MILITARY STANDARD

ENVIRONMENTAL TEST METHODS AND ENGINEERING GUIDELINES

TO ALL HOLDERS OF MIL-STD-810D

1. The following pages of MIL-STD-810D have been revised and supersede the pages listed:

NEW PAGE	DATE	SUPERSEDED PAGE	DATE
iii	31 Jul 86	111	19 Jul 83
iv	19 Jul 83	iv	REPRINTED WITHOUT CHANGE
9	31 Jul 86	9	19 Jul 83
10	31 Jul 86	10	19 Jul 83
11	19 Jul 83	11	REPRINTED WITHOUT CHANGE
12	31 Jul 86	12	19 Jul 83
19	31 Jul 86	19	19 Jul 83
20	19 Jul 83	20	REPRINTED WITHOUT CHANGE
500.2-3	31 Jul 86	500.2-3	19 Jul 83
500.2-4	31 Jul 86	500.2-4	19 Jul 83
501.2-11	31 Jul 86	501.2-11	19 Jul 83
501.2-12	19 Jul 83	501.2-12	REPRINTED WITHOUT CHANGE
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505.2-4a	31 Jul 86		
507.2-13	31 Jul 86	507.2-13	19 Jul 83
507.2-14	19 Jul 83	507.2-14	REPRINTED WITHOUT CHANGE
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507.2-18	19 Jul 83	507.2-18	REPRINTED WITHOUT CHANGE
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511.2-9	31 Jul 86	511.2-9	19 Jul 83
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NEW PAGE	DATE	SUPERSEDED PAGE	DATE
512.2-5	19 Jul 83	512.2-5	REPRINTED WITHOUT CHANGE
512.2-6	31 Jul 86	512.2-6	19 Jul 83
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514.3-33	31 Jul 86	514.3-33	19 Jul 83
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514.3-37	31 Jul 86	514.3-37	19 Jul 83
514.3-38	31 Jul 86	514.3-38	19 Jul 83
514.3-47	31 Jul 86	514-3.47	19 Jul 83
514.3-48	31 Jul 86	514.3-48	19 Jul 83
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520.0-27	31 Jul 86	520.0-27	19 Jul 83
520.0-28	19 Jul 83	520.0-28	REPRINTED WITHOUT CHANGE

2. RETAIN THIS NOTICE AND INSERT BEFORE TABLE OF CONTENTS.

3. Holders of MIL-STD-810D will verify that page changes and additions indicated above have been entered. These notice pages will be retained as a check sheet. This issuance, together with appended pages, is a separate publication. Each notice is to be retained by stocking points until the military standard is completely revised or canceled.

Custodians
Army - TE
Navy - AS
Air Force - 11

Preparing activity
Air Force - 11

Project ENVR-0020

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

International interest (see 6.3).

FOREWORD

MIL-STD-810D 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. Each individual method has 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. Safety compliance testing may require tests not covered herein.

Technical questions may be addressed to the following offices:

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Supersedes page iii of 19 July 1983

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Temperature:	25°C ±10°C (77°F ±18°F)
Relative humidity:	Uncontrolled room ambient
Atmospheric pressure:	Site pressure

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

Temperature:	23°C ±2°C (73°F ±3.6°F)
Relative Humidity:	50 percent ±5 percent
Atmospheric Pressure:	$96.45\ ^{+66}_{-10.0}$ kPa
	($725\ ^{+50}_{-70}$ mmHg)
	($28.5\ ^{+2.0}_{-3.0}$ inHg)

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

a. Temperature. The test item shall be totally surrounded by an envelope of air (except at necessary support points). The temperature of the test section measurement system and the temperature gradient throughout this envelope, which is measured close to the test item, shall be within ± 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. When pressure is 1.3 x 10^{-3} Pa or higher, it shall be measured with an accuracy of ±5 percent of the measured value.

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

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

e. Vibration amplitude

Sinusoidal:	±10 percent
Random:	See method 514.3

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

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

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

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

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

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

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

4.4.3 Stabilization of test temperature

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

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

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

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

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

4.5 General test performance guidance

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Preparing activity:
Air Force - 11

Project No. ENVR- 0020

Review activities:

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

International interest (see 6.3)

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

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

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

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

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

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

TABLE 500.2-I. Minimum cargo compartment pressures.

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

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

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

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

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

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

(3) Relatively gradual loss of pressure due tc 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.

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

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

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

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

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

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

(4) Modified with kits for special applications.

e. Humidity. Low relative humidity (RH) may occasionally have a significant effect on some material during high-temperature testing. In such instances, consideration must be given to controlling RH as indicated in tables 501.2-I and 501.2-II. Otherwise, relative humidity (RH) control during high temperature tests is not necessary.

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

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

I-4 SPECIAL CONSIDERATIONS

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

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

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

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

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

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

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

a. Test procedure.

b. Critical components, if applicable.

c. Location of temperature sensors.

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

e. Test duration.

f. Test item configuration.

g. Relative humidity control requirements (if necessary).

h. Additional guidelines.

I-5. REFERENCES

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

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

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

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

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

(b) Stored at low temperatures.

(c) Manipulated at low temperatures.

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

(a) The expected temperature at the deployment location.

(b) The expected duration at the deployment location.

(c) The test item configuration.

(d) Additional guidelines as appropriate.

I-3.1 Choice of test procedure(s)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

II-2 PREPARATION FOR TEST

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

a. Determine the test temperature levels.

b. Determine the test item configuration.

c. Determine the operational requirements.

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

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

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

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

Step 3. Document the results.

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

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

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

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

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 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 1 hour or until the test item has been stabilized, whichever is longer.

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

Step 3. Transfer the test item to the low-temperature environment as above, and stabilize 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 restablized at the temperature of the last successfully completed period before the interruption (see II-1.3).

Step 4. Repeat steps 2 and 3.

Step 5. Repeat step 4.

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

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

II-4 INFORMATION TO BE RECORDED

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

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

(1) Pretest.

(2) During test.

(3) Post-test.

(a) The anticipated areas of deployment.

(b) The test item configuration.

(c) Additional guidelines as appropriate.

I-3.1 Choice of test procedure

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

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

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

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

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

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

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

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 intensely and duration), the spectrum must be as close as possible to that of natural sunlight.

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

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

a. Diurnal cycle. For Procedure I, two high temperature dirunal cycles are provided in table 505.2-I with the same solar radiation conditions for both. The first cycle (Hot Dry) has a peak temperature of 49°C (120°F) and 1120 W/m^2 (355 $Btu/ft^2/hr$) and represents the hotest conditons 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 Dry) is less severe and peaks at an air temperature of 44°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 of the United States, Mexico, Africa, Asia and Australia, Southern Africa, South America, Southern Spain and Southwest Asia. (See Method 501.2 for area descriptions.) This cycle is also used when special precautions are taken to provide protection against the sun in hot, dry areas (such as with munitions). (RH values in table 505.2-I are for information only, not for test.)

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 505.2-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.

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

METHOD 507.2

HUMIDITY

SECTION II

II-1 APPARATUS

II-1.1 Test facility

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

b. Unless otherwise specified, the test volume of the chamber or cabinet and the accessories contained therein shall be constructed and arranged in such a manner as to prevent condensate from dripping on the test item(s). The test volume shall be vented to the atmosphere to prevent the buildup of total pressure and prevent contamination from entering. Relative humidity shall be determined by employing either solid-state sensors whose calibration is not affected by water condensation or by an equivalent method, such as fast-reacting wet-bulb/dry-bulb sensors or dewpoint indicators. Sensors that are sensitive to condensation, such as the lithium chloride type, are not recommended for tests with high relative humidity levels. A data collection system separate from the chamber controllers shall be employed to measure test volume conditions. A recording device shall be mandatory for the data collection system. If charts are used, the charts shall be readable to within $\pm 0.6^{\circ}C$. If the wet-wick control method is approved for use, the wet bulb and tank shall be cleaned and a new wick installed before each test and at least every 30 days. Water used in wet-wick systems shall be of the same quality as that used to produce the humidity. Water bottle, wick, sensor, and other components making up relative humidity measuring systems shall, 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 4.5 meters per second (900 feet per minute), and the wet wick shall be on the suction side of the fan to eliminate the effect of fan heat. The flow of air anywhere within the envelope of air surrounding the test item shall be maintained between 0.5 and 1.7 meters per second (98 to 325 ft/min).

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

SUPERSEDES
Page 507.2-13
19 July 1983

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

e. Dehumidification, humidification, heating, and cooling of the air envelope surrounding the test item shall be achieved by methods that do not change the chemical composition of the air, water, or water vapor within that volume of air.

II-1.2 Controls

a. Test parameters. Unless otherwise specified in the requirements documents, temperature and relative humidity measurements made during the test shall be continuous if measurements are in analog form, or at intervals of 15 minutes or less if measurements are in digital form.

b. All instrumentation used with the selected test chamber shall be capable of meeting the accuracies, tolerances, etc., of General Requirements, 4.4.1 and 4.4.2.

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

a. Undertest interruptions. An undertest interruption may be best handled by keeping the chamber closed in an effort to maintain tolerances. As long as the tolerances are maintained, testing may be resumed by reestablishing the prescribed conditions and continuing from the point of the interruption. If an unscheduled interruption occurs that causes the test conditions to exceed the allowable tolerances toward standard ambient temperatures, the test must be reinitiated at the end of the last successfully completed cycle. Any test item failure that occurs shall be treated as a failure.

b. Overtest interruptions. An interruption that results in exposure of the test item to conditions more extreme than required by the requirements documents should be followed by a complete physical examination and operational check of the test item (where possible) before any continuation of testing. This is especially true where a safety problem could exist, such as with munitions. If a problem is discovered, the preferable course of action is to terminate the test and reinitiate testing with a new test item. If this is not done and test item failure occurs during the remainder of the test, the test results may be considered invalid. If no problem has been encountered, reestablish preinterruption conditions and continue from the point where the test tolerances were exceeded.

II-2 PREPARATION FOR TEST

II-2.1 Preliminary steps. Before initiating any testing:

a. Determine from the test plan which test procedures are required.

b. Determine from the test plan the temperature-humidity operation and storage requirements and corresponding temperature-humidity cycle(s) from table 507.2-I.

Step 5. Maintain the 30°C (86°F) and 95% ± 5% relative humidity for an additional 8 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. Previous test methods to which the test item has been subjected.

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

c. Length of time required for each performance check.

d. Procedure and test levels used.

e. Exposure durations.

f. Time versus temperature and humidity.

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I-3.2 Choice of related test conditions. After choosing the test procedure, choose the values of the test variables and decide whether or not the test item is to operate during the test. The specific test conditions to be used in these tests should be based on field data (General Requirements, 4.3). If field data are not available, the test conditions should preferably be selected from the applicable requirements documents. If this information is not available, the following may be used as guidance.

a. Temperature. Unless otherwise specified, these tests should be conducted at the operating or storage temperature obtained from the temperature response of the test item from method 501.2.

b. Relative humidity. High levels of relative humidity may cause caking of dust particles. Consequently, the test chamber RH should not exceed 30%.

c. Air velocity

(1) Blowing dust. The air velocities used in the blowing dust (small particle) test procedure include a minimum air velocity to maintain test conditions (1.5 m/s or 300 ft/min) and a higher air velocity typical of desert winds (8.9 m/s or 1750 ft/min) that shall be used for most tests. Other air velocities may be used, but test chamber limitations must be considered. Excessively high air velocities may lessen the caking or clogging caused by lower air velocities.

(2) Blowing sand. An air velocity in the range of 18 to 29 m/s (3540 to 5700 ft/min) is suggested for most blowing sand applications.1/ Winds of 18 m/s that would blow the large particles are common, and gusts up to 29 m/s are not uncommon. Other air velocities may be used if the induced flow velocity around the equipment in its field application is known.

d. Sand and dust composition

(1) The small-particle (blowing dust) procedure may be conducted with either of the following dust compositions, by weight.

(a) Red china clay is common throughout much of the world and contains:

$CaCO_3$, $MgCO_3$, CaO, MgO, Na_2O, TiO_2, etc.	5%
Ferric oxide (Fe_2O_3)	10 ± 5%
Aluminum oxide (Al_2O_3)	20 ± 10%
Silicon dioxide (SiO_2)	remaining percentage

1/ From MIL-STD-210.

(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 silicia 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 (at least 95% by weight SiO_2). The amount 1.0% ±0.5% of the sand shall be retained by a 20 mesh screen (850 µm), 1.7% ± 0.5% of the sand shall be retained by a 30 mesh screen (590 µm), 14.8% ±1% by a 40 mesh screen (420 µm), 37.0% ±1% by a 50 mesh screen (297 µm), 28.6% ±1% by a 70 mesh screen (210 µm), 12.7% ±1% by a 100 mesh screen (149 µm), and 5.2% ±1% shall pass a 100 mesh screen. The sand shall be of subangular structure with a mean Krumbein number (roundness factor) equal to 0.2 and a hardness factor of 7 mohs.

e. Sand and dust concentrations

(1) The dust concentration for the blowing dust test shall be maintained at 10.6 ±7 g/m^3 (0.3 ±0.2 g/ft^3) unless otherwise specified. This figure is not unrealistic and is used because of the limitations of most chambers.

(2) The sand concentrations[2/] shall be as follows unless otherwise specified.

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

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

(c) For test items that will be subjected only to natural conditions 0.177 g/m^3 (0.0050 g/ft^3).

f. Test item configuration. The configuration of the test item must reproduce, reproduce, as closely as technically possible, the configuration that it would assume during storage or use, such as:

2/ MIL-STD-210

Step 2. Make provision to circulate the fuel-air mixture into the case being tested. In the case of forced-air-cooled equipment, the cooling air must contain the proper fuel-air mixture. For equipment not using forced-air cooling it is necessary to drill the case for insertion of a hose from a blower, take adequate precautions to prevent ignition of the ambient mixture by backfire or release of pressure through the supply hose. Any modification to facilitate the introduction of ignitable vapor shall not alter the case by more than ±5%.

Step 3. Provide positive means of igniting the explosive mixture within the case. The case may be drilled or tapped for a spark gap, or a spark gap may be mounted internally. Points of ignition should not be more than 0.5 inch from any vent holes or flame arresting devices, and as many of such ignition sources should be installed within the case as there are vent holes or flame arresting devices. Where the design of equipment makes this impractical, use as many points of ignition as are practical.

Step 4. A thermocouple inserted into the case and attached to a sensitive galvanometer outside the test chamber may be used to detect explosions within the case.

Step 5. Insure that the air within the test chamber has a water vapor dewpoint lower than 10°C (50°F).

Step 6. If the site atmospheric pressure at the test location is less than 633 mmHg, make provisions to pressurize the test chamber to at least 633 mmHg. Ground level pressures referred to in paragraph II-3.2 step 5 shall consist of pressures from 633 to 800 mmHg, inclusive.

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

II-3 PROCEDURES

II-3.1 Procedure I - Operation in explosive atmosphere

Step 1. Perform preparation for test.

Step 2. Seal chamber with test item mounted inside.

Step 3. Raise the ambient temperature of air inside the chamber to that determined in paragraph I-3.1.3. Wait until temperatures of test item and test chamber inner walls come within 11°C of chamber ambient air temperature.

Step 4. Adjust the chamber air pressure to simulate the test altitude plus 1500 meters, plus adequate additional altitude to allow for introducting, vaporizing and mixing the fuel with the air, as given in paragraph I-3.1.5.

Step 5. Inject the required quantity of n-hexane into the test chamber.

Step 6. Circulate the test atmosphere at least three, but not more than four, minutes to allow for complete vaporization of fuel and the development of a homogeneous mixture.

Step 7. Operate the test item. Operation shall be continuous from step 7 thru step 13. Make and break electrical contacts as frequently as reasonably possible.

Step 8. Slowly increase the air pressure in the test chamber by bleeding air into the chamber. Simulate change of altitude at a rate no faster than 100 meters per minute.

Step 9. Stop air pressure change at 1500 meters below test altitude or at ground level, whichever is reached first.

Step 10. Check the potential explosiveness of the air-vapor mixture by attempting to ignite a sample of the mixture by a spark-gap or glow plug ignition source having sufficient energy to ignite a 3.82-percent hexane mixture. If ignition does not occur, return the chamber to ambient atmospheric pressure, purge the chamber of the fuel vapor, and reinitiate the test at the most recent test altitude.

Step 11. If the lower limit of simulated altitude reached in step 9 is 3000 meters or greater above sea level, reduce the value of the test altitude by 3000 meters. If the station ambient pressure altitude (i.e., ground level) was reached, go to step 13. If the station ambient pressure was not reached, return the simulated altitude to station ambient pressure, purge the chamber to remove all fuel vapor, and then evacuate the chamber to the new value of test altitude.

Step 12. Using the new value of test altitude from step 11, conduct steps 5 through 10.

Step 13. Document test results per paragraph II-4.

II-3.2 Procedure II - Explosion containment test

Step 1. Perform preparation for the test as given in II-2.2.

Step 2. Seal the chamber with test item inside.

Step 3. Raise the ambient air temperature inside chamber.

Step 4. Wait until temperatures of test item and test chamber inner walls come within 11°C of chamber ambient air temperature.

Step 5. Change chamber air pressure to 1500 meters of simulated altitude above the station ambient pressure (i.e., ground level).

Step 6. Inject the required quantity of n-hexane into the test chamber to obtain optimum fuel-vapor/air mixture at station ambient pressure or as given in I-3.1.4b for n-hexane.

Step 7. Circulate the test atmosphere for at least 3 but no more than 4 minutes to allow for the complete vaporization of fuel and the development of a homogeneous mixture within the test item and within the test chamber.

Step 8. Bleed air into the chamber to return the pressure altitude to station ambient pressure (i.e., ground level).

Step 9. Energize the internal case ignition source.

Step 10. Confirm the occurrence of an explosion within the test item using the installed thermocouple. If no explosion occurs, purge the chamber and the test item of all air/fuel vapor and return to step 2.

Step 11. If the explosion inside the test item's case did not propagate to the fuel-air mixture outside the test item, repeat steps 7 through 10 four times if the test item's case is not in excess of one fiftieth of the test chamber volume. If the test item volume is greater than one fiftieth of the chamber volume, purge the chamber and test item of air/fuel vapor and return to step 2.

Step 12. Check the potential explosiveness of the air-fuel vapor mixture by attempting to ignite a sample of the mixture by a spark or glow plug. If chamber sample does not ignite, purge the chamber of all air/fuel-vapor mixture, and repeat the entire test from step 2.

Step 13. Document the test results.

II-4 <u>INFORMATION TO BE RECORDED</u>

a. Test procedure number.

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

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

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

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

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

APPENDIX A

METHOD 511.2

EXPLOSIVE ATMOSPHERE

CHAMBER, FLAMMABLE ATMOSPHERE TESTING

A-1 This appendix describes one test chamber capable of producing the flammable atmosphere conditions required for this test method.

A-1.1 Component parts. The facility shall consist preferably of a steel test chamber and associated pumps, ignition system, fuel metering system, power source, and any other equipment necessary to meet the requirements for test method 511.2 for flammable atmosphere testing.

A-1.2 Design and construction. The explosive atmosphere testing facility shall be a portable self-contained unit or a permanent installation consisting of a well-lighted test chamber equipped with a system for mixing and circulation of explosive air-fuel vapor mixtures, a means of ignition of air-vapor mixture, an explosion relief valve system (figure A1 is a drawing of a differential pressure explosion-relief valve), and a vacuum pump to permit the simulation of altitude. Adequate controls and instrumentation shall be provided. The facility shall be assembled on a chassis or frame and could be mounted on pneumatic-tired wheels for portability. The design may conform in general to figure A2 and shall be capable of compliance with the requirements of this method.

A-1.2.1 Chamber. A practically sized test chamber should provide a minimum clear working space 3 feet in diameter and 5 feet long and should be capable of maintaining any desired pressure altitude within performance limits specified in paragraph A-1.3.5 below.

A-1.2.1.1 Openings. The chamber shall have pressure relief valves and shall be capable of conformance with the applicable requirements of A-1.3 below. Pressure-tight jacks for transmission of power to and from the test item shall be provided, together with openings for the insertion of sealed mechanical controls, as required. Observation windows shall be provided in both sides of the chamber.

A-1.2.1.2 Floor. A removable floor, having a minimum area of 0.75 square meter (8 square feet) and capable of supporting 4880 kilograms per square meter (100 pounds per square foot) within the chamber.

A-1.2.1.3 Lighting. The test chamber shall be lighted with two 150-watt lamps of explosion-proof design, one located at each end of the chamber, to provide uniform illumination.

A-1.2.1.4 Stuffing boxes. Two stuffing boxes shall be provided to facilitate the penetration of cabling connectors and control shafts.

b. Physical size of the test item (to determine test facility requirements).

c. Tiedown precautions (to prevent unrealistic stress).

d. Test item configuration.

e. Conditioning temperature and duration.

f. Covering/immersion depth.

g. Duration of immersion.

h. Additional guidelines.

I-5 <u>REFERENCES</u>

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

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

METHOD 512.2

LEAKAGE (IMMERSION)

SECTION II

II-1 APPARATUS

II-1.1 Test facility

a. The required test apparatus should include a water container that can achieve a covering depth of 1m (3.3 ft) (or other required depths) of water over the uppermost point of the test item and maintain the test item at that depth. Also required is a chamber or cabinet capable of heating the test item to the required temperature.

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

II-1.2 Controls

a. The temperature of the water shall be $18^{\circ} \pm 10^{\circ}$C ($64^{\circ} \pm 18^{\circ}$F).

b. The temperature of the test item shall be $27^{\circ} \pm 2^{\circ}$C ($49^{\circ} \pm 4^{\circ}$F) above (Δt) 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, 4.5.4.)

a. Undertest interruptions. An interruption that results in less severe conditions than specified should be treated as a "no test." The test item should be dried and stabilized at standard ambient conditions and the entire test procedure repeated from the beginning. Any failure discovered during an undertest condition should be treated as a failure.

b. Overtest interruptions. Any interruption that results in more severe conditions than specified should be followed by a complete examination of the test item and an operational check (where possible) before continuation of testing. If no problem is evident, the test should be restarted, preferably with a new test item.

II-2 PREPARATION FOR TEST

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

a. The immersion depth and time and, if applicable, the preheat temperature and duration.

SUPERSEDES
Page 512.2-6
19 July 1983

TRANSPORTATION VIBRATION

I-3.2.1 Category 1 - Basic transportation

All equipment shipped as secured cargo by land, sea or air will encounter this environment. The test levels are based upon land transport stress levels because these are higher than air or sea stresses, and all air and sea transport scenarios include prior or subsequent land transport.

This test is tailorable to the maximum extent of available data. The test levels shown in figures 514.3-1 thru 514.3-22 represent real, measured stresses. The land mobile environment is characterized by broadband vibration resulting from the interaction of vehicle suspension and structures with road and surface discontinuities. Representative conditions experienced in moving materiel from point of manufacture to end use are depicted in figure 1 of General Requirements. These conditions may be divided into two phases, common carrier transportation and mission/field transportation. Common carrier transportation is movement from the manufacturer's plant to any continental United States storage or user installation. This movement is usually accomplished by large truck and/or tractor-trailer combination. Mileage for this transportation generally ranges from 2000 to 4000 miles over improved or paved highways.

Mission/field transportation is that movement of materiel as cargo where the platform may be two wheeled trailers, 2-1/2 ton to 10-ton trucks, semitrailers, and/or tracked vehicles. Typical distances for this phase are 300 to 500 miles. Road conditions for mission/field transport differ from the common carrier in that, in addition to the paved highway, the vehicles will traverse unimproved roads and unprepared terrain (off-the-road) under combat conditions.

a. Test levels. Whenever possible, measured data should be collected on a variety of large conventional trucks, semitrailers, forklifts with shipping pallets, and conventional flatbed transport vehicles used in the common carrier environment with a realistic load configuration of 75% of the vehicle load capacities by weight. For the mission/field environment, data are required from typical tactical vehicles, to include: two wheeled trailers, 2-1/2 ton to 10-ton trucks, semi-trailers, and any tracked vehicle capable of or used for transport of cargo. This data shall then be used to develop test spectra as outlined in appendix A. If measured data are not available, the vibration inputs contained in figures 514.3-1 thru 514.3-22 may be used.

In the development of the vibration test it must be determined if the test item will experience the common carrier, mission/field, or both transportation environments. For test items that will only be transported via common carrier, test levels and conditions shall be derived from the measured data of the common carriers or from figures 514.3-1 thru 514.3-3. Test items that will experience both transportation environments should be tested at the higher levels associated with the mission/field transportation. The levels for this environment can be obtained from figures 514.3-4 thru 514.3-22. The test must be developed from a typical mission/field transportation scenario to obtain the proper mix and representative combination of platform and mileage requirements.

Figures 514.3-1 thru 514.3-3 depict the common carrier environment. These figures are based upon data measured at the cargo floor of seven different configurations of trucks and tractor-trailer combinations. Both conventional suspensions and air-cusioned suspensions are represented. The data was collected from typical interstate highways with rough portions as part of the data base.

Figures 514.3-4 thru 514.3-6 represent the cargo environment at the floor of the M105 two-wheeled trailer. The data include differing vehicle load conditions traversing over specially designed courses ranging from paved highway to offroad conditions at various vehicle speeds. As seen, the spectrum is broadband random with peaks and notches at various discrete frequency bands. The break points of the peaks and notches are given for establishing the spectrum shape. Two-wheeled trailers of significantly different size and design may provide substantially different input to the cargo loaded on the bed than displayed in figures 514.3-4 thru 514.3-6 and spectra should be adjusted accordingly.

Figures 514.3-7 thru 514.3-9 represent the cargo environment at the cargo bed of a composite of tactical wheeled vehicles, the 5-ton M813 truck and the 12-ton M127 semi-trailer. The data include differing vehicle loading conditions traversing over specially designed courses ranging from paved highway to offroad conditions at various vehicle speeds. Again the spectrum is broadband random with peaks and notches at various discrete frequency bands. Break points are provided for establishing the spectrum shape. Tactical wheeled vehicles of significantly different size and design from the M813 and M127 may provide substantially different input to the cargo loaded on the bed than displayed in figures 514.3-7 thru 514.3-9 and spectra should be adjusted accordingly.

Figures 514.3-10 thru 514.3-22 represent the environment at the floor of the M548 tracked vehicle. The data utilized for establishing these spectra were derived from measurements of the vehicle operating at various speeds over specially designed courses ranging from paved highway to offroad conditions. This environment contains a low level of broadband random upon which is superimposed narrowband random at discrete frequency bands. The broadband random base is from the basic movement of the vehicle, suspension system and road discontinuities. The narrowband random excitation is associated with the track-laying pattern and road surface.

b. Test durations. The test duration for Basic Transportation should be based upon total miles of expected transportation. A method for development of test durations is included in appendix A. The common carrier spectra given in figures 514.3-1 thru 514.3-3 have a test time duration of 60 minutes per 1000 miles. For tests which utilize the test spectra contained in figures 514.3-4 thru 514.3-22, the time durations per test axis are given on the individual figures, with the exception of the M548 Cargo Carrier. The total test time for that particular vehicle is 60 minutes per 16 miles, which consists of testing in several phases per axis (the test time per phase is given on the appropriate figure) to accommodate the total swept narrowband random-on-random environment.

Most current turboprop aircraft and many turbine engines are constant-speed machines. This means that rpm is held constant and power changes are made through fuel flow changes and variable-pitch blades, vanes, and propellers. These machines produce the fixed frequency spikes of figure 514.3-25. These spikes have an associated bandwidth because there is minor rpm drift and because 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 514.3-25 must be modified if used for these cases.

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.

a. Test level. Whenever possible, flight vibration measurements should be used to develop vibration criteria for laboratory tests. Appendix A provides guidance for the development of test criteria from field data. In the absence of flight measurements, the test levels of table 514.3-II can be used with the spectra of figure 514.3-25. The turboprop levels are based on data from various C-130 and P-3 aircraft measurements and are fairly representative of the environments of these aircraft. The decline of spike acceleration spectral density with frequency is based on relatively recent data analyzed in a spectral density format. Engine levels are based on data measured on several current Air Force aircraft engines.

b. Test duration. Test durations should be developed from flight measurements or field data. Refer to appendix A for guidance in developing test durations from field data. If field data are not available for development of the test durations, then tests should be conducted for 1 hour per axis at the test levels listed in table 514.3-II, modified according to the guidance in I-4.3, I-4.6, I-4.7, I-4.8 and I-4.9. These levels represent maximum actual operating conditions and are functional test levels.

c. Test setup. The test time shall be installed in a vibration fixture which simulates the actual application configuration. To the extent practical, the vibration test setup should incorporate actual mounting and isolation provisions from the carrying aircraft. Fixture designs which utilize the maximum amount of platform structure possible will allow the test item to respond to the laboratory excitation in a manner more closely duplicating its response in the actual field environment. However, all equipment items protected from vibration by these means should also pass the minimum integrity test requirements of I-3.2.12 with the test item hard-mounted to the fixture.

I-3.2.5 Category 5 - Jet aircraft and tactical missiles. The vibration environment for equipment installed in jet aircraft and tactical missiles (except engine-mounted) stems from four principal mechanisms. These vibrations are random and, except where the elastic response of primary aircraft structure is the source, broadband. These sources are as follows:

(1) Engine noise impinging on aircraft structures.

(2) Turbulent aerodynamic flow along external aircraft structures.

(3) Pressure pulse impingement due to repetitive firing of guns.

(4) Airframe structural motions due to maneuvers, aerodynamic buffet, landing, taxi, etc.

The guidance provided in this section considers sources (1) and (2). Method 519 covers source (3). General airframe motions (4) cannot be adequately covered by general criteria. They are the result of responses of flexible structures to various transient events. Two examples of such responses are rebound of wings and pylons when heavy stores are ejected, and separate flow or shed vortex excitation of flight surfaces during sustained maneuvers. The vibration spectra are characteristic of the particular airframe involved and must be evaluated through measured data. Airframe structural motions are usually important for the outer regions of flexible structures (i.e. outer 1/2 of wings, empennage, pylons, etc). They are usually not important for fuselage-mounted equipment.

Jet-noise-induced vibration is usually dominant in vehicles which operate at lower dynamic pressures, i.e. limited to subsonic speeds at lower altitudes and transonic speeds at high altitudes. Aerodynamically induced vibration usually predominates in vehicles which operate at transonic speeds at lower altitudes or supersonic speeds at any altitude.

When equipment is used in more than one application, the vibration criteria should be enveloped and test criteria based on a worst-case composite.

Only functional tests are performed for tactical missiles.

a. Test levels. In the absence of satisfactory measurements of field environments, functional test levels approximating jet-noise-induced and flow-induced vibration may be derived from table 514.3-III and figures 514.3-26 and 514.3-27.

TABLE 514.3-III. Broadband vibration test values for jet aircraft equipment.

CRITERIA

Aerodynamically induced vibration (figure 514.3-26) 1/

Functional test level 3/, 4/

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

Jet engine noise induced vibration (figure 514.3-26) 1/

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

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

DEFINITIONS

K = 64.4×10^{-8} 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 = 334×10^{-8} for equipment attached to structure in compartments adjacent to or immediately aft of external surfaces having discontinuities (cavities, chines, blade antennas, speed brakes, etc.) and equipments 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 = 5858 Kg/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 sec (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 is engine exhaust velocities are in meters/sec.

TABLE 514.3-III. Broadband vibration test values for jet aircraft equipment. - Continued

NOTES

1/ Envelop aerodynamically induced and jet engine induced and use the worst-case composite.

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

3/ For equipment weighing more than 80 pounds, the W_o vibration test level of figure 514.3-26 may be reduced according to figure 514.3-27.

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 computed using maximum V_c and V_f without afterburner.

6/ For instrument panel equipment, reduce the 0.04 g^2/Hz value of figure 514.3-26 by 3dB and reduce the calculated value W_o by 6dB for functional testing. Endurance is 0.04 g^2/Hz.

TABLE 514.3-VI. Vibration criteria for external stores carried on airplanes.

Parametric Equations for Figures 514.3-30 and 514.3-33

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

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

Eq (3)2/, 3/ 9/: $f_1 = (C)x10^5\ (t/R^2)Hz$

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

Eq (5)5/, 6/, 7/, 9/: $f_o = (C)(t/R^2) \times 10^5 + 100$ HZ

Location, Configuration, Special Adjustments

	Factor	
	A_1	A_2
TER (tri-ejection rack, cluster mount)	1	2
MER (multiple ejection rack, cluster mount)	2	4
Single station	1	1
	B_1	B_2
Aft half of air fired missiles	1	4
Aft half of all other stores	1	2
Forward half of all stores	1	1
	C_1	C_2
Blunt nosed stores, single station and TER	2	4
Blunt nosed stores, MER	1	2
All other stores	1	1
	D_1	D_2
Free fall munitions with non-integral finned sheet metal tail cones	8	16
Air fired missiles	1	1
All other stores	4	4
	E_1	E_2
Firebombs (jelly filled)	1/2	1/4
All other conditions	1	1

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

Store Type	Max q	ρ 8/	N Endurance	T Endurance	f_1(Hz)	f_2(Hz)
Missile, air to ground	1600	100	3	None	500	1500
Missile, air to air	1600	100	100	1	500	1500
Instrument pod	1800	50	500	1	500	1500
Dispenser (reusable)	1200	50	50	1	200	1200
Demolition bomb	1200	120	3	None	125	2000
Fire bomb	1200	40	3	None	100	1100

See next page for Definitions and Notes

TABLE 514.3-VI. Vibration criteria for external stores carried on airplane. - Continued

DEFINITIONS

q = maximum captive flight dynamic pressure in Kgs/M^2 (lbs/ft^2). (See Note 1)

ρ = average store weight density in Kgs/M^2 (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, $q = 5858$ Kgs/M^2 (1200 psf) 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 $W_1 = 0.04 g^2/Hz$; $W_2 = 0.3\ g^2/Hz$; f_1 = 100 Hz; f_2 = 1000 Hz.

4. Acceptance range for parameter values: $40 \le \rho \le 150$ where ρ is in lb/ft^3

   $0.001 \le t/R^2 \le 0.02$ where t&R are in inches.

   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.

6. C = 1 where t&R are in inches

   $C = 2.54 \times 10^{-2}$ where t&R are in meters

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

8. Units of lb/ft^3 and lb/ft^2 respectively.

9. $H = 5 \times 10^{-5}$ if q is in lbs/ft^2

   $H = 2.1 \times 10^{-6}$ of q is in Kgs/M^2

c. Test setup. Testing shall be accomplished in three mutually perpendicular axes with the mounting lugs in the up position. The test item should be attached to the fixture by its normal mounting means (e.g., suspension lugs for 2.75 inch FFAR launchers). The vibration fixture shall utilize, if feasible, actual aircraft components for accomplishing this test attachment. Low level 0.05g, 5 to 500 Hz sweeps to identify the store's resonant frequencies and transmissibilities shall be conducted before and after exposure to the test vibration environment. Significant changes in resonant properties shall be considered as failures even though the item still functions to specification levels.

I-3.2.10 Category 8 - Ground mobile. The ground mobile environment consists largely of broadband random vibration resulting from the interaction of vehicle suspension and structures with road and surface discontinuities. The nature of the terrain, vehicle speed, vehicle dynamic characteristics, and suspension loading all affect vibration responses.

There is presently no analytical model of this environment suitable for generalized test application. In general, the vibration spectrum of wheeled vehicles and trailers is predominantly random, with peaks and notches, considerably higher and lower than the mean level, at various discrete frequency bands. This environment can be simulated by a wide-band random vibration test similar to the minimum integrity spectrum for aircraft as given in I-3.2.12. The use of a smooth spectrum similar to figure 514.3-36, generally will produce an overtest at some parts of the frequency spectrum. The spectrums shown in I-3.2.1 and figure 514.3-2 thru 514.3-10 are composites of the cargo beds of typical wheeled vehicles and trailers and again could produce unrealistic test conditions for installed equipment. When these curves are used, consideration must be given to the structure's response at the location where the equipment is installed as it relates to the major structural members supporting the cargo bed.

The track-laying vehicle environment is characterized by the strong influence of the track-laying pattern. The movement of the vehicle, its suspension system, and road discontinuities produce a broadband random excitation which is further extended or excited at frequencies associated with the track pattern. This environment is best simulated by superimposing narrowband random over a broadband random base.

a. Test levels. As discussed above, generalized test levels have not been developed which would be applicable to a specific case. The information, levels and curve presented in I-3.2.1 and I-3.2.12 must be adapted for a specific test item. Whenever possible and justified by the program requirements, the actual vibration environments should be measured before testing the equipment and the results used to formulate a more accurate spectrum shape and level.

b. Test duration. The test duration must be related to the test item's service scenario. Appropriate test durations are given in I-3.2.1 and I-3.2.2; however, their application for this category must be related again to the specific equipment's service scenario. In development of the test duration from measured data, the procedure outlined in appendix A should be reviewed.

c. Test setup. The test item shall be attached to the vibration generator directly or with a fixture, and securely held by its normal means of attachment. The fixture shall incorporate actual service structures as much as possible to minimize unrealistic response characteristics during test exposure. Any connection to the test item, such as cables pipes, wires, and the like, shall be arranged so that it imposes restraints and mass similar to those present when the equipment is installed in the operational configuration. Excitation shall be applied through the three orthogonal axes of the test item.

I-3.2.11 Category 9 - Shipboard vibration. Equipment installed in ships will receive vibration stresses resulting from natural environmental inputs to the ship's superstructure and local unit transmissibilities (amplifications) within the equipment and its mounting structure. Vibration testing of shipboard equipment should address both the levels of environmental inputs and the susceptibility of equipment/mounting resonances to input frequencies.

Shipboard vibration spectra have a random component induced by the variability of cruising speeds, sea states, maneuvers, etc. and a periodic component imposed by propeller shaft rotation and hull resonances. Equipment mounted on masts (such as antennas) can be expected to receive higher input than equipment mounted on the hull or deck.

a. Test levels. Whenever possible, measurements should be used to develop the test criteria. Appendix A provides guidance for the development of criteria from measured data. In the absence of shipboard measurements, levels found in figure 514.3-34 should be used. The random vibration test of shipboard equipment should follow either the Basic Transportation Test (I.3.2.1) or the Bench Handling Shock Test (method 516.3, Procedure VI).

In order to verify structural integrity and the compatibility of equipment/ mounting resonance frequencies with shipboard input frequencies, a sinusoidal vibration test should be conducted in accordance with MIL-STD-167 for Type I (Environment Vibration). In the event that actual shipboard vibration data recorded on candidate vessels show levels or frequency ranges different from those for MIL-STD-167, Type I, the test levels should be tailored to envelope the highest values for each frequency, with appropriate consideration given to the fatigue life of the equipment.

b. Test duration. The test durations for shipboard applications should be based upon the anticipated deployment scenarios. A method for development of test durations is included in appendix A. For tests which utilize the test levels from figure 514.3-33, the first duration should be two hours along each of three orthogonal axes.

c. Test setup. Equipment should be mounted in its normal configuration with normal shock/vibration isolation mounts used throughout the test.

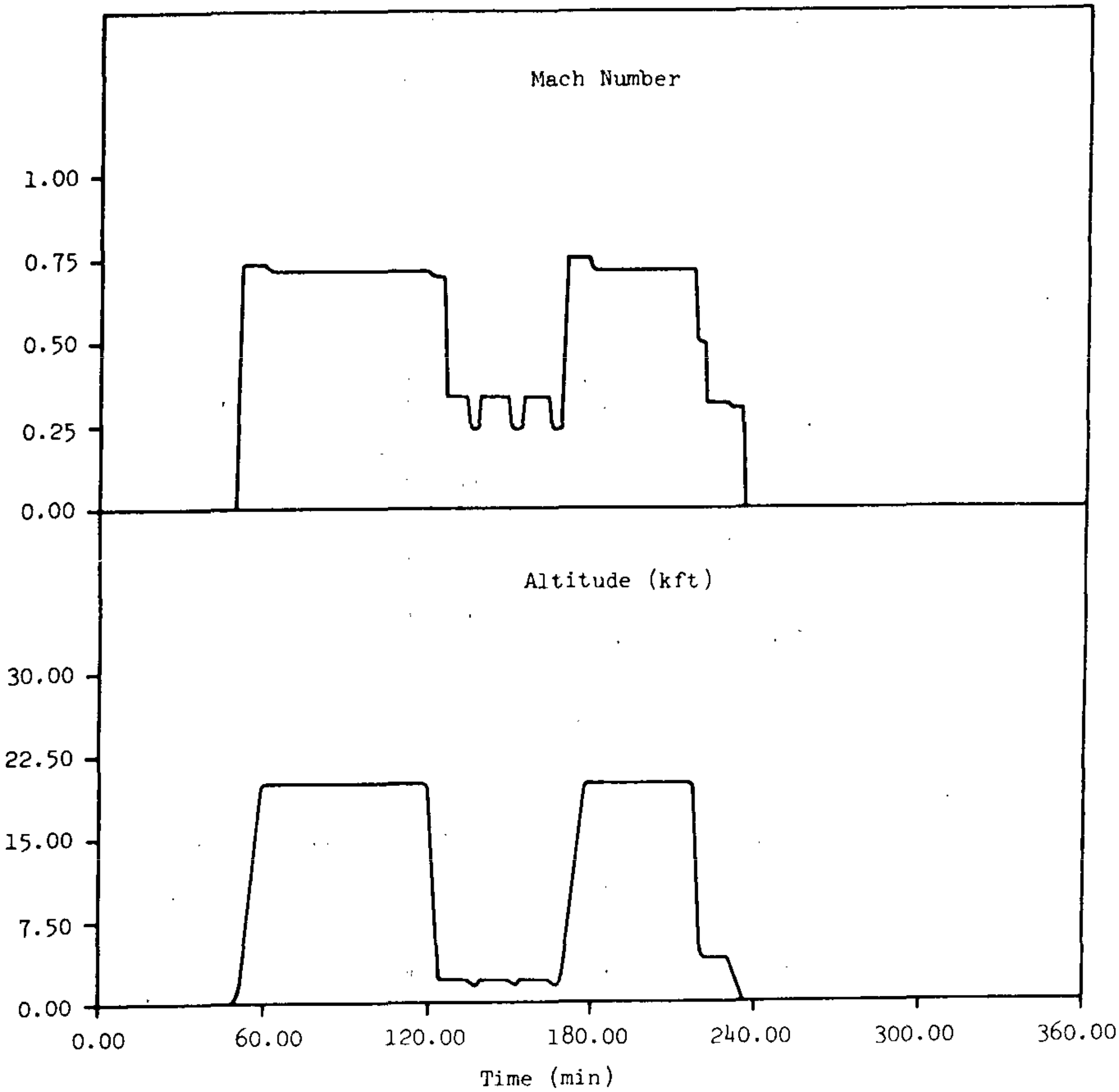

FIGURE 520.0-3. Schematic mission profile, altitude and mach number.

I-3.2.2.4 Environmental stresses. The second step is to determine environmental stresses including vibration, temperature, supplemental cooling, humidity, altitude, and electrical stresses. Test levels for each stress are determined from mission profile information in the manner described in I-3.2.2.5 thru I-3.2.2.9. Other information, such as engine rpm or data on the aircraft's environmental control system (ECS) may also be needed.

TABLE 520.0-I. Example utilization rates of mission profiles.

Mission	Percent Utilization Rate
Ground Attack, Training	40
Ground Attack, Combat	20
Defensive Maneuvers	20
Search and Rescue	10
Functional Check	5
Training Cycle	5
	100%

Since the first three missions, as a group, total 80 percent of the utilization rate, then these three mission profiles would be selected for combined environment testing. If any of the other missions are determined to include extreme or sustained environmental conditions not encountered in the first three missions, then those missions containing these extreme or sustained conditions and adding the most diversity to the test cycle also should be selected. If the first mission selected is utilized twice as much as the other two missions, then Mission 1 should be run twice as much per cycle.

I-3.2.2.5 Vibration stress. Random vibration shall be applied to all equipment items designated for jet aircraft installation. Random vibration or sine superimposed on random vibration should be used for all equipments designated for propeller aircraft. Vibration of an appropriate level and spectrum shape shall be applied continuously during mission profile simulation in the test cycle. Unless measured data exist, it is recommended that the appropriate tables and figures of method 514 of MIL-STD-810 be used to determine vibration conditions except as modified in table 520.0-II.

Short duration vibration events and those that occur infrequently need not be included in the test cycle. These events include firing of onboard guns, general aircraft motion, and shock of hard landings. These events may be tested separately using the appropriate MIL-STD-810 test method.

The vibration stresses to be considered for the test cycle are those due to both attached and separated aerodynamic airflow along the vehicle's external surfaces, jet engine noise, or pressure pulses from propeller or helicopter blades on the aircraft structure. The vibration spectrum and level can be determined for each mission segment by careful use of measured data. Guidance written below shall be applied in those cases.

In many instances, measured flight data are not available for the specific aircraft, equipment location in the aircraft, or flight phases. In such cases, there are several analytical techniques for vibration spectrum and level prediction that can be used to determine vibration test conditions (ref. a).

II-3.3 Procedure III - Qualification test

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

Step 2. Start the test cycle developed from paragraph I-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 paragraph I-3.3c.

Step 5. Check the test item for functioning in accordance with General Requirements paragraph 4.5.

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

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

II-4 INFORMATION TO BE RECORDED

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

b. Test cycle, including environmental conditions applied.

c. Test time history of each failure occurrence.

d. Nature of failure, including environmental effects.

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

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

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

h. Description and calibration status of data recording and analysis equipment.

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

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

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

l. Prior test history of test item.

m. Corrective action proposed.

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