L3	.0342	3	12	3	7.59	67.5	66- 78	.2431	6	132-156	.9714	12	198-234	1.0473	18	264-312	.3255	24	330-390	.1346	30
L4	.0054	2	12	3	2.79	67.5	84-114	.1483	15	168-228	.0811	30	252-342	.0215	45						

AV = Number of Spectral Averages per Loop   AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AXIII. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR INSTALLED EQUIPMENT ON THE DECK OF THE M110A2 SELF-PROPELLED HOWITZER

Test Phase	5-500 Hz Floor g2/Hz	No Sweeps	AV	AWF	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NARROWBAND 1 Ampl g2/Hz	NARROWBAND 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NARROWBAND 2 Ampl g2/Hz	NARROWBAND 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NARROWBAND 3 Ampl g2/Hz	NARROWBAND 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NARROWBAND 4 Ampl g2/Hz	NARROWBAND 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NARROWBAND 5 Ampl g2/Hz	NARROWBAND 5 Sweep BW Hz
VERTICAL AXIS																					
V1	.0086	5	12	3	2.68	54.0	24- 30	.0627	3	48- 60	.0580	6	72- 90	.0856	9	96-120	.1023	12	120-150	.0514	15
V2	.0332	5	12	3	7.40	54.0	36- 42	1.1701	3	72- 84	.8630	6	108-126	2.2076	9	144-168	.6489	12	180-210	.2355	15
V3	.0177	2	16	3	6.62	54.0	48- 60	.8503	6	96-120	.4623	12	144-180	.3564	18	192-240	.2534	24	240-300	.4508	30
V4	.0334	2	11	3	12.18	54.0	68- 84	1.0014	8	136-168	1.2804	16	204-252	.7831	24	272-336	1.0793	32	340-420	1.3497	40
V5	.0320	1	18	2	13.23	54.0	92-114	1.6425	11	184-228	.8965	22	276-342	.6735	33	368-456	1.4367	44	460-500	.7516	20
TRANSVERSE AXIS																					
T1	.0091	7	10	4	2.50	54.0	30- 36	.2088	3	60- 72	.0091	6	90-108	.0091	9	120-144	.1063	12			
T2	.0299	5	12	3	5.50	54.0	42- 48	.5949	3	84- 96	.5447	6	126-144	.7349	9	168-192	.2151	12	210-240	.1711	15
T3	.0231	2	16	3	8.25	54.0	54- 66	.2660	6	108-132	.1937	12	162-198	.3084	18	216-264	1.3153	24	270-330	.5905	30
T4	.0303	1	20	2	10.00	54.0	72- 90	.3552	9	144-180	.6218	18	216-270	.6180	27	288-360	.7675	36	360-450	.6735	45
T5	.0327	1	20	2	14.20	54.0	96-114	.4503	9	192-228	.4985	18	288-342	.8524	27	384-456	1.4883	36	480-500	2.2304	10
LONGITUDINAL AXIS																					
L1	.0050	7	10	4	1.71	54.0	24- 36	.0394	6	48- 72	.0243	12									
L2	.0267	5	12	3	5.59	54.0	42- 48	.5509	3	84- 96	.8962	6	126-144	.7247	9	168-192	.2472	12	210-240	.1838	15
L3	.0185	2	16	3	5.72	54.0	54- 66	.1802	6	108-132	.6280	12	162-198	.2395	18	216-264	.2525	24	270-330	.2092	30
L4	.0227	1	20	2	8.50	54.0	72- 90	.4601	9	144-180	.5017	18	216-270	.2465	27	288-360	.4978	36	360-450	.5852	45
L5	.0138	1	20	2	5.04	54.0	96-114	.0715	9	192-228	.1047	18	288-342	.2490	27	384-456	.1310	36	480-500	.1428	10

AV = Number of Spectral Averages per Loop AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AXIV. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR INSTALLED EQUIPMENT ON THE GUN MOUNT OF THE M110A2 SELF-PROPELLED HOWITZER

Test Phase	5-500 Hz Floor g2/Hz	No. Sweeps	AV	AWF	Overall RMS g	Time min	Narrowband 1 BW Hz	Narrowband 1 Ampl g2/Hz	Narrowband 1 Sweep BW Hz	Narrowband 2 BW Hz	Narrowband 2 Ampl g2/Hz	Narrowband 2 Sweep BW Hz	Narrowband 3 BW Hz	Narrowband 3 Ampl g2/Hz	Narrowband 3 Sweep BW Hz	Narrowband 4 BW Hz	Narrowband 4 Ampl g2/Hz	Narrowband 4 Sweep BW Hz	Narrowband 5 BW Hz	Narrowband 5 Ampl g2/Hz	Narrowband 5 Sweep BW Hz
VERTICAL AXIS																					
V1	.0017	7	10	4	1.04	54.0	24- 36	.0183	6	48- 72	.0128	12									
V2	.0182	5	12	3	4.93	54.0	42- 48	.4019	3	84- 96	.3528	6	126-144	.5447	9	168-192	.3205	12	210-240	.2726	15
V3	.0125	2	16	3	4.96	54.0	54- 66	.6367	6	108-132	.6391	12	162-198	.2143	18	216-264	.0944	24	270-330	.0627	30
V4	.0147	1	20	2	6.77	54.0	72- 96	.4788	12	144-192	.7858	24	216-288	.1234	36	288-384	.2347	48			
V5	.0047	7	10	4	1.75	54.0	102-114	.0914	6	204-228	.0233	12									
TRANSVERSE AXIS																					
T1	.0303	7	10	4	5.55	67.5	36- 42	1.0479	3	72- 84	.1262	6	108-126	.7384	9	144-168	.2433	12	180-210	.2463	15
T2	.0044	3	12	3	2.07	67.5	48- 60	.0310	6	96-120	.0378	12	144-180	.0251	18	192-240	.0339	24	240-300	.0195	30
T3	.0331	3	12	3	8.97	67.5	66- 78	.8721	6	132-156	2.4664	12	198-234	.5855	18	264-312	.7900	24	330-390	.0888	30
T4	.0088	1	20	2	6.21	67.5	86-114	1.9514	14	172-228	.1219	28	258-342	.0605	42	344-456	.0394	56			
LONGITUDINAL AXIS																					
L1	.0281	7	10	4	5.72	67.5	42- 48	.1040	3	84- 96	.3768	6	126-144	.3527	9	168-192	.1136	12	210-240	.8670	15
L2	.0189	3	12	3	6.11	67.5	54- 66	.4277	6	108-132	1.1609	12	162-198	.0516	18	216-264	.2360	24	270-330	.2180	30
L3	.0233	2	12	3	8.01	67.5	72- 90	.9363	9	144-180	.9017	18	216-270	.1414	27	288-360	.4952	36	360-450	.2104	45
L4	.0042	6	10	4	2.28	67.5	96-114	.3013	9	192-228	.0300	18									

AV = Number of Spectral Averages per Loop   AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AXV. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR INSTALLED EQUIPMENT ON THE HULL DRIVER COMPARTMENT OF THE M110A2 SELF-PROPELLED HOWITZER

Test Phase	5-500 Hz Floor g2/Hz	No. Sweeps	AV	AWF	Overall RMS g	Time min	Narrowband 1 BW Hz	Narrowband 1 Ampl g2/Hz	Narrowband 1 Sweep BW Hz	Narrowband 2 BW Hz	Narrowband 2 Ampl g2/Hz	Narrowband 2 Sweep BW Hz	Narrowband 3 BW Hz	Narrowband 3 Ampl g2/Hz	Narrowband 3 Sweep BW Hz	Narrowband 4 BW Hz	Narrowband 4 Ampl g2/Hz	Narrowband 4 Sweep BW Hz	Narrowband 5 BW Hz	Narrowband 5 Ampl g2/Hz	Narrowband 5 Sweep BW Hz
VERTICAL AXIS																					
V1	.0052	9	11	3	1.68	54.0	30- 36	.0391	3	60- 72	.0052	6	90-108	.0201	9						
V2	.0253	5	12	3	5.14	54.0	42- 48	.2574	3	84- 96	.4282	6	126-144	.4139	9	168-192	.2844	12	210-240	.3028	15
V3	.0175	2	16	3	5.62	54.0	54- 66	.2413	6	108-132	.2622	12	162-198	.1099	18	216-264	.2019	24	270-330	.4353	30
V4	.0217	1	20	2	7.56	54.0	72- 90	.1101	9	144-180	.4506	18	216-270	.2908	27	288-360	.3665	36	360-450	.4270	45
V5	.0128	2	12	3	3.97	54.0	96-114	.1494	9	192-228	.0661	18	288-342	.1716	27	384-456	.0938	36			
TRANSVERSE AXIS																					
T1	.0081	5	12	3	2.28	54.0	30- 36	.0081	3	60- 72	.0081	6	90-108	.0081	9	120-144	.0856	12	150-180	.0264	15
T2	.0233	5	12	3	4.57	54.0	42- 48	.2035	3	84- 96	.0990	6	126-144	.4478	9	168-192	.2204	12	210-240	.1662	15
T3	.0213	2	16	3	4.66	54.0	54- 66	.1207	6	108-132	.3215	12	162-198	.0623	18	216-264	.1426	24	270-330	.1318	30
T4	.0265	1	20	2	8.60	54.0	72- 90	.1445	9	144-180	.4487	18	216-270	.3014	27	288-360	.6389	36	360-450	.5300	45
T5	.0287	1	20	2	8.29	54.0	96-114	.3548	9	192-228	.2676	18	288-342	.7922	27	384-456	.4408	36	480-500	.2925	10
LONGITUDINAL AXIS																					
L1	.0034	7	10	4	1.36	54.0	48- 72	.0172	12												
L2	.0227	5	12	3	4.42	54.0	42- 48	.2119	3	84- 96	.2254	6	126-144	.2459	9	168-192	.1139	12	210-240	.2498	15
L3	.0160	2	16	3	4.09	54.0	54- 66	.0617	6	108-132	.1350	12	162-198	.1597	18	216-264	.0811	24	270-330	.1153	30
L4	.0195	1	20	2	5.97	54.0	72- 90	.2262	9	144-180	.2939	18	216-270	.1536	27	288-360	.1097	36	360-450	.2930	45
L5	.0096	2	12	3	3.08	54.0	96-114	.0777	9	192-228	.0629	18	288-342	.0762	27	384-456	.0477	36			

AV = Number of Spectral Averages per Loop   AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AXVI. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR INSTALLED EQUIPMENT ON THE SPONSONS OF THE M113A1 ARMORED PERSONNEL CARRIER

Test Phase	5-500 Hz Floor g2/Hz	No. Sweeps	AV	AWF	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NARROWBAND 1 Ampl g2/Hz	NARROWBAND 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NARROWBAND 2 Ampl g2/Hz	NARROWBAND 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NARROWBAND 3 Ampl g2/Hz	NARROWBAND 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NARROWBAND 4 Ampl g2/Hz	NARROWBAND 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NARROWBAND 5 Ampl g2/Hz	NARROWBAND 5 Sweep BW Hz
VERTICAL AXIS																					
V1	.0056	4	12	3	2.20	45.0	24- 30	.1523	3	48- 60	.0844	6	72- 90	.1025	9	96-120	.0226	12	120-150	.0123	15
V2	.0120	4	12	3	3.53	45.0	36- 42	.3098	3	72- 84	.5120	6	108-126	.0938	9	144-168	.0736	12	180-210	.0908	15
V3	.0132	2	12	3	6.05	45.0	48- 60	2.9623	6	96-120	.2508	12	144-180	.1737	18	192-240	.1615	24	240-300	.1143	30
V4	.0110	2	14	3	5.06	45.0	67- 78	2.4820	5	134-156	.1573	11	201-234	.1719	16	268-312	.0613	22	335-390	.0549	27
V5	.0180	1	18	2	7.49	45.0	84-102	2.4861	9	168-204	.5375	18	252-306	.3000	27	336-408	.1212	36	420-500	.1134	40
V6	.0208	3	10	4	8.95	45.0	108-120	6.7305	6	216-240	1.1798	12	324-360	.6259	18	432-480	.2177	24			
TRANSVERSE AXIS																					
T1	.0075	4	12	3	2.82	45.0	24- 30	.0238	3	48- 60	.1397	6	72- 90	.2698	9	96-120	.0601	12	120-150	.0358	15
T2	.0149	4	12	3	5.39	45.0	36- 42	.2406	3	72- 84	1.2746	6	108-126	1.0559	9	144-168	.2446	12	180-210	.1039	15
T3	.0152	2	12	3	7.93	45.0	48- 60	4.2320	6	96-120	1.0347	12	144-180	.4844	18	192-240	.1891	24	240-300	.1900	30
T4	.0124	4	12	3	4.46	45.0	66- 72	2.9725	3	132-144	.3121	6	198-216	.1896	9	264-288	.0858	12	330-360	.0498	15
T5	.0098	1	18	2	11.01	45.0	84-102	10.435	9	168-204	.3376	18	252-306	.4768	27	336-408	.0833	36	420-500	.0386	40
T6	.0234	3	10	4	12.00	45.0	108-120	18.712	6	216-240	.6378	12	324-360	.6412	18	432-480	.1028	24			
LONGITUDINAL AXIS																					
L1	.0010	4	12	3	.94	45.0	24- 30	.0568	3	48- 60	.0174	6	72- 90	.0098	9	96-120	.0016	12	120-150	.0030	15
L2	.0020	4	12	3	1.43	45.0	36- 42	.1525	3	72- 84	.0643	6	108-126	.0064	9	144-168	.0149	12	180-210	.0039	15
L3	.0041	2	12	3	2.19	45.0	48- 60	.1122	6	96-120	.0289	12	144-180	.0765	18	192-240	.0176	24	240-300	.0109	30
L4	.0041	2	12	3	1.84	45.0	66- 78	.1661	6	132-156	.0118	12	198-234	.0129	18	264-312	.0074	24	330-390	.0057	30
L5	.0073	1	18	2	3.27	45.0	84-102	.5564	9	168-204	.0788	18	252-306	.0344	27	336-408	.0127	36	420-500	.0063	40
L6	.0073	3	10	4	2.76	45.0	108-120	.5482	6	216-240	.0316	12	324-360	.0316	18	432-480	.0084	24			

AV = Number of Spectral Averages per Loop   AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AXVII. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR INSTALLED EQUIPMENT ON TOP OF THE M113A1 ARMORED PERSONNEL CARRIER

Test Phase	5-500 Hz Floor g2/Hz	No. Sweeps	AV	AWF	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NARROWBAND 1 Ampl g2/Hz	NARROWBAND 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NARROWBAND 2 Ampl g2/Hz	NARROWBAND 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NARROWBAND 3 Ampl g2/Hz	NARROWBAND 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NARROWBAND 4 Ampl g2/Hz	NARROWBAND 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NARROWBAND 5 Ampl g2/Hz	NARROWBAND 5 Sweep BW Hz
VERTICAL AXIS																					
V1	.0057	4	12	3	2.61	45.0	24- 30	.3166	3	48- 60	.0571	6	72- 90	.2471	9	96-120	.0284	12	120-150	.0253	15
V2	.0101	4	12	3	3.77	45.0	36- 42	.3222	3	72- 84	.4779	6	108-126	.1729	9	144-168	.2408	12	180-210	.0902	15
V3	.0136	2	12	3	6.04	45.0	48- 60	.5418	6	96-120	.5462	12	144-180	.3483	18	192-240	.4488	24	240-300	.1387	30
V4	.0104	2	12	3	3.96	45.0	66- 78	.5959	6	132-156	.2800	12	198-234	.1679	18	264-312	.0208	24	330-390	.0349	30
V5	.0164	1	18	2	7.97	45.0	84-102	4.0698	9	168-204	.8382	18	252-306	.0992	27	336-408	.0621	36	420-500	.0214	40
V6	.0254	3	10	4	11.88	45.0	108-120	14.599	6	216-240	3.0643	12	324-360	.2433	18	432-480	.0608	24			
TRANSVERSE AXIS																					
T1	.0018	4	12	3	1.11	45.0	24- 30	.0582	3	48- 60	.0153	6	72- 90	.0105	9	96-120	.0018	12	120-150	.0029	15
T2	.0033	4	12	3	1.64	45.0	36- 42	.1131	3	72- 84	.0460	6	108-126	.0300	9	144-168	.0157	12	180-210	.0095	15
T3	.0049	2	12	3	2.75	45.0	48- 60	.4060	6	96-120	.0803	12	144-180	.0362	18	192-240	.0390	24	240-300	.0203	30
T4	.0032	3	10	4	2.03	45.0	66- 78	.3632	6	132-156	.0192	12	198-234	.0104	18	264-312	.0050	24			
T5	.0067	2	14	3	3.52	45.0	84-102	.7592	9	168-204	.0891	18	252-306	.0368	27						
T6	.0063	4	10	4	2.58	45.0	108-120	.2799	6	216-240	.1276	12	324-360	.0311	18						
LONGITUDINAL AXIS																					
L1	.0017	6	10	4	.99	45.0	24- 30	.0074	3	48- 60	.0042	6	72- 90	.0124	9	96-120	.0022	12			
L2	.0039	4	12	3	1.60	45.0	36- 42	.0324	3	72- 84	.0626	6	108-126	.0088	9	144-168	.0088	12	180-210	.0105	15
L3	.0043	2	12	3	1.97	45.0	48- 60	.0394	6	96-120	.0460	12	144-180	.0275	18	192-240	.0224	24	240-300	.0112	30
L4	.0036	2	12	3	1.63	45.0	66- 78	.0618	6	132-156	.0226	12	198-234	.0113	18	264-312	.0058	24	330-390	.0068	30
L5	.0066	2	10	4	3.28	45.0	84-102	.3528	9	168-204	.1764	18	252-306	.0472	27	336-408	.0133	36			
L6	.0075	3	10	4	3.05	45.0	108-120	.2910	6	216-240	.1969	12	324-360	.0858	18	432-480	.0159	24			

AV = Number of Spectral Averages per Loop AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AXVIII. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR INSTALLED EQUIPMENT ON THE DECK OF THE M113A1 ARMORED PERSONNEL CARRIER

Test Phase	5-500 Hz Floor g2/Hz	No. Sweeps	AV	AWF	Overall RMS g	Time min	Narrowband 1 BW Hz	Narrowband 1 Ampl g2/Hz	Narrowband 1 Sweep BW Hz	Narrowband 2 BW Hz	Narrowband 2 Ampl g2/Hz	Narrowband 2 Sweep BW Hz	Narrowband 3 BW Hz	Narrowband 3 Ampl g2/Hz	Narrowband 3 Sweep BW Hz	Narrowband 4 BW Hz	Narrowband 4 Ampl g2/Hz	Narrowband 4 Sweep BW Hz	Narrowband 5 BW Hz	Narrowband 5 Ampl g2/Hz	Narrowband 5 Sweep BW Hz
VERTICAL AXIS																					
V1	.0090	4	12	3	3.91	45.0	24- 30	.0488	3	48- 60	.2881	6	72- 90	.7876	9	96-120	.0922	12	120-150	.0783	15
V2	.0154	4	12	3	5.80	45.0	36- 42	.5468	3	72- 84	2.8516	6	108-126	.5710	9	144-168	.1080	12	180-210	.1003	15
V3	.0190	2	12	3	6.97	45.0	48- 60	1.3670	6	96-120	1.4124	12	144-180	.4079	18	192-240	.2432	24	240-300	.0853	30
V4	.0150	2	12	3	6.17	45.0	66- 78	2.4200	6	132-156	.8518	12	198-234	.2334	18	264-312	.0632	24	330-390	.0528	30
V5	.0263	1	18	2	14.62	45.0	84-102	17.566	9	168-204	.8421	18	252-306	.3058	27	336-408	.4541	36	420-500	.1437	40
V6	.0311	3	10	4	14.41	45.0	108-120	25.374	6	216-240	.9117	12	324-360	.5616	18	432-480	.8734	24			
TRANSVERSE AXIS																					
T1	.0041	4	12	3	1.74	45.0	24- 30	.1118	3	48- 60	.0223	6	72- 90	.0230	9	96-120	.0143	12	120-150	.0233	15
T2	.0088	4	12	3	3.02	45.0	36- 42	.3225	3	72- 84	.1002	6	108-126	.2736	9	144-168	.0427	12	180-210	.0396	15
T3	.0100	2	12	3	4.82	45.0	48- 60	1.0548	6	96-120	.2878	12	144-180	.1795	18	192-240	.0939	24	240-300	.1308	30
T4	.0083	2	12	3	3.82	45.0	66- 78	1.0893	6	132-156	.1479	12	198-234	.0600	18	264-312	.0514	24	330-390	.0203	30
T5	.0138	1	18	2	5.90	45.0	84-102	1.9798	9	168-204	.2213	18	252-306	.1805	27	336-408	.0594	36	420-500	.0240	40
T6	.0082	3	10	4	7.11	45.0	108-120	5.7063	6	216-240	.6276	12	324-360	.1972	18	432-480	.0718	24			
LONGITUDINAL AXIS																					
L1	.0027	4	12	3	1.35	45.0	24- 30	.0679	3	48- 60	.0144	6	72- 90	.0240	9	96-120	.0040	12	120-150	.0034	15
L2	.0059	4	12	3	2.05	45.0	36- 42	.2259	3	72- 84	.0543	6	108-126	.0233	9	144-168	.0115	12	180-210	.0137	15
L3	.0067	2	12	3	2.57	45.0	48- 60	.1404	6	96-120	.0697	12	144-180	.0442	18	192-240	.0201	24	240-300	.0320	30
L4	.0055	2	12	3	2.10	45.0	66- 78	.1074	6	132-156	.0218	12	198-234	.0333	18	264-312	.0148	24	330-390	.0102	30
L5	.0093	1	18	2	3.12	45.0	84-102	.6231	9	168-204	.1252	18	252-306	.0422	27	336-408	.0406	36	420-500	.0248	40
L6	.0104	3	10	4	3.89	45.0	108-120	.9753	6	216-240	.1415	12	324-360	.0830	18	432-480	.0646	24			

AV = Number of Spectral Averages per Loop AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AXIX. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR INSTALLED EQUIPMENT ON THE CREW COMPARTMENT WALLS OF THE M113A1 ARMORED PERSONNEL CARRIER

Test Phase	5-500 Hz Floor g2/Hz	No. Sweeps	AV	AWF	Overall RMS g	Time min	NARROWBAND 1 BW Hz	Ampl g2/Hz	Sweep BW Hz	NARROWBAND 2 BW Hz	Ampl g2/Hz	Sweep BW Hz	NARROWBAND 3 BW Hz	Ampl g2/Hz	Sweep BW Hz	NARROWBAND 4 BW Hz	Ampl g2/Hz	Sweep BW Hz	NARROWBAND 5 BW Hz	Ampl g2/Hz	Sweep BW Hz
VERTICAL AXIS																					
V1	.0064	4	12	3	2.68	45.0	24- 30	.2962	3	48- 60	.1278	6	72- 90	.1955	9	96-120	.0398	12	120-150	.0266	15
V2	.0125	4	12	3	4.33	45.0	36- 42	.7321	3	72- 84	1.0687	6	108-126	.2696	9	144-168	.1037	12	180-210	.0587	15
V3	.0141	2	12	3	7.17	45.0	48- 60	2.8761	6	96-120	1.0410	12	144-180	.3277	18	192-240	.1882	24	240-300	.1821	30
V4	.0125	2	12	3	5.82	45.0	66- 78	2.8602	6	132-156	.2816	12	198-234	.1287	18	264-312	.0541	24	330-390	.1570	30
V5	.0202	1	18	2	10.43	45.0	84-102	6.8127	9	168-204	1.3442	18	252-306	.2859	27	336-408	.1937	36	420-500	.0314	40
V6	.0250	3	10	4	12.63	45.0	108-120	18.518	6	216-240	1.6032	12	324-360	.8852	18	432-480	.0998	24			
TRANSVERSE AXIS																					
T1	.0113	4	12	3	3.26	45.0	24- 30	.1763	3	48- 60	.1422	6	72- 90	.1813	9	96-120	.0845	12	120-150	.1009	15
T2	.0227	4	12	3	6.70	45.0	36- 42	.5202	3	72- 84	.6531	6	108-126	.4183	9	144-168	.6025	12	180-210	1.2154	15
T3	.0330	2	12	3	13.63	45.0	48- 60	1.8847	6	96-120	.7840	12	144-180	1.5925	18	192-240	4.0892	24	240-300	.8258	30
T4	.0214	2	12	3	7.34	45.0	66- 78	1.2874	6	132-156	.4257	12	198-234	1.2570	18	264-312	.3104	24	330-390	.0787	30
T5	.0429	1	18	2	16.18	45.0	84-102	11.511	9	168-204	5.9112	18	252-306	1.0630	27	336-408	.1524	36	420-500	.0498	40
T6	.0429	3	10	4	15.87	45.0	108-120	10.474	6	216-240	11.734	12	324-360	1.3871	18	432-480	.1900	24			
LONGITUDINAL AXIS																					
L1	.0043	4	12	3	1.65	45.0	24- 30	.0720	3	48- 60	.0180	6	72- 90	.0300	9	96-120	.0084	12	120-150	.0072	15
L2	.0092	4	12	3	2.70	45.0	36- 42	.2467	3	72- 84	.1920	6	108-126	.0332	9	144-168	.0213	12	180-210	.0475	15
L3	.0098	2	12	3	3.89	45.0	48- 60	.2628	6	96-120	.1436	12	144-180	.1202	18	192-240	.0637	24	240-300	.1398	30
L4	.0098	2	12	3	3.82	45.0	66- 78	.3640	6	132-156	.0498	12	198-234	.0336	18	264-312	.0840	24	330-390	.1746	30
L5	.0175	2	10	4	6.69	45.0	84-102	1.1316	9	168-204	.2252	18	252-306	.5461	27	336-408	.2395	36			
L6	.0202	3	10	4	6.70	45.0	108-120	1.0985	6	216-240	.4835	12	324-360	1.2664	18	432-480	.0371	24			

AV = Number of Spectral Averages per Loop   AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AXX. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR INSTALLED EQUIP ON THE WALLS AND SPONSON OF THE ENGINE COMPARTMENT OF THE M113A1 ARMORED PERSONNEL CARRIER

Test Phase	5-500 Hz Floor g2/Hz	No. Sweeps	AV	AWF	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NARROWBAND 1 Ampl g2/Hz	NARROWBAND 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NARROWBAND 2 Ampl g2/Hz	NARROWBAND 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NARROWBAND 3 Ampl g2/Hz	NARROWBAND 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NARROWBAND 4 Ampl g2/Hz	NARROWBAND 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NARROWBAND 5 Ampl g2/Hz	NARROWBAND 5 Sweep BW Hz
VERTICAL AXIS																					
V1	.0046	4	12	3	1.87	45.0	24- 30	.0373	3	48- 60	.0573	6	72- 90	.0712	9	96-120	.0124	12	120-150	.0118	15
V2	.0091	4	12	3	2.95	45.0	36- 42	.1519	3	72- 84	.3380	6	108-126	.1030	9	144-168	.0586	12	180-210	.0322	15
V3	.0109	2	12	3	4.98	45.0	48- 60	1.3120	6	96-120	.5050	12	144-180	.1634	18	192-240	.0497	24	240-300	.0787	30
V4	.0100	2	12	3	4.15	45.0	66- 78	1.3752	6	132-156	.0881	12	198-234	.0432	18	264-312	.0294	24	330-390	.0790	30
V5	.0165	1	18	2	7.70	45.0	84-102	3.2306	9	168-204	.4918	18	252-306	.2326	27	336-408	.1017	36	420-500	.1223	40
V6	.0193	3	10	4	7.82	45.0	108-120	5.3995	6	216-240	.7815	12	324-360	.4642	18	432-480	.1112	24			
TRANSVERSE AXIS																					
T1	.0032	4	12	3	1.51	45.0	24- 30	.0747	3	48- 60	.0273	6	72- 90	.0231	9	96-120	.0076	12	120-150	.0100	15
T2	.0062	4	12	3	2.44	45.0	36- 42	.2437	3	72- 84	.0966	6	108-126	.0580	9	144-168	.0836	12	180-210	.0210	15
T3	.0070	2	12	3	3.76	45.0	48- 60	.5248	6	96-120	.3112	12	144-180	.1500	18	192-240	.0484	24	240-300	.0185	30
T4	.0063	2	12	3	3.02	45.0	66- 78	.5984	6	132-156	.0898	12	198-234	.0690	18	264-312	.0123	24	330-390	.0126	30
T5	.0101	1	18	2	5.13	45.0	84-102	1.6349	9	168-204	.2450	18	252-306	.0673	27	336-408	.0330	36	420-500	.0125	40
T6	.0121	3	10	4	4.67	45.0	108-120	1.7649	6	216-240	.2714	12	324-360	.0825	18	432-480	.0496	24			
LONGITUDINAL AXIS																					
L1	.0028	4	12	3	1.21	45.0	24- 30	.0138	3	48- 60	.0062	6	72- 90	.0055	9	96-120	.0023	12	120-150	.0030	15
L2	.0060	4	12	3	1.86	45.0	36- 42	.0406	3	72- 84	.0219	6	108-126	.0091	9	144-168	.0117	12	180-210	.0185	15
L3	.0066	2	12	3	2.67	45.0	48- 60	.1042	6	96-120	.0399	12	144-180	.0619	18	192-240	.0177	24	240-300	.0612	30
L4	.0064	2	12	3	2.60	45.0	66- 78	.0921	6	132-156	.0147	12	198-234	.0134	18	264-312	.0379	24	330-390	.0762	30
L5	.0121	1	18	2	4.45	45.0	84-102	.2885	9	168-204	.0876	18	252-306	.2499	27	336-408	.1128	36	420-500	.0107	40
L6	.0140	4	10	4	4.34	45.0	108-120	.3588	6	216-240	.2203	12	324-360	.4211	18						

AV = Number of Spectral Averages per Loop   AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AXXI. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR INSTALLED EQUIPMENT IN THE TURRET OF THE M60A3 TANK

Test Phase	5-500 Hz Floor g2/Hz	No. Sweeps	AV	AWF	Overall RMS g	Time min	NARROWBAND 1 BW Hz	NARROWBAND 1 Ampl g2/Hz	NARROWBAND 1 Sweep BW Hz	NARROWBAND 2 BW Hz	NARROWBAND 2 Ampl g2/Hz	NARROWBAND 2 Sweep BW Hz	NARROWBAND 3 BW Hz	NARROWBAND 3 Ampl g2/Hz	NARROWBAND 3 Sweep BW Hz	NARROWBAND 4 BW Hz	NARROWBAND 4 Ampl g2/Hz	NARROWBAND 4 Sweep BW Hz	NARROWBAND 5 BW Hz	NARROWBAND 5 Ampl g2/Hz	NARROWBAND 5 Sweep BW Hz
VERTICAL AXIS																					
V1	.0006	10	11	3	.61	54.0	20- 25	.0139	2.5	40- 50	.0088	5	60- 75	.0012	7.5						
V2	.0007	10	20	2	.63	54.0	30- 35	.0163	2.5	60- 70	.0040	5									
V3	.0027	3	12	3	1.62	54.0	40- 50	.0859	5	80-100	.0352	10	120-150	.0193	15	160-200	.0110	20	200-250	.0075	25
V4	.0016	3	12	3	1.25	54.0	55- 65	.0933	5	110-130	.0265	10	165-195	.0035	15	220-260	.0034	20	275-325	.0019	25
V5	.0016	10	20	2	1.01	54.0	70- 75	.0732	2.5	140-150	.0105	5									
TRANSVERSE AXIS																					
T1	.0004	10	11	3	.46	54.0	20- 25	.0038	2.5	40- 50	.0009	5	60- 75	.0005	7.5						
T2	.0005	10	20	2	.51	54.0	30- 35	.0015	2.5	60- 70	.0016	5									
T3	.0010	4	11	3	.83	54.0	40- 50	.0204	5	80-100	.0085	10	120-150	.0017	15	160-200	.0012	20			
T4	.0012	8	11	3	.99	54.0	55- 65	.0710	5	110-130	.0052	10									
T5	.0013	10	11	3	.90	54.0	70- 75	.0583	2.5	140-150	.0045	5	210-225	.0014	7.5						
LONGITUDINAL AXIS																					
L1	.0004	10	20	2	.47	54.0	20- 25	.0067	2.5	40- 50	.0026	5									
L2	.0005	10	20	2	.51	54.0	30- 35	.0067	2.5												
L3	.0009	8	11	3	.72	54.0	40- 50	.0141	5	80-100	.0023	10									
L4	.0009	8	11	3	.72	54.0	55- 65	.0133	5	110-130	.0026	10									
L5	.0014	10	20	2	.86	54.0	70- 75	.0154	2.5	140-150	.0026	5									

AV = Number of Spectral Averages per Loop   AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AXXII. NARROWBAND RANDOM-ON-RANDOM VIBRATION PROGRAM DATA FOR INSTALLED EQUIPMENT IN THE HULL OF THE M60A3 TANK

Test Phase	5-500 Hz Floor g2/Hz	No. Sweeps	AV	AWF	Overall RMS g	Time min	NARROWBAND 1 BW Hz	Ampl g2/Hz	Sweep BW Hz	NARROWBAND 2 BW Hz	Ampl g2/Hz	Sweep BW Hz	NARROWBAND 3 BW Hz	Ampl g2/Hz	Sweep BW Hz	NARROWBAND 4 BW Hz	Ampl g2/Hz	Sweep BW Hz	NARROWBAND 5 BW Hz	Ampl g2/Hz	Sweep BW Hz
										VERTICAL AXIS											
V1	.0012	10	20	2	.78	54.0	20- 25	.0029	2.5	40- 50	.0017	5									
V2	.0018	10	11	3	.96	54.0	30- 35	.0038	2.5	60- 70	.0052	5	90-105	.0020	7.5						
V3	.0027	3	12	3	1.42	54.0	40- 50	.0364	5	80-100	.0133	10	120-150	.0144	15	160-200	.0125	20	200-250	.0042	25
V4	.0034	3	12	3	1.75	54.0	55- 65	.0909	5	110-130	.0231	10	165-195	.0238	15	220-260	.0164	20	275-325	.0109	25
V5	.0042	6	11	3	1.70	54.0	70- 75	.0984	2.5	140-150	.0470	5	210-225	.0349	7.5	280-300	.0097	10	350-375	.0098	12.5
										TRANSVERSE AXIS											
T1	.0008	10	11	3	.65	54.0	20- 25	.0029	2.5	40- 50	.0029	5	60- 75	.0026	7.5						
T2	.0012	10	11	3	.80	54.0	30- 35	.0054	2.5	60- 70	.0069	5	90-105	.0024	7.5						
T3	.0018	4	11	3	1.26	54.0	40- 50	.0696	5	80-100	.0190	10	120-150	.0142	15	160-200	.0024	20			
T4	.0023	3	12	3	1.62	54.0	55- 65	.1704	5	110-130	.0465	10	165-195	.0125	15	220-260	.0038	20	275-325	.0036	25
T5	.0027	8	11	3	1.40	54.0	70- 75	.1662	2.5	140-150	.0420	5	210-225	.0047	7.5	280-300	.0031	10			
										LONGITUDINAL AXIS											
L1	.0010	10	20	2	.73	54.0	20- 25	.0018	2.5	40- 50	.0072	5									
L2	.0014	6	11	3	.86	54.0	30- 35	.0103	2.5	60- 70	.0032	5	90-105	.0024	7.5	120-140	.0019	10	150-175	.0016	12.5
L3	.0022	3	12	3	1.38	54.0	40- 50	.0513	5	80-100	.0200	10	120-150	.0247	15	160-200	.0046	20	200-250	.0020	25
L4	.0031	3	12	3	1.56	54.0	55- 65	.0374	5	110-130	.0463	10	165-195	.0181	15	220-260	.0047	20	275-325	.0041	25
L5	.0035	6	11	3	1.46	54.0	70- 75	.0407	2.5	140-150	.0506	5	210-225	.0090	7.5	280-300	.0035	10	350-375	.0055	12.5

AV = Number of Spectral Averages per Loop   AWF = Averaging Weighting Factor

Exaggeration Factor = 2.00

TABLE 514.4-AXXIII. Test durations - installed equipment.

MODE OF TRANSPORT	TABLE	TRANSPORT DISTANCE km (miles)	TEST DURATION (minutes per axis*)
M1A1 Tank (ammunition hull rack)	AIV	8000 (5000)	225
M1 Tank (ammunition hull rack)	AV	8000 (5000)	225
M109A3 Self-propelled Howitzer (ammunition bustle rack)	AVI	7000 (4250)	191.25
M109A3 Self-propelled Howitzer (ammunition deck rack)	AVII	7000 (4250)	191.25
M109A3 Self-propelled Howitzer (ammunition on sponson)	AVIII	7000 (4250)	191.25
M109A3 Self-propelled Howitzer (propelling charge)	AIX	7000 (4250)	191.25
M109A3 Howitzer, SP, 155mm			
Turret	AX	9600 (6000)	270
Walls	AXI	9600 (6000)	270
M110A2 Howitzer, SP, 8-inch			
Trunnion	AXII	9600 (6000)	270
Deck	AXIII	9600 (6000)	270
Gun mount	AXIV	9600 (6000)	270
Driver compartment	AXV	9600 (6000)	270
M113A1 Armored Personnel Carrier			
Sponsons	AXVI	9600 (6000)	270
Top	AXVII	9600 (6000)	270
Deck	AXVIII	9600 (6000)	270
Walls	AXIX	9600 (6000)	270
Engine compartment	AXX	9600 (6000)	270
M60A3			
Turret	AXXI	9600 (6000)	270
Hull	AXXII	9600 (6000)	270

* The test durations for each of three axes are based on 45 minutes of laboratory vibration being equivalent to 1600km (1000 mi) of vehicle transport.

METHOD 515.4

ACOUSTIC NOISE

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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

NOTE: The tailoring process as described in section 4 of this document should be used to determine the appropriate tests and test variables.

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.

(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 or 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 dB (ref 20 μPa) overall, and if its exposure in every one-Hertz band is less than 100 dB (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 (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:

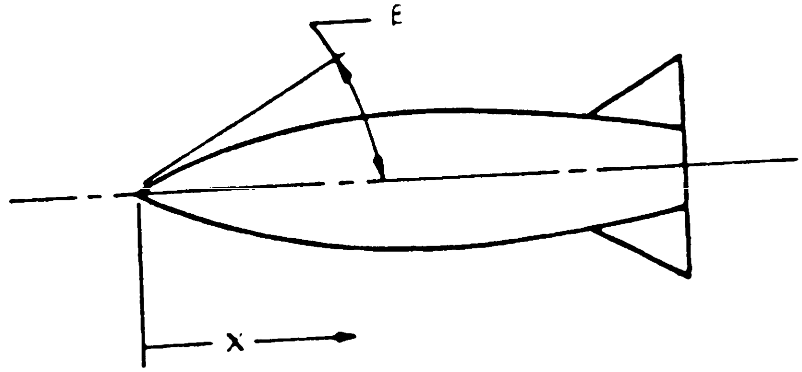


FIGURE 515.4-3. Typical store profile

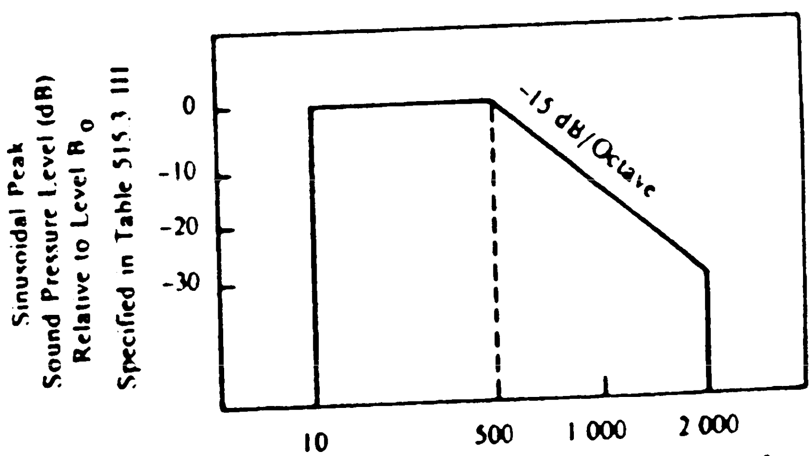


FIGURE 515.4-4. Cavity resonance Acoustic test levels

I-3.2.3 Test duration. For procedure III, test duration should be determined as described in I-3.2.3.1. For all other procedures, determine the test duration by referring to table 515.4.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 five 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 five 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 five 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 515.4-1 can be ignored and the tolerances on figure 515.4-2 can be -3 dB to plus infinity. For qualification testing the tolerances should be as shown on figure 515.4-1 and for figure 515.4-2 they can be -3 dB for each one-third octave band.

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.

TABLE 515.4-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 nose 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 515.4-III	Airborne	Aircraft	Near or in open cavities exposed to the airstream	See Table515.4-III
I	See Table 515.4-II	Airborne	Aircraft	Externally-carried stores	See Table 515.4-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 μPa ($2x10^{-4}$ 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.

I-3.2.5.2 Progressive wave testing. This technique is used to simulate a strong localized acoustic source. The acoustic 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 Hz and, preferably, to 10,000 Hz.

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. Recognizing that aeroacoustic noise is more efficient than reverberant or progressive wave acoustic noise at frequencies below the first structural resonance and less efficient above the first resonance, the flight test measurements must be adjusted. The parametric relationships specified in tables 515.4-II and 515.4-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 Method 514.4 tolerances for random vibration. This acoustic test environment can be considered as the operational or flight environment. The parametric relationships specified in tables 515.4-II and 515.4-III can be used to extrapolate to other conditions.

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.

TABLE 515.4-II Suggested acoustic test levels for assembled externally-carried aircraft-stores.

Functional test

L_o 1/, 5/, 6/, 7/ = 20 Log (q_1) + 11 Log (X) + 7 Log (1-cos β) + G+HdB

f_o 2/, 3/, = 600 Log (X/R) + C

Endurance test

L_o 1/, 5/, 6/, 7/, = 20 Log (q_2/q_1) + 2.5 Log (N/3T) + functional level dB

f_o 2/, 3/ = 600 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; 400 all other locations
D 4/ = maximum store diameter in inches
β = local nose cone angle at X equals 1/Tanβ = (R/X) (Figure 515.4-3)
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; -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

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

$$L_o = 20 \text{ Log } (q_2) + 11 \text{ Log } (X) + F + 2.5 \text{ Log } (N/3T) + H$$

METHOD 515.4

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 reverberant 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, 5.2.2. The item shall be in the operational configuration.

Step 4. Mount test item. For Procedure IV, go to step 7. Suspend the 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.

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 the appropriate test procedure.

II-3 PROCEDURE

II-3.1 Procedure I-- Environmental worthiness-test

Step 1. Mount the test item in the test chamber and position the instrumentation as given in II-2.

Step 2. Expose the 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 the test item for loose parts, chafed wires, and any other obvious diameter. Correct or repair before proceeding to Step 4.

Step 4. Energize the test item. Check the test item functions for proper operation. Correct or repair any damage.

Step 5. Expose the test item to the required acoustic noise for the specified amount of time with the test item functioning as if it were in actual operation or flight.

Step 6. Check the 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 the 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. Operate the test item as if it were 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.

Step 5. Expose test item to endurance levels as in I-3.2a.

Step 6. Check test item for function in accordance with General Requirements, 5.0.

Step 7. If test item is not a store, go to Step 10.

Step 8. If a free flight test is required, expose test item to acoustic levels as specified in I-3.2.2.a and check in Step 9.

Step 9. Operate store through free flight performance requirements.

Step 10. Document the test as in II-4.

II-3.3 Procedure III - Mission profile tests

Step 1. Using the guidance of II-2, mount the test item in the test chamber.

Step 2. Position instrumentation as given in II-2.

Step 3. Expose the test item to the mission profile developed in I-3.2.3.1.

Step 4. During the mission profile test, perform functional checks on the test item as required by General Requirements, 5.0.

Step 5. Conduct the mission profile for desired number of missions.

Step 6. During Step 5 testing, operate the test item as given in General Requirements.

Step 7. Document the test as in II-4.

II-3.4 Procedure IV - Cavity resonance test

Step 1. Conduct the 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 ± 3dB 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 the post-test inspection.

Step 6. Document as given in II-4.

II-4 INFORMATION TO BE RECORDED

a. Test item identification (manufacturer, serial number, etc.).

b. Prior history of the test item.

c. Inspection and test procedures including inspection requirements, test criteria, instrumentation, data requirements, and failure criteria.

d. List of test equipment including noise generators, measurement and data analysis equipment, mounts, and fixtures.

e. Descriptions of the test setup and instrumentation locations including drawings and photographs as appropriate.

f. Log of all actions from pretest through post-test inspection.

g. Recorded data.

h. Analyses of all failures, malfunctions, and test incidents.

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

$$3[(\pi/2)G(f)fQ]^{1/2}$$

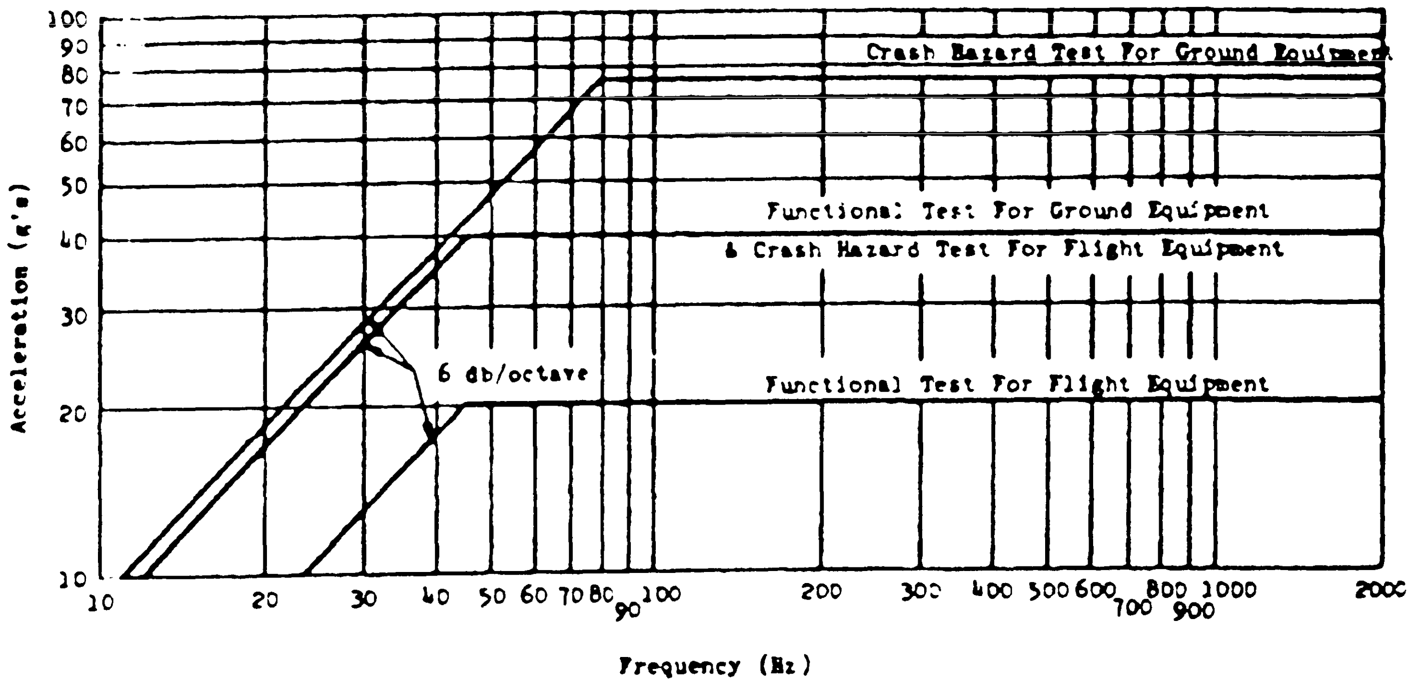
in units of acceleration, where G(f) is acceleration spectral density (ASD) at frequency f (reference a). A comparison of the shock response levels found in figure 516.4-1 with ASD levels is found in figure 516.4-2.

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.

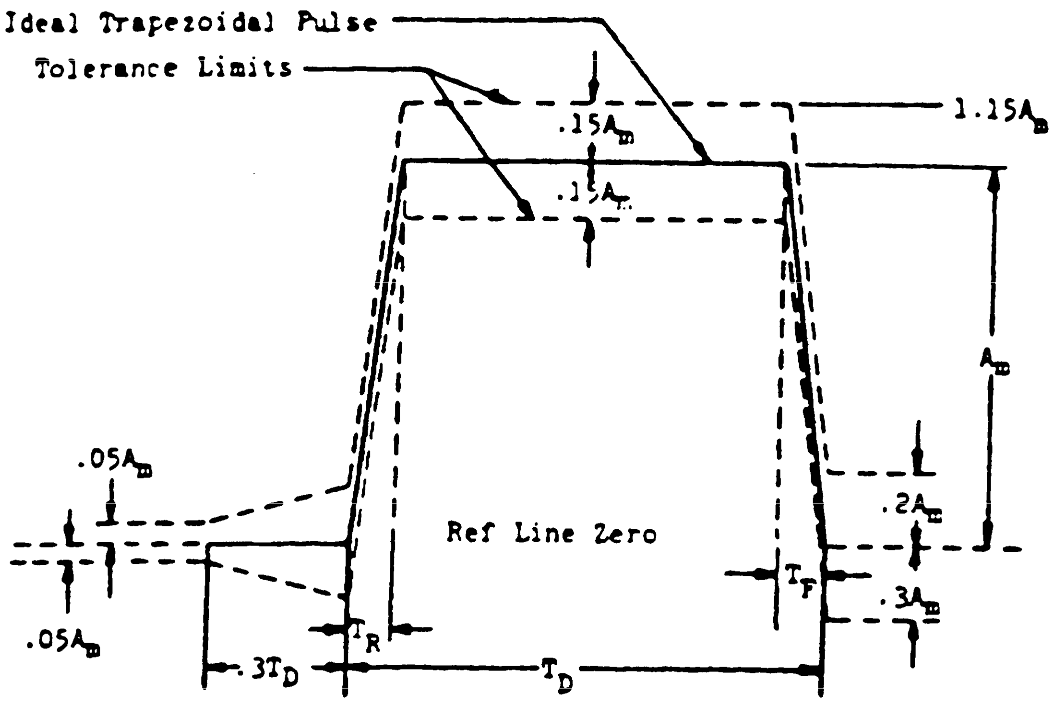
(a) Measured data available. The shock response spectrum required for the test will be determined from reduction of the environmental acceleration spectra. The spectra will be a composite of spectra for positive and negative directions, sometimes called maximax spectra. The analyses will be performed for $Q = 10$ at a sequence of natural frequencies at intervals of 1/6 octave or smaller to span at least 5 to 20,000 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 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 516.4A 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.



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 516.4-1. Test shock response spectrum for use if measured data is not available.



TEST	PEAK VALUE (A_m) g's	NOMINAL DURATION (T_D) ms
Fragility	10 to 50	
Packaged shock	30	$\frac{2\sqrt{(2\frac{h}{g})}}{A_m}$

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) and 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 516.4-5. Trapezoidal shock pulse configuration and its tolerance limits.

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 516.4-5):

$V = A_m\, g\, (0.9\, t_D)$ (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).

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 516.4-II. The test item shall be tested in the same configuration that is used in 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 122cm.) Field data have shown that a typical piece of man-portable equipment will be dropped from heights up to 122cm (48 inches) an average of four to six times during its life cycle. The 26-drop requirement exists to ensure that each vulnerable position (faces, edges, and corners) of a typical test item receives an impact.

I-3.7 Procedure V - Crash hazard

a. Applications. 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.

TABLE 516.4-II. Transit drop test.

Weight of Test Item & Case	Largest Dimension	Notes	Height of Drop	Number of Drops
Under 45.4kg (100 lbs) Manpacked or man-portable	Under 91cm (36 inches)	A	122cm (48 in.)	Drop on each face, edge and corner; total of 26 drops D/
	91cm & over	A	76cm (30 in.)	
45.4 - 90.8kg (100-200 lbs) inclusive	Under 91cm	A	76cm	Drop on each corner; total of eight drops
	91cm & over	A	61cm (24 in.)	
90.8-454kg (200-1000 lbs) inclusive	Under 91cm	A	61cm	
	91-152cm (36-60 inches)	B	61cm	
	Over 152cm	B	61cm	
Over 454kg	No limit	C	46cm (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 13cm (five inches) in height, and at the other corner or edge of the same end by a block 30cm (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 times (see I-3.6).

b. Restrictions. Procedure V is not intended for equipment transported as cargo. (For cargo, use method 514.4)

c. Test conditions. Use figure 516.4-1 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 516.4-4 may be used as an alternative to figure 516.4-1.

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. Applications. 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.

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 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 re-entry 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 0.8f, where f is the frequency in Hz. (The 0.8f acceleration limit corresponds to approximately 19.7 cm/sec (50 in./sec) spectral velocity. A basis for use of velocity as a criterion of severity is given in reference c. The value of 19.7 cm/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 250 cm/sec (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.

d. Rationale. This procedure generally conforms to requirements for pyrotechnic shock testing in MIL-STD-1540 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. Purpose of test. Procedure VIII is intended to test equipment that will be transported by rail; to determine the effect of normal railroad car impacts that occur during rail shipment, and to verify the structural integrity of the test item and the adequacy of the tiedown system and the tiedown procedures. All test items shall be tested at their maximum gross weight (fully loaded) rating unless otherwise specified in the transportability requirements for the item.

b. Restrictions. Procedure VIII is not intended for the separate testing of small, individually packaged pieces of equipment that would normally be shipped (and tested) when mounted on a pallet.

c. Test conditions. This test is conducted by mounting the test item on a rail car in its rail shipment configuration and then performing a series of at least four impacts. The first three impacts shall be at 6.4, 9.7 and 13 km/h (4, 6 and 8 mph), respectively, in the same direction. The fourth shall be conducted at 13 km/h in the reverse direction. All four impacts shall have a tolerance of +0.8, -0.0 km/h. If the test commodity can be shipped in two orientations (such as lengthwise and crosswise on the rail car), the four impacts shall be repeated for each orientation.

d. Rationale. Data for the rail impact test were derived from statistical data on the frequency of impacts with relationship to speed and frequency of concurrence. Brakes are set on the buffer car to provide a more conservative test.

e. Failure analysis. A test item shall be classified as not having survived the rail impact test and will be deemed a test failure if any item that is attached to or included as an integral part of the test item breaks free, loosens or shows any sign of permanent deformation beyond specification tolerances. A test item that passes this procedure should be capable of rail transport without damage to the item or tiedowns.

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, 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.

(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, longitudinal

(6) Number of bursts - determined by the specific application (for example, 30 bursts, each followed by a 10 second rest period)

METHOD 516.4

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 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 procedure 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 one dB across the frequency range specified for the accelerometer (see II-1.1.3a).

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 ($dB = 20 \log A/A_o$).

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 516.4-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 6.4, 9.7 and 13 Km/hr (4, 6 and 8 mph) within ±5%.

b. Accelerometers and associated circuitry to measure the impact, shock, and equipment response, if these measurements are specified.

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 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 516.4-I. If maximum test item velocity change values are required for design drop heights other than those listed, the following relationship may be used.

$$\Delta V = 2\sqrt{(2gh)}$$

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/s² (386 in/s²)

The drop height of the shock test apparatus will not necessarily be the same as the design drop height.

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 516.4-5.

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.

Step 7. Examine or functionally test the test item to determine if damage due to shock has occurred.

Step 8. If no damage has occurred, 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 Procedure IV - Transit drop

Step 1. Install the test item in its transit or combination case as prepared for field use.

Step 2. From 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 II-1.2. The drops should be in accordance with table 516.4-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 item(s).

Step 6. Document the results for comparison with data obtained in 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 II-2.2, step 5.

II-3.5 Procedure V - Crash hazard

NOTE: If calibration of the test apparatus is required, perform steps 1 and 2 of 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 I-3.7c) along three orthogonal axes of the test item for a maximum total of 12 shocks.

TABLE 519.4-II. Typical gun Configurations associated with aircraft classes.

Aircraft/POD	Gun (Quantity)	Location	Firing Rate (Rnds/Min)	Rounds Capacity
A-4	MK12 (2)	Wing Roots	1000	100/gun
A-7D	M61A1 (1)	Nose, Left Side	4000 & 6000	1020
A-10	GAU-8/A (1)	Nose	2100 & 4200	1175
A-37	GAU-2B/A (1)	Nose	6000	1500
AH-1	M97E1/E2, M197 (1)	Chin Turret	730 $\pm$50	750
AH-1	GPU-2A M197 (1)	Store Station Gun Pod	750/1500	300
AH-1	M-18 M134/GPU-2B (1)	Store Station Gun Pod	3000/6000	1500
UH-60	XM-144 M-60 (2)	Pintle Mount Windows	550 ea.	200/gun
AH-64	M139 M230 (1)	Chin Turret	625 $\pm$25	1200
UH-1	M23 M-60 Gun (2)	Pintle Mount (Door Gun)	550	550
OH-6	M27 M134/GAU-2B (1)	Side Mount	2000/4000	2000
MH-60	G.E.M134 (2)	Pintle-Windows	2000/4000	2000/gun
MH-47	G.E. M134 (2)	Pintle-Door Window	2000/4000	4000/gun
CH47	M24 M-60 Gun (2)	Pintle Door/ Window	550 ea.	200/gun (approx)
AH-6G	IESP			
	M134 (2)	Plank-	1000/4000	1400 ea.
	AN/M-2 (2)	Rear comp't	750 $\pm$50	250 ea.
OH58D	Contract Fab AN/M2 (1)	Store Station (L.H)	750 $\pm$50	500
F-4	M61A1 (1)	Nose	4000 & 6000	638
F-5E	M39 (2)	Nose	3000	300/gun
F-5F	M39 (1)	Nose	3000	140
F-14	M61A1 (1)	Nose, Left Side	4000 & 6000	676
F-15	M61A1 (1)	Right Wing Root	4000 & 6000	940
F-16	M61A1 (1)	Left Wing Root	6000	510
F-18	M61A1 (1)	Nose, Top Center	4000 & 6000	570
F-111	M61A1 (1)	Underside of Fuselage	5000	2084
GEPOD 30	GE430 (1) (GAU-8/A)	POD	2400	350
SUU-11/A	GAU-2B/A (1)	POD	3000 & 6000	1500
SUU-12/A	AN-M3 (1)	POD	1200	750
SUU-16/A	M61A1 (1)	POD	6000	1200
SUU-23/A	GAU-4/A (1)	POD	6000	1200

TABLE 519.4-III. Gun specifications.

Gun	Gun Caliber (mm)	Gun Caliber (in)	Blast Energy, E (J)*	Rate of Fire-spm
GAU-2B/A/M-134	7.62	.30	6,700	1.5k, 2k, 4k, 6k
M60	7.62	.30	6,700	550
GAU-4/A	20	.79	74,600	6000
M240	7.62	.30	6,700	600→800
GAU-8/A	30	1.18	307,500	2100, 4200
M230	30	1.18	101,000	625 ±25
AN-M3	12.7	.50	26,000	1000-1200
AN-M2	12.7	.50	26,000	500-600
M3 (NAVY)	20	.79	83,000	
XM218	12.7	.50	26,000	700-800
MK24 (NAVY)	20	.79	80,500	
M30 (USAF)	20	.79	74,600	1400-1500
M61A1 (AF/NAVY)	20	.79	74,600	3000, 4000, 6000
MK11 (NAVY)	20	.79	86,500	4200
MK12 (NAVY)	20	.79	86,500	

*joules (J) x 0.7376 = foot-pounds

300 sorties. The maximum gunfire time per sortie can be determined from table 519.4-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.

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 $f = \eta f_1$; where f_1 is the basic gunfire rate and $\eta = 1, 2, 3, \ldots K$. The last integer (K) is that value of η for which ηf_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 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 of 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.

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.

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 environmental 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.

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 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. Depending upon available facilities, environmental stresses may be tested in combination or singly.

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 520-1 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 than 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 520.1-2). During a test cycle, temperature, vibration, humidity, and cooling airflow shall be varied.

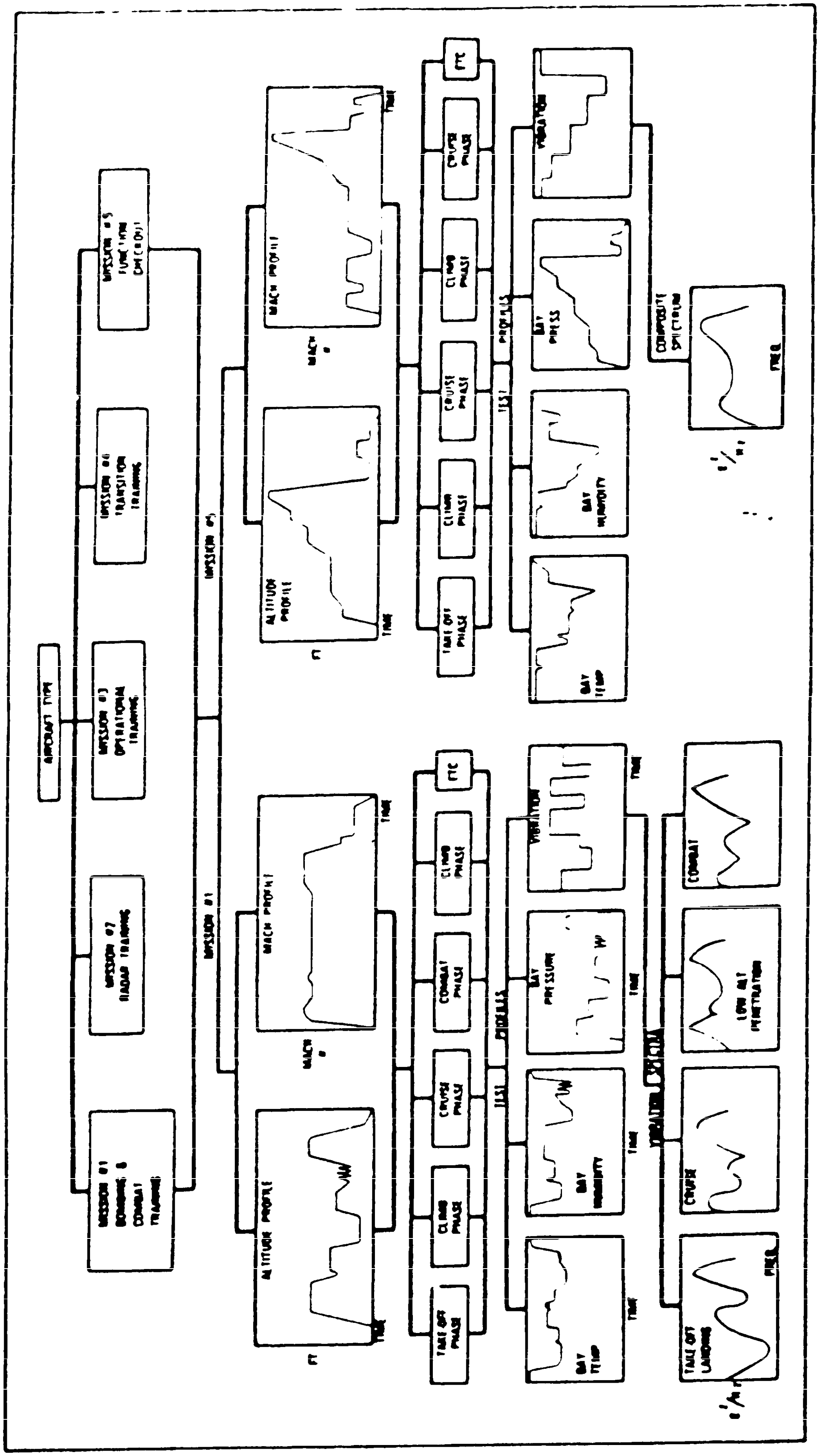


FIGURE 520.1-1. Test profile generation flow diagram.

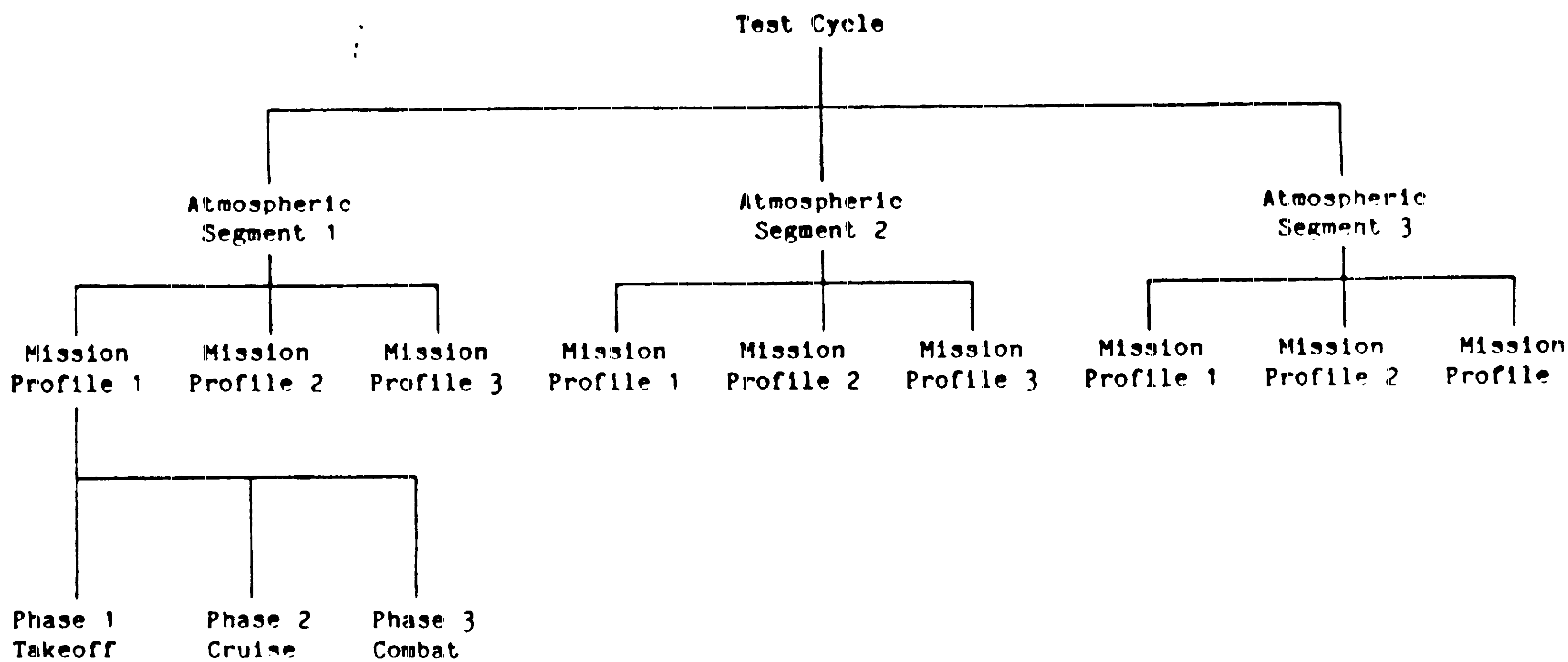


FIGURE 520.1-2. Bottom up view of a test cycle.

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.

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 of 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 comprise 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 520.1-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 I-3.2.2.3. One test cycle using the mission profiles in I-3.2.2.3b will be developed to simulate routine usage and another test cycle using the mission profiles in I-3.2.2.3c will be developed to simulate usage under combat or combat-training conditions.

TABLE 520.1-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.

TABLE 520.1-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		--
Ram Air Cooled	-54	-40	60	54	75% at 43°C	--
Unconditioned	-54	-40	60	54		--
CREW STATION						
Open Areas	-54	-40	60	25		--
Behind Instrument Panels	-54	-40	100	75	75% at 43°C	--
Supplemental Cooling Airflow to Equipment	-51	-51	54	54	75% at 43°C	+0% of design -80% point

METHOD 520.1

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 5 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 from defect disclosure. If neither axis seems to offer a distant 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 514.4.

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 analysis 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, 5.3.2. 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.

II-3 PROCEDURES

II-3.1 Procedure I - Engineering development

Step 1. Mount test item in accordance with 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 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 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 II-4.

II-3.2 Procedure II - Flight/operational support test.

Step 1. Mount test item in accordance with 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 520.1-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 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 I-3.3b).

Step 8. Document entire test per II-4.

II-3.3 Procedure III - Qualification test

Step 1. Mount the test item and instrumentation per II-2.

Step 2. Start the test cycle developed from I-3.2.3.

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 I-3.3c.

Step 5. Check the test item for functioning in accordance with General Requirements 5.2.

Step 6. Repeat steps 1 through 5 for each of the single or combined environment tests specified in I-3.2.3 unless they were conducted as one test that combines all the environments.

Step 7. Document test results as given in II-4.

II-4 INFORMATION TO BE RECORDED

a. Test item identification (manufacturer, serial number, etc.).

b. Pretest, during test, and post-test performance data according to General Requirements, and the individual test specification and/or test plan.

c. Test cycle, including environmental conditions applied.

d. Test time history of each failure occurrence.

e. Nature of failure, including environmental effects

f. DC ripple voltage, as applied during the mission simulation portion of each test cycle.

g. AC voltage variation, as conducted during the mission-simulation portion of each test cycle.

h. Type, location, and orientation of stress-measuring sensors.

i. Description and calibrations status of data recording and analysis equipment.

j. Voltage modulation, as applied during the mission-simulation portion of each test cycle.

k. Frequency modulation, as applied during the mission-simulation portion of each test cycle.

l. Electrical stress induced by mission-related transients within the electrical system.

m. Prior test history of test item.

n. Corrective action proposed.

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 out-of-doors on land, the same test is applicable for all such equipment. Unless specifically measured data for the anticipated situation are available, the following ice thicknesses are recommended:

(1) 6mm - represents general conditions, light loading.

(2) 13mm - represents general conditions, medium loading.

(3) 37mm - represents heavy ground loading and marine mast loading.

(4) 75mm - represents extremely heavy ground loading and marine deck loading.

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 manual method.

(3) A single, handheld nozzle directing the spray over the surfaces of the test item.

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, 5.2.7)

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.

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. Ice thickness.

I-5. REFERENCES

a. TOP 2-2-815, Rain and Freezing Rain, 19 June 1975. DTIC number AD-A029-317.

b. Letter from C, Test & Support Branch, TERWT, Eglin AFB, FL, subject: Freezing Rain Tests, to: US Army Test and Evaluation Command, ATTN: DRSTE-AD-M, Aberdeen Proving Ground MD, 15 November 1979.

c. American National Standards Institute. Test Code for High Voltage Air Switches, ANSI C37.34A-1975. IEEE 326.

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

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f. Synopsis of Background Material for MIL-STD-210B, Climatic Extremes for Military Equipment,. Bedford, MA. Air Force Cambridge Research Laboratories, 1974.

g. AMC Pam 706-116, Engineering Design Handbook, Environmental Series, Part Two, Natural Environmental Factors, 15 April 1975.

h. Tattleman, P. and I. Gringorten, Estimated Glaze Ice and Wind Loads at the Earth's Surface for the Contiguous United States, AFCRL-TR-73-0646, October 1973. DTIC number AD-775-068.

i. Bowden, D. T. et al, Engineering Summary of Air Frame Icing Technical Data. U.S.A.: Federal Aviation Agency, March 1964. F.A.A. Technical Report ADS4.

j. DEF STAN 07-55 (Part 2) Section 2/1. Test - BIP Icing/Frosting, London, England: Ministry of Defence, April 1975.

METHOD 521.1

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, 5.1.2)

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, 5.2.4)

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:

c. 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.

d. Length of time required for each performance check.

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

f. Defects noted during visual examinations.

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

h. Test temperatures.

i. Duration of each exposure.

j. Appropriate anthropometric measurements of personnel performing manipulation tests.

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

l. Initial analysis of any failure.

m. Ice thickness.

METHOD 523.1
VIBRO-ACOUSTIC, TEMPERATURE

SECTION

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I-2 ENVIRONMENTAL EFFECTS 523.1-1
I-3 GUIDELINES FOR DETERMINING TEST PROCEDURES AND TEST CONDITIONS. 523.1-3
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SECTION II

II-1 APPARATUS. 523.1-14
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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 methods 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 b) 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.

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 = adiabatic 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 cylindrical 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.

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 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:

$$q = \frac{kP_hM^2}{2}$$

Where:

q - dynamic pressure (pounds per sq. ft.)

k - ratio of specific heats (1.4 for air)

P_b - 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

NOTE: The tailoring process as described in section 4 of this document should be used to determine the appropriate tests and test variables.

a. Application. This method applies to reliability-related testing of externally carried aircraft stores (table 523.1-I).

TABLE 523-1-I. Typical applications.

TEST TYPE	PURPOSE	APPLICATION	TYPE OF INFORMATION REQUIRED: FAILURE MODES	TYPE OF INFORMATION REQUIRED: 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 <u>not</u> 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.

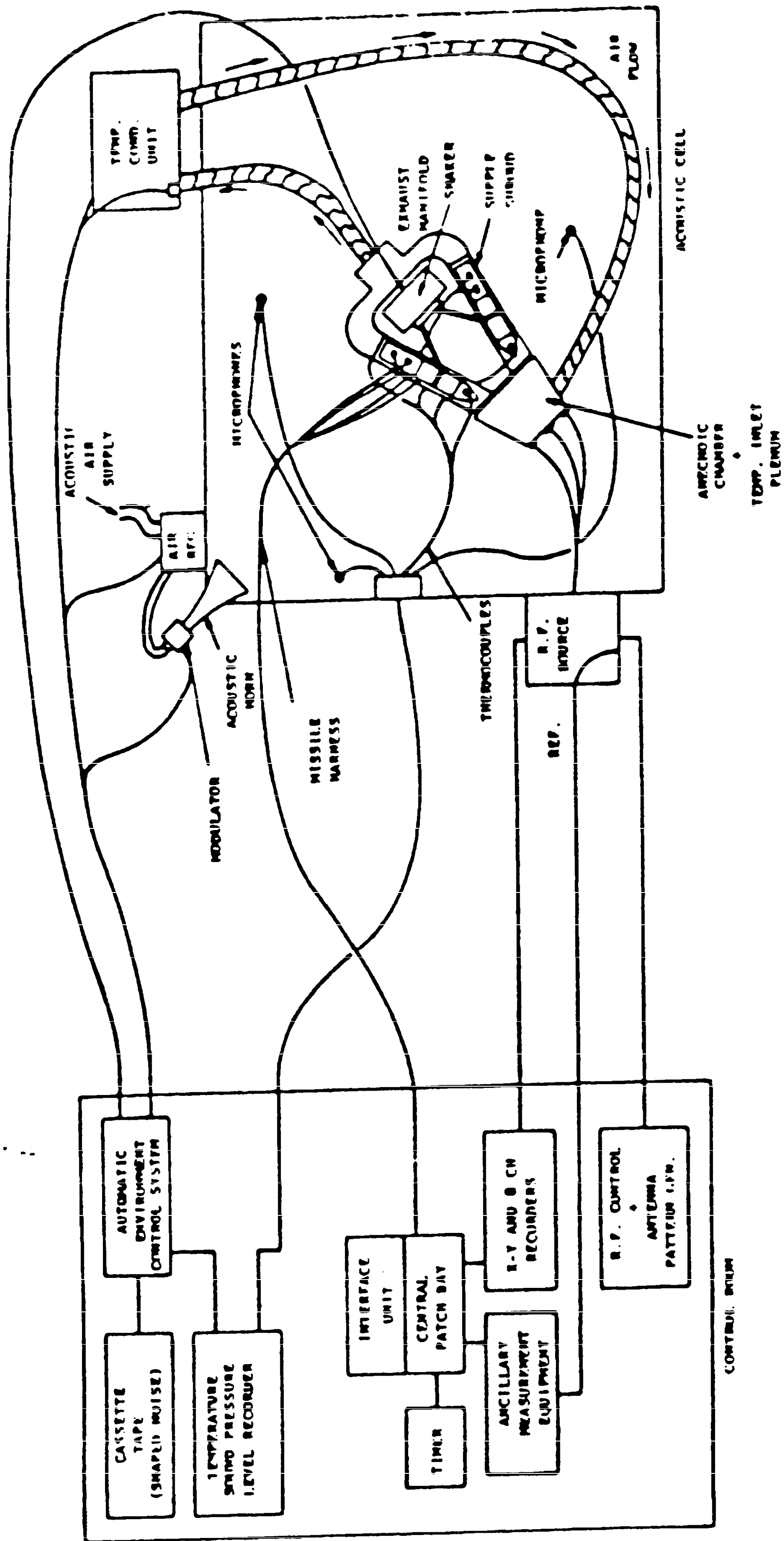

FIGURE 523.1-7 Typical arrangement of apparatus.

METHOD 523.1

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 514.4 will furnish some guidelines for this procedure. A possible arrangement is diagrammed in figure 523.1-7

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.).

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 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, theater 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 are to be handled and specify 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 even-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.

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 523.1-5). 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).

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 5 of this standard shall be followed where applicable.

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