AECTP 300

CLIMATIC

ENVIRONMENTAL TESTS

(January 2006)

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NORTH ATLANTIC TREATY ORGANIZATION

NATO STANDARDISATION AGENCY (NSA)

NATO LETTER OF PROMULGATION

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ALLIED ENVIRONMENTAL CONDITIONS AND TEST PUBLICATIONS

AECTP 300

CLIMATIC ENVIRONMENTAL TESTS

INDEX

AECTP 300 is one of 5 documents included in STANAG 4370. It is important for users to note that the content of AECTP 300 is not intended to be used in isolation, but is developed to be used in conjunction with the other four AECTPs to apply the Environmental Project Tailoring process. This process ensures that materiel is designed, developed and tested to requirements that are directly derived from the anticipated Service use conditions. It is particularly important that AECTP is used in conjunction with AECTP 100 which addresses strategy, planning and implementation of environmental tasks, and AECTP 200 which provides information on the characteristics of environments and guidelines on the selection of test methods.

AECTP 300 test methods address climatic elements which may occur either individually or in combination with other climatic elements or mechanical environments. While the application of combined environments is realistic, is encouraged, and is often preferred to produce synergistic effects, analysis of results is often difficult with regard to assigning failure to a particular element.

The enclosed index of AECTP 300 Methods reflects currently-completed draft methods. It is not comprehensive in that it will be revised as other methods are developed. It is not intended that all test methods shall be applied to all materiel, but selected as required for the particular application.

In developing a test program, consideration shall be given to the anticipated life cycle of the materiel. The cumulative damage caused by long term exposure to the various combinations of climatic and mechanical environments should be simulated. The interface with the appropriate platform shall also be taken into account.

The tests herein are believed to provide a reasonable demonstration of the test item's resistance to the effects of climatic elements. The tests are not necessarily intended to duplicate the environment and, where possible, guidance on the limitations or application is provided.

When possible, the use of measured and response data to develop test severities is recommended.

METHOD 301

GENERAL GUIDANCE AND REQUIREMENTS

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METHOD 301

GENERAL GUIDANCE AND REQUIREMENTS

1. SCOPE

1.1. Purpose

a. To centralize information common to the climatic test methods (AECTP 300).

b. To provide general guidance and requirements for preparing the environmental test specification and/or test plan, and procedures unique to the program under consideration.

1.2. Application.

This Method (301) includes information relative to:

a. Test program development.

b. Test parameter values.

c. Exposure duration.

d. Test item configuration.

e. Information required prior to and following testing.

f. Test parameter tolerances.

g. Characteristics of test facilities.

h. Temperature stabilization.

i. Test controls.

j. Test interruption.

k. Pretest checks.

l. Failure criteria.

Each of these items (a-l) must be considered when using any of the AECTP 300 climatic methods. The documents in AECTP 300 contain generic test procedures that are intended to be tailored for the specific test program.

1.3. Limitations

It is impossible to simulate the total natural environment in a laboratory (chamber). Additionally, gradients through the test item that are produced by the natural environment are, in most cases, difficult to achieve. However, the tests outlined and described in this set of documentation attempt to provide exposure to simulated conditions from which a degree of confidence in the test results can be assumed. Any inability to test all associated equipment at the same time must be considered in evaluating final suitability of the test item and of the test method. Significant limitations relevant to the application of the AECTP 300 climatic methods include:

a. identification and application of all the relevant environmental elements.

b. inability to operate and evaluate the test item as required in service.

c. limited environmental data (response or input).

d. inability of test facilities to apply the climatic elements as they occur in the service environment.

e. impracticality of performing tests for durations comparable to field exposure.

The responsibility for reconciling these and other limitations to specific program needs lies with the environmental engineering specialist in conjunction with the program manager (see AECTP 100). Any one of the AECTP 300 procedures is not intended to be complete for a particular application. Each procedure shall be tailored and translated into test plans and procedures that satisfy the specific needs of each test program.

2. GUIDANCE ON TEST PROGRAM DEVELOPMENT

2.1. Testing in the Natural Environment

Testing in the natural environment is the most realistic approach. However, since it is not possible to control the natural environment, it is rarely possible to ensure that the required extreme environment is available for the test. For such situations, laboratory testing becomes essential, accepting that all factors contributing to the natural environment may not be capable of accurate replication.

2.2. Tailoring

The tailoring process (as described in AECTP 100, Guidelines on the Management of Environmental Testing of Defence Materiel, or equivalent national documents) shall be used to determine the appropriate tests and test variables. Whenever possible, data obtained under actual end-use conditions should be utilized to define test parameters. When measured data are not available, analytical derivations and data from similar applications may be used. The requirements documents must, in all cases, define the anticipated operational scenarios for the test item, so that the environmental test conditions can be derived.

2.3. Sequence

The sequence of tests should normally reflect the sequence of environments that the materiel is expected to experience during its life cycle. Practically, limitations such as time, scheduling and resources may require modification to this approach. There are, in some situations, specific guidelines or recommendations for test sequence. These are identified in the individual test methods.

2.4. Combined Environments

The tailoring process (AECTP 100) may identify a need to apply combined environments to the test item. Such combinations as temperature and altitude, temperature and vibration, or temperature and shock may produce a more realistic representation of the effects of the environment than a series of single tests. Combined environment testing is encouraged, and the appropriate test procedures should be blended by the environmental engineering specialist to provide the required simulation.

2.5. Synergistic Effects

Materiel will frequently experience two or more environmental stresses either simultaneously or consecutively, producing cumulative or synergistic effects that do not occur as a result of single stresses. Accordingly, it is recommended that, to the maximum extent possible, the same test item(s) be used throughout the test sequence for both climatic and dynamic tests. Exceptions to this guidance are provided in the individual test methods as appropriate.

3. CLIMATIC TEST PARAMETER VALUES

The climatic test parameter values shall be based upon actual measurements, documentation containing climatic data such as Leaflet 2311, similar national documents, or data banks.

3.1. Parametric Considerations

In determining parameters, consideration shall be given to the following:

a. Natural climatic conditions: The naturally-occurring ambient environmental conditions anticipated for the areas of use, which are not modified by the structure in or on which the materiel is placed.

b. Induced environment: The ambient environmental conditions resulting from the modification of the natural climatic conditions due to the structure in or on which the materiel is utilized. Examples of values that may be considered if no specific data are available, are given in AECTP 200, Leaflet 2310.

c. Constant environment: The steady state conditions that exist in environments that are relatively controlled, e.g., aircraft cargo bays, maintenance rooms, inside storage areas, or other conditioned enclosures.

Where there is any likelihood of differential stressing from thermal cycling being significant, it may be appropriate to use cyclic temperature testing or, in some instances, thermal shock testing. For other situations, constant temperature testing is appropriate.

3.2. Use Throughout the World

When the materiel is intended to be used throughout the world, allowance should be made for the conditions encountered in the most extreme climatic zones. However, there may be short periods of time during which actual field conditions exceed the environmental extremes presented in these methods and, during which, proper materiel functioning may be inhibited. Once an acceptable frequency of occurrence of a climatic element has been determined, the corresponding climatic value can be ascertained from the climatic data documentation. Appropriate diurnal cycles are given in AECTP 200, Leaflets 2310/11. Care should be taken when considering frequencies exceeding 87 hours per year (1% of the duration of one month) because of underdesign possibilities. For worldwide low temperatures, consideration should be given to the possibility of the materiel entering the C3 category. Since the C4 category only covers the coldest areas of Greenland and Siberia, it is only necessary to consider this for very specialised materiel. If the materiel is likely to enter C3, then -51°C is an appropriate low temperature to use for design and test purposes. For other cold categories, appropriate cycles are provided in AECTP 200, Leaflets 2310/11. The use of more extreme values may not be justified unless safety is a prime consideration.

3.3. Choice of High Temperature Tests

The possible types of exposure to high temperatures necessitates a careful evaluation of the anticipated exposure situation in order to apply the appropriate test or tests. Three standard high temperature tests are available:

a. Solar Radiation (METHOD 305) for actinic (photochemical) degradation, and best approximation of test item temperature response, including thermal gradients.

b. High Temperature (including radiative heating) (METHOD 302), which applies either uniform heating (convection chambers), and/or directional radiative heating.

c. High Temperature, High Humidity (METHOD 306), which applies uniform heating (convection chambers) in combination with high relative humidity.

4. EXPOSURE DURATION

4.1 The duration of exposure to severe temperatures may have a significant impact on materiel and its component materials. Normal diurnal cycling of high temperature and solar radiation will involve thermal lag for which maximum test item response is normally achieved after a maximum of 7 cycles. Constant (non-cyclic) heat sources will generally produce thermal stabilization in a shorter period of time. Conversely, severe low temperatures are normally associated with a lack of solar loading (warming), and certain materials are known to fail after extended periods of low temperature exposure (see Method 303, paragraph 2.3.1).

4.2 The total time of materiel temperature exposure for any test program should not exceed the life expectancy time of any component material for either high temperature exposure or low temperature exposure. Determine the total exposure time from the sum of the pre-conditioning time, plus any standby time, plus actual laboratory testing time. A total exposure duration greater than the materiel life limit can create an accelerated material failure mode, or materiel degradation that is unrelated to the simulated environmental test condition. In particular, use caution during testing of energetic or chemically reactive materials that degrade under elevated temperature conditions.

4.3 To determine the total exposure time, the test program engineer must consider each phase of environmental testing (mechanical, climatic, and electrical), and any additional standby time prior to final operational or performance tests. Standby or pre-conditioning time, such as maintaining the item at conditioned temperature over a weekend, can have a significant impact. The test conditions of concern include the duration for high and low temperature storage and operational tests, high and low temperature conditioning before and during vibration, and possibly solar radiation tests. STANAG 4570 provides further guidance on accelerated aging.

5. TEST ITEM CONFIGURATION

The configuration used for the selected test should, as far as possible, be the actual configuration of the materiel in storage, in operation or during manipulation. It will usually be determined from the specifications. As a minimum, the following configurations shall be considered:

a. In a shipping/storage container or transit case.

b. Protected or unprotected.

c. In its normal operating and thermal configuration (representative or to the extent practical).

d. Modified with kits for special applications.

6. INFORMATION REQUIRED

The following paragraphs list the minimum essential information necessary for conduct of the AECTP 300 Methods.

6.1 Pretest Information

a. Operational and storage climatic conditions, type and number of cycles, and appropriate change rates.

b. Appropriate test procedure(s) from this document.

c. Location of sensors.

d. Test item configuration.

e. When and how operation and performance are to be assessed.

f. Test item performance tolerances.

g. Degree of disassembly for examinations.

h. Baseline performance data and the required accuracy of the measurements.

I Test item point(s) at which stabilization shall be measured (e.g., known critical components).

6.2. Pretest Information Provided by the Tester

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

b. Complete identification of all test equipment, fixtures and accessories.

c. Description of the test setup (include schematics/photographs).

d. Identification and location of environmental sensors.

6.3. Post-test Information

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

b. Deviations from the planned test program and test procedures.

c. Record of environmental conditions and durations under which performance was evaluated, versus time.

d. Test item responses to environmental conditions.

e. Identification and location of environmental sensors.

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

    (1) Prior to test.
    (2) During test.
    (3) Post-test.

g. Initial characteristics of any failure and the associated environmental conditions.

h. Test item point(s) at which stabilization was measured.

7 PARAMETER TOLERANCES

Unless otherwise specified in the test procedure or in the test item requirements documents, measurements and tests shall be made at one or more of the following conditions as appropriate:

7.1. Standard Atmospheric Conditions

The standard range of atmospheric conditions for carrying out measurements and tests shall be as follows:

Temperature: 25 ± 10°C

Relative humidity: 50 ± 15%

Air pressure: 96 ± 10 kPa

***NOTE 1**: Where it is impractical to perform checkouts under the standard atmospheric conditions for testing, a note to this effect shall be added to the test report. The relative humidity may be disregarded (but recorded) where it is considered to have no influence on the test results.*

***NOTE 2:** The temperature and humidity shall be essentially constant during a series of measurements carried out as a part of one test on one test item.*

7.2. Controlled Conditions

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

Temperature: 23 ± 2°C

Relative Humidity: 50 ± 5%

Air Pressure: 96.45 $^{+6.6}_{-10.0}$ kPa

7.3. Tolerances for Test Parameters

Unless otherwise specified, the parameters listed below (and the specified values of same) and used during test conduct shall be applied with the tolerances listed below. These tolerances and the accuracies mentioned in paragraph 10.2 are not to be construed as allowing opposite limits of combined environmental parameter and accuracy tolerances to be combined in such a manner as to reduce the intended stress.

a. Temperature. The test item shall be totally surrounded by an envelope of air (except at necessary support points). Except during transitions, the temperature throughout this envelope measured close to the test item shall be within ± 2°C of the test temperature (test item nonoperating). Wider temperature tolerances are acceptable in situations such as:

   (1) For large items with a volume greater than 5 m^3, the temperature tolerance can be ±3°C. Justify any larger tolerance and obtain approval for its use from the procuring activity.

   (2) For required temperatures greater than 100°C, the temperature tolerance can be ±5°C. Specify the actual tolerance achieved.

b. Pressure: ± 5% of the value, or ± 200Pa (whichever is greater)

c. Relative humidity: ± 5%

d. Air velocity: ± 10% of the value.

e. Time: ± 5 minutes for durations of 8 hours or less;
± 1% of the value for durations > 8 hours.

8. RECOMMENDED CHARACTERISTICS OF TEST FACILITIES

a. Unless otherwise specified, the required apparatus shall consist of test equipment and auxiliary instrumentation capable of maintaining and monitoring (See Paragraph 10.3) the prescribed test parameters within the tolerances in 7.3 above.

b. To optimize the conditions of heat transfer between a heat dissipating test item[1] and the atmosphere, the following should be considered:

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[1] *A test item is heat-dissipating if the hottest point of its surface, measured in free air conditions, is more than 5°C above the ambient temperature of the surrounding air after temperature stabilization of the test item has been reached.*

(1) It is recommended that a minimum volume ratio of 5 to 1 between the internal chamber volume and the test item volume be used, provided there is sufficient distance between the test item and the walls of the test chamber or other test items to ensure adequate airflow.

(2) Radiative: The temperature of the chamber's (internal) walls should not differ more than 3% from that of the chamber's air temperature (expressed in K). The emissivity of chamber's walls should be minimized to the extent possible.

(3) Conductive: The temperature of the support surface on which the test item is placed/mounted should be approximately equal to that anticipated during the life cycle of the materiel.

(4) Convective: Any necessary air circulation should not change the surface temperature of the test item more than 5°C as compared to surface temperature in calm air.

9. STABILIZATION OF TEST TEMPERATURE

9.1 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[2] is changing no more than 2°C per hour.

9.2. Test Item Non-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 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. In some cases, structural or passive members need not be 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 a response temperature in a critical component or area of the test item beyond the specified design temperature limits for the test item.

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[2] *Alternate measurement points may be identified by the requirements documents.*

10. CONTROLS

10.1. Recommended Controls

Unless otherwise specified in the requirements documents or test procedures, the following controls are recommended:

a. To prevent unintentional thermal shocks, limit temperature excursions at the beginning or the end of the test to 3°C/minute.

b. Maintain airflow throughout the test section at the minimum required to provide for adequate conditioning, but not more than 2 m/s to prevent unrealistic heat transfer rates.

c. It is essential that water used for humidity (water vapor and wet bulb socks), salt fog and mold growth (all aspects) tests not unfairly impose contaminants or unintended products on test items, or affect mold germination. Chemicals commonly found in commercial water supplies such as chlorine can cause unintended corrosive effects. Solubles such as calcium carbonate (lime) or insolubles can cause nozzles to clog or leave deposits. Water with a non-neutral pH could cause unintended effects on materiel. Accordingly, rather than impose unrealistic water purity requirements on test establishments, recommend water used for these tests be relatively clean of impurities and chemicals, and have a pH in the range of 6.5 to 7.2 at the time of the test. NOTE: A water resistivity in the range of 150,000 (open tank humidity generators that act as additional distillers, greatly increasing the purity of the water actually arriving at the test item), to 250,000 ohm cm is recommended. This can be produced using distillation, demineralization, reverse osmosis or deionization.

10.2. Measurement Accuracy

Measurement instruments and test equipment shall be calibrated according to the requirements of laboratory standards, traceable to the National Standards via primary standards. Unless otherwise specified, they shall have an accuracy of at least one third of the tolerance of the variable to be measured. Calibration intervals shall meet the guidelines of ANSI NCSL Z540-1 or ISO 10012-1.

10.3. Monitoring Test Chamber Parameters

It is good practice to monitor chamber conditions to ensure that the chamber settings are correct and that the desired environmental conditions within the chamber are being maintained within specified tolerances throughout the duration of the test. In determining the monitoring requirements, the following points should be considered:

a. The frequency of monitoring may vary depending on the data requirements and how that data are to be used. Test parameter levels should be monitored at intervals that are meaningful for the item under test and such that a failure to maintain the prescribed parameter levels may be corrected without jeopardizing the validity of the test.

b. A record of the parameter levels should be maintained, either by manual or electronic means. Exact parameter monitoring intervals and methods of recording will vary for different methods and for different items being tested using a specific method. In some instances monitoring chamber parameters may be required only at long intervals but in others continual, non-stop recording may be necessary.

c. The technology involved in recording parameter levels may involve visual checks at prescribed intervals, real-time continuous recording (such as a circular chart), periodic recording on a device such as a data logger, or other agreed techniques.

It is equally important to monitor the test item itself to record the effects of the chamber environment on the physical condition or performance of the item under test. This will ensure that pertinent changes in the condition of the item under test are captured at appropriate intervals throughout the duration of the test enabling meaningful failure analysis to be performed. The frequency of monitoring will vary depending on the data requirements and how the data are to be used. For example, during conditioning it may be desirable to monitor the condition of the test item infrequently because the information gathered during this period of testing, though important, may not be highly critical. However, during cycled static testing or system performance testing, the frequency of monitoring the test item may be higher at the beginning of a test to capture initial, fast occurring degradation. Other minimum intervals may be set to capture transient events that may occur at any time during the test.

11. TEST INTERRUPTION GUIDANCE

An interruption is defined as the occurrence of out-of-tolerance test conditions. Unless otherwise specified in the individual methods or test plan, the following procedures should be followed when a test is interrupted. Any deviation should be explained in the test report.

11.1. Undertest Interruption

Unless otherwise specified in the test plan and in the individual test methods, if any action causes the test conditions to become less severe than the required test condition, reestablish the prescribed conditions (except as noted in the individual methods), and continue the test from the point that the test tolerances were exceeded.

11.2. Overtest Interruption

a. In general, the preferable course of action is to terminate the test and reinitiate testing with a new test item. If this is not done and a test item failure occurs during the remainder of the test, the possible effects of the interruption, the influence of the overtest, and the extended length of the test must be considered in the failure analysis.

b. In lieu of the above, if any action other than normal test item operation causes the test conditions to become more severe than the required test conditions, stop the test and conduct an operational and visual check of the test item. For hazardous materiels (and possible other items), it is recommended that this interruption be followed by non-destructive testing of the test item under normal temperature conditions. If no fault is revealed, restabilize the test item at the test conditions that correspond to the point of interruption and continue the test. Consider the time at overtest conditions as valid test time. If a fault is revealed, restart the test from the beginning with a new test item.

12. PRETEST STANDARD AMBIENT CHECK

A pretest standard ambient check shall be conducted to provide baseline data for all test items. A change of step sequence may be required for some test items, such as when a visual examination cannot be performed in the chamber.

Step 1. Install temperature sensors in or on the test item as required by the test plan to determine test item temperatures and to establish temperature stabilization.

Step 2. Install temperature sensors in the envelope of air around the test item to verify temperature gradients.

Step 3. Visually examine the test item with special attention to stress areas, and document the results.

Step 4. Insert the test item into the chamber in the required test configuration. Ensure that all cable connections have been made; that unused electrical (or other) connections have been adequately covered to simulate the actual operational environment, and that other similar requirements for proper operation have been accomplished.

Step 5. Install any additional test instrumentation required.

Step 6. Conduct an operational test (functional performance test - except for such items as munitions) in accordance with the approved test plan, to establish baseline performance data.

Step 7. If the test item operates in accordance with the specifications, proceed to the appropriate test procedure. If not, resolve the problems and restart at Step 1 above.

13. EVALUATION OF THE TEST RESULTS

13.1 Failures.

Any one of the following conditions shall normally constitute a test item failure:

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

***NOTE**: Degraded performance at specified environmental extremes is permissible if identified in the test plan. Degraded performance is a failure if:*

(1) Degradation exceeds the permissible limits, or
(2) Specified performance is not restored upon removal of the environmental extreme.

b. Nonfulfillment of safety requirements or the development of safety hazards.
c. Nonfulfillment of specific test item requirements.

d. Changes to the test item that could prevent it from meeting its intended service life or maintenance requirements. (For example: Corroded oil drain plug cannot be removed with commonly available tools or without damaging the surrounding components.)

All failure criteria shall be detailed in the test item specification.

13.2. Retests

Test items with parts or assemblies that have been replaced, repaired or redesigned should be exposed to the complete test environment.

13.3. Exceptions

The following conditions by themselves need not necessarily constitute a failure of the test item, although a retest would normally be necessary.

a. Failure of a test tool, fixture or other associated support equipment.

b. Operator error.

c. Mishandling or improper assembly during troubleshooting or maintenance of the test item.

d. Failure of associated government furnished equipment (GFE).

e. Test item failures induced by test tools, fixtures, GFE, and associated support equipment.

f. Failure of test item elements or assemblies during retest (at conditions more extreme than those detailed in the deployment scenario) that have previously met environmental testing requirements.

g. Failures induced by the failure of test item elements or assemblies during retest that have previously met environmental testing requirements outside the extremes specified in the equipment specification.

14. REFERENCES AND RELATED DOCUMENTs

- AECTP 200, Category 230 – Climatic Conditions.

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METHOD 302

HIGH TEMPERATURE (INCLUDING RADIATIVE HEATING)

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METHOD 302

HIGH TEMPERATURE (INCLUDING RADIATIVE HEATING)

NOTE: *METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD.*

1. SCOPE

1.1. Purpose

The main objectives of these tests are to determine if:

a. the materiel is safe to handle and/or operate during and following exposure to a high temperatures, or

b. the materiel can be stored and operated as specified in the requirements documents during and following exposure to the high temperatures (cyclic or constant) that it is expected to encounter during its service life, or

c. the materiel experiences physical damage during and/or after experiencing high temperature.

1.2. Application

a. This test method is used when the requirements documents state that the materiel is likely to be stored or operated in areas where high temperatures (above standard ambient) occur. The high temperatures may be caused by nearby sources of heat, direct solar loading, or indirect solar loading. When simulation of solar heating is required, the use of measured data from the natural environment, or data obtained as detailed in Method 305, "Solar Radiation," is essential. The application of this Method depends on a knowledge of thermal transfer mechanisms (primarily radiative or primarily conductive/convective). Consideration should be given to the test item enclosure; the sources of heat; the test item surface characteristics, and the test item duty cycles.

b. Although not written for such, this test may be used in conjunction with shock and vibration tests to evaluate the effect of dynamic events (e.g., shipping, handling, shock) on hot materiel.

1.3. Limitations

This method does not address the actinic effects of solar radiation, or the high gradients caused by transient events, nor does it consider direct aerodynamic heating.

2. TEST GUIDANCE

See General Guidance and Requirements, paragraphs 1 and 2.

2.1. Effects of the Environment

High temperatures may either temporarily or permanently impair the performance of the test item by changing the physical properties or dimensions of its construction material(s). High temperature tests should be considered whenever the materiel will be exposed to temperatures above the standard ambient range maximum of 35^{o}C. Examples of problems that could occur as a result of high temperature or solar exposure are as follow. The list is not intended to be all-inclusive, and some of the examples may overlap the categories.

2.1.1. High temperature

2.1.1.1. Physical

a. Melting and exudation, and other phase changes.

b. Dimensional changes, particularly in extruded solid propellants.

c. Distortion, binding, failure of bearings, shafts and packings.

d. Gaskets and seals deteriorating; developing permanent set.

e. Differential thermal expansion, particularly non-metallic against metallic, e.g., explosives, propellants in sealed containers, or casings.

f. Development of internal pressure.

g. Changes in physical properties such as modulus, strength and elongation.

h. Lubricants becoming less viscous; joints losing lubrication by outward flow of lubricant.

j. Unintentional functioning of thermally activated devices.

k. Failure of insulation protection.

l. Increased occurrence of cavitation.

m. Difficulty in handling.

2.1.1.2. Chemical

a. Increased rates of diffusion.

b. Increased rates of reaction:

  (1) More rapid aging caused by reaction with oxygen, water, contaminants, etc., leading to failure, cracking, crazing or discoloring.

  (2) Burning rates of explosives and propellants increased.

c. Failure of chemical agent protection.

d. Release of vapors leading to corrosion, etc.

***NOTE**: Vapors released may present a health hazard to personnel. Precautions should be taken to minimize exposure to same.*

2.1.1.3. Electrical

a Resistors and other components changing in value and life expectancy.

b. Variations in circuit characteristics, electric, electronic or optical.

c Failure of transformers, electromechanical devices, etc., when thermal dissipative capacity becomes insufficient.

d. Altering of operating/release margins of electromechanical devices.

e. Static electricity when humidity is low.

2.1.2. Radiative Heating

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

2.2. Type of Energy Transfer

Materiel can be heated in different ways: radiative, conductive/convective, and self-generated.

2.2.1. Radiative

Radiative heating is caused by or arises from the heating experienced from direct exposure to the sun or to other sources of heat, and will usually produce temperature gradients across the mass of the materiel, resulting in materiel stresses.

2.2.2. Conductive/convective

Conductive and convective heating involve the transfer of heat energy through liquids or solids, or the heating of the air surrounding the materiel, respectively. This typically occurs to materiel inside containers or compartments.

2.2.3. Self-Generated

Self-generated heat causes non-uniform internal heating which is not readily simulated by other means.

2.3. Choice of Test Procedure

(See General Guidance and Requirements, paragraphs 1 and 3.3.) There are three types of test procedures included in this Method.

a. Procedure I is used to assess the possible effects of storage of the materiel at high temperatures (with the associated low humidity, if appropriate) upon its performance and safety in use.

b. Procedure II is used to assess the possible effect of exposure to high temperature upon the operational performance of the materiel and upon safety in use.

c. Procedure III is used if the materiel 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.

2.3.1. Procedure I - High Temperature Storage

In each of the three climatic regions, A1, A2 and A3 (Table 1), the maximum response temperature of the materiel may be higher than the maximum ambient air temperature because the heating from solar or other radiation is greater on materiel than on the free atmosphere, and the platform may amplify the thermal load. Assess the storage situation with respect to the following:

a. The climatic zone concerned or the induced conditions (including duration) caused by any heat source (associated maximum temperature and relative humidity).

b. Whether the service environment is cyclic or approximately steady state.

c. Exposure to solar loading or radiation from other sources of heat falling directly upon the materiel or on its storage enclosure.

d. The degree of ventilation.

e. The heat transfer paths.

2.3.2. Procedure II - High Temperature Operation

Based on the requirements, define the function to be performed by the materiel during or after exposure to high temperature, as well as the modification of ambient temperatures by the platform with which the materiel is associated. This test will, in most cases, be preceded by a storage test. The test can be carried out in different ways:

a. Exposure to cyclic temperatures, with the test item operating continuously, or

b Exposure to cyclic temperatures, with the test item operating after its response temperature has peaked, or

c. Exposure to constant temperature with the test item operational either throughout the test or after temperature stabilization.

The approach for this procedure is to determine the peak response temperature of the test item (at a point or points as identified in the test plan - see Method 301, paragraph 9) to the anticipated cycles to include any influence of the platform, and then to stabilize and operate the test item at that temperature. It is essential to specify whether or not the test item is heat-dissipating, since this will impact the stabilization point. Heat-dissipating materiel may be required to operate throughout the test period or be subjected to a hot start, but shall at least be operated through the highest expected ambient air temperatures.

2.3.3. Procedure III - Radiative Heating

The solar radiation test (Method 305, Procedure I) should be used when the heating caused by solar radiation is unknown. After the induced temperatures have been determined, the high temperature test (with or without directional heating) could (for economic reasons and if actinic effects are not important) be substituted for the solar radiation test. For non-solar heat sources, simulation of the radiation may be difficult unless the actual source is available.

2.4. Choice of Test Parameters

(See General Guidance and Requirements, paragraphs 1 through 4.) The essential parameters for defining the high temperature tests (procedures I and II) include air temperature and surface temperature, exposure time (duration), and test item configuration. Typical high temperature data extracted from AECTP 200, Category 230 (for consideration if measured data are not available) are provided in Table 1. These data should not be used without reference to source documents (AECTP 200, Category 230 or equivalent national documents) that provide guidance on their significance.

2.4.1. Temperature Severities

The temperature severities are directly related to the type of exposure. They are based upon actual measurements, taken from climatic data documents such as AECTP 200, Category 230, equivalent national documents, or from data banks. Alternatively, they may be measured using the Solar Radiation Method, test procedure 1 of Method 305. This approach is particularly valuable for materiel whose surface has unusual spectral properties, e.g., infrared camouflage paint. The maximum temperatures which the materiel is likely to encounter during the various phases of operation and storage throughout its life cycle should be included. These temperatures will obviously vary according to the immediate environment of the materiel, which may be:

a. In an enclosed shelter.

b. Stacked.

c. Exposed to the wind.

d. On the ground, raised above it, or buried.

e. Self-generated (internal heat source).

f. Enclosed in a controlled temperature environment.

g. Directly or indirectly exposed to the sun.

Where differential stressing from thermal cycling is likely to be insignificant, it may be appropriate to use constant temperature testing. Examples of such materiel are small items, components, etc., together with materiel of any size in an essentially constant temperature environment, such as near a continuously operating engine or other source of heat. For other materiels, cycling, diurnal or otherwise, is appropriate.

2.4.1.1. Ambient Air Conditions

These conditions are the meteorological conditions to which the materiel is likely to be exposed in well ventilated situations and sheltered from direct solar radiation.

2.4.1.2. Induced Conditions

These are conditions to which the materiel will be exposed when enclosed in less than fully ventilated areas, and the heating effects of solar or other radiation indirectly cause the temperature of the surrounding air to rise above the ambient air temperature, e.g.,:

a. Within an unventilated enclosure.

b. Inside a vehicle.

c. In tents or under a tarpaulin.

These conditions are difficult to determine because of the numerous variables involved (amount of air space, solar intensity, surface reflectivity, insulation, etc.), and are best determined through actual measurements. Examples of values that may be considered if no other data are available are given in AECTP 200, Category 230 as "Storage and Transit Conditions," but these are, for the most part, infrequently encountered. However, temperature extremes exceeding those given in AECTP 200, Category 230 have been measured under tarpaulins.

2.4.1.3. Extreme Induced Conditions

These conditions involve an even greater rise in temperature due to solar or other radiation, or to other heating sources. The air temperatures, for example, may be significantly higher than 71°C. Materiel may be exposed to these conditions when in open or closed compartments with transparent panels (cockpits, vehicle cabs, etc.) or close to sources of heat. Again, the conditions are best determined through actual measurements.

2.4.1.4. Operating Test Conditions

Parameters such as the mass of the test item relative to the volume of air surrounding it, the heat transfer path, etc., should be taken into account, along with the temperature of the most significant or relevant components. The operating test for non-heat dissipating materiel should normally be conducted when the test item has reached its stabilized response temperature with respect to the operational air temperature requirements. For heat dissipating materiel, operation shall be through the most adverse part of the duty cycle.

2.4.1.5. Application

Test items representing materiel whose anticipated deployment will result in direct solar or heat source exposure, shall be subjected to radiative heating. The temperature environment to be used should be derived from measured data in the natural environment or from data measured near appropriate heat sources. If solar exposure data are not available, the test item should be initially subjected to Method 305 (Procedure I). Once the response temperature of the test item has been determined, extended testing can be accomplished in high temperature chambers using lamp-banks (infra-red) or heaters to maintain the same response temperature.

2.4.1.6. Temperature Levels

Three sets of values are proposed for each type of test. They correspond to the meteorological cycles in the three climatic categories (A1, A2 and A3) of AECTP 200, Category 230. Table 1 provides high temperature diurnal cycles for all three procedures. Measured data should be used for other heat sources.

2.4.2. Test Duration

The test durations are expressed in numbers of 24 hour cycles. The time of test item exposure to a high temperature may be as important as the temperature itself.

Caution : *When temperature conditioning, ensure the total test time at the most severe temperature does not exceed the life expectancy of any material.* See General Guidance and Requirements, paragraph 4.

2.4.2.1. Procedure I - Storage Test

a The choice between cycling and constant temperature testing will depend on design assessment, i.e., whether or not the materiel may be sensitive to thermo-mechanical stressing, and on the anticipated temperature range of any cyclic environment. If 24-hour cycles are appropriate, the minimum number of cycles should be seven. Since the cycles presented are typical of the extreme cycles for the region, and each includes one hour at the peak temperature anticipated to exist for seven hours in the most extreme month of the year in the region under consideration, seven cycles will provide a total of seven hours at the extreme condition. For cycles of other durations, guidance will need to be obtained from the requirements documents subject to an anticipated minimum of seven cycles.

b. To provide confidence that an extended life will be achieved, longer periods of cycling will be needed as part of a sequence of tests representing the manufacture-to-target sequence (MTS) or cradle-to-grave of the materiel. A relationship between number of cycles and minimum real-life age may be derived using the Arrhenius equation (see Method 306, para 2.4.2). However, specialist advice will be needed to apply this method to estimate suitable activation energy values and to minimize the likelihood of unrepresentative failures occurring during test.

c. For constant temperature testing, the temperature chosen should ensure that all likely failure modes will be encompassed. The duration should depend on the purpose of the test. For short term effects, a minimum duration of 16 hours is recommended to give reasonable confidence in less critical situations than those for which cyclic testing was selected. To simulate long term effects, much longer periods may be required. These may be derived as above using the Arrhenius equation.

2.4.2.2. Procedure II - Operating Test

The minimum number of cycles for the operational exposure test is three. This number is normally sufficient for the test item to reach its maximum response temperature. A maximum of seven cycles is suggested when repeatable temperature response is difficult to obtain. This number may be modified in the way best suited to the requirements in the specifications. An extension of the test time may provide information on ageing. For steady state situations, the test should be continued until the temperature of the surface of the test item does not vary by more than 2^{o}C per hour.

2.4.2.3. Procedure III - Radiative Heating Test

2.4.2.3.1. Solar Heating

A minimum of 3 cycles is recommended. This number will usually produce a maximum response temperature in materiel. However, the test should be continued until the maximum temperature reached by the test item during one cycle and the subsequent cycle differ by less than 2^{o}C. If more exact simulation is required, meteorological data for the particular areas under consideration should be consulted.

2.4.2.3.2. Non-Solar Heating

a. For cyclic situations, the test should be continued until the maximum temperature reached by the materiel during one cycle and the subsequent cycle differ by less than 2^{o}C.

b. For steady state situations, the test should be continued until the temperature of the test item at critical components does not vary more than 2^{o}C per hour. If no details of critical components are available, the test should be continued until the surface temperature of the test item facing the source of radiation does not vary by more than 2^{o}C per hour.

2.4.3. Humidity

In certain cases, low relative humidity (less than 10%) can have a significant effect on physical or electrostatic properties of certain types of test items (e.g., computer equipment). In such instances, consideration must be given to controlling the relative humidity as shown in appropriate tables of climatic data documentation or as derived from special measurements, if any. Otherwise, relative humidity control during these high temperature tests is not necessary.

2.4.4 Test Item Orientation

The orientation of the test item relative to the direction of radiation will have a significant impact on the heating effects. In cases where several test item components are known to be sensitive to radiative heating, the relative test item-source orientation may have to be adjusted to simulate the actual conditions.

2.4.5 Substrate

The test item should be mounted either on raised supports or on a substrate of specified properties, e.g., a layer of concrete of specified thickness or a sand bed of a conductivity representative of actual deployment, as provided in the requirements documents.

3. INFORMATION TO BE PROVIDED IN THE TEST INSTRUCTION

In addition to General Guidance and Requirements, paragraphs 5 and 6, the following information is required:

a. Orientation of the test item with respect to the radiation source.

b. Position of the temperature sensors on/in the test item.

c. Substrate characteristics.

4. TEST CONDITIONS AND PROCEDURES

See General Guidance and Requirements, paragraphs 7 - 10, for test conditions, test facility, and test control information.

4.1 Test Facility

See General Guidance and Requirements, paragraph 8.

4.2. Controls

See General Guidance and Requirements, paragraph 10 and consider the following:

4.2.1 Directional (Radiative) Heating

Directional heating can be accomplished using either lamp banks which produce the required solar spectrum (Method 305, Procedure I), or with concentrated heat sources such as heater strips, IR lamps, etc., or with a combination of these. The simulation of directional heating using lamps or heaters to achieve and maintain a known test item response temperature, requires the control of both the airflow as well as the heat source using sensors mounted in or on the test item.

4.2.2. Temperature Measurement

a. The temperature of the air surrounding the test item must be measured at a distance equal to half that separating the test item from the walls of the enclosure, without exceeding 1 meter from the test item. Precautions must be taken when taking these measurements. It is imperative to protect the sensors from direct source radiation and to provide ventilation for the sensors.

b. The temperature sensors used to measure the thermal response of the test item shall also be protected against the direct source radiation (see Method 505, Annex A, paragraph 4.3 for more explanations).

4.2.3. Measurement Of Solar Radiation

See Method 305, paragraph 4.2.2.

4.3. Test Interruptions

See General Guidance and Requirements, paragraph 11.

4.4. Procedures

The following test procedures alone, or in combination, provide the basis for assessing the suitability of the test item in a high temperature environment. For situations in which steady state high temperatures are anticipated, use a constant high temperature related to the real life exposure of the materiel for either storage or operation (whichever is appropriate).

4.4.1. Preparation For Test

Before starting any of the test procedures, determine the information specified in General Guidance and Requirements, paragraphs 5 and 6.1, and perform the test preparation procedure specified in General Guidance and Requirements, paragraph 12.

4.4.2. Procedure I - High Temperature Storage

Step 1. Place the test item in its storage configuration, and install it in the test chamber. (If appropriate, the configuration may include loading due to normal stacking configurations.)

Step 2. Adjust the chamber air temperature to the required storage conditions and maintain for the specified time following temperature stabilization of the test item.

Step 3. For cyclic storage conditions, expose the test item to the temperature (and humidity, if applicable) conditions of the storage cycle for at least seven cycles (if 24-hour cycles are used, this would be a total of 168 hours) or as specified in the test plan.

Step 4. At the completion of Step 2 or the last cycle of Step 3, stabilize the test item at standard ambient conditions.

Step 5. Visually examine the test item to the extent practical.

Step 6 Place the test item in an operational configuration and conduct an operational check of the test item when appropriate.

4.4.3. Procedure II - High Temperature Operation

***NOTE**: For constant temperature exposure, proceed directly to Step 7.*

Step 1. With the test item configured for operation, adjust the chamber air conditions to either the standard or controlled ambient conditions (paragraph 7 of General Guidance and Requirements), and conduct a pretest checkout.

Step 2. Adjust the chamber air conditions to the initial temperature (and humidity, if applicable) level of the required operational cycle (see table 1).

Step 3. For heat-dissipating test items, operation during cycling is required and shall begin at this point. However, if a hot start is required, begin operation when the highest temperature in the test cycle is achieved.

Step 4. Expose the test item (operating or not operating) to the required climatic cycle for at least three cycles, or as necessary to obtain repeated test item response within 2°C. A maximum of seven cycles is suggested if repeated response is difficult to obtain.

Step 5. For test items that have been operating since Step 3, proceed to Step 10

Step 6. From the monitored temperature response data, determine the maximum response temperature of the non-operational test item. This will be the operational temperature for Step 7.

Step 7. Adjust the chamber air temperature to the operational temperature determined in Step 6 or the constant operational temperature specified in the test plan and, if required, adjust the humidity to the appropriate level. Maintain these chamber conditions until temperature stabilization of the test item has been achieved.

Step 8. Visually examine the test item to the extent practical.

Step 9. Conduct an operational check of the test item in accordance with the approved test plan, and document the results.

Step 10. With the test item not operating, stabilize the test item at standard or controlled ambient conditions.

Step 11 Conduct an operational check of the test item in accordance with the approved test plan, and document the results for comparison with pretest data. Visually examine the test item to the extent practical, to determine the extent of any physical damage.

4.4.4. Procedure III - Radiative Heating

Step 1. Install the test item with the associated radiation sources in the appropriate configuration in the test chamber.

Step 2. Bring the air temperature in the chamber to the minimum value of the temperature cycle at which radiation is non-existent.

Step 3. If necessary, create the initial relative humidity conditions specified by the test plan.

Step 4. For cyclic exposure, conduct the required number of cycles during which temperature and radiation levels are changed in accordance with the schedule followed. For steady state exposure, see paragraph 2.4.2.3.2b.

Step 5. Perform the operational checks of the test item at the times called for in the test program.

Step 6. At the end of the test, stabilize the test item at standard ambient conditions.

Step 7. Visually examine the test item to the extent practical.

5. EVALUATION OF THE TEST RESULTS

See General Guidance and Requirements, paragraph 13.

6. REFERENCES AND RELATED DOCUMENTS

See General Guidance and Requirements paragraph 14.

TABLE 1. - High Temperature Diurnal Cycles.
(From AECTP 200, Category 230)

Local Time Hour	**Meteorological conditions**						**Induced conditions** [1]		
	A1		**A2**		**A3**		**A1**	**A2**	**A3**
	Ambient Air Temp	RH %	Ambient Air Temp	RH %	Ambient Air Temp	RH %	Induced Air Temperature °C	Induced Air Temperature °C	Induced Air Temperature °C
01	35	6	33	36	30	69	35	33	31
02	34	7	32	38	29	72	34	32	29
03	34	7	32	43	29	74	35	32	29
04	33	8	31	44	28	76	33	31	28
05	33	8	30	44	28	78	33	30	28
06	32	8	30	44	28	78	33	31	29
07	33	8	31	41	29	74	36	34	31
08	35	6	34	34	30	67	40	38	35
09	38	6	37	29	31	59	44	42	40
10	41	5	39	24	34	51	51	45	44
11	43	4	41	21	36	47	56	51	50
12	44	4	42	18	37	45	63	57	54
13	47	3	43	16	38	44	69	61	56
14	48	3	44	15	38	43	70	63	58
15	48	3	44	14	39	43	71	63	58
16	49	3	44	14	39	44	70	62	56
17	48	3	43	14	38	46	67	60	53
18	48	3	42	15	37	48	63	57	50
19	46	3	40	17	35	50	55	50	46
20	42	4	38	20	34	53	48	44	41
21	41	5	36	22	34	56	41	38	37
22	39	6	35	25	32	59	39	35	34
23	38	6	34	28	32	63	37	34	33
24	37	6	33	33	31	66	35	33	37

[1] Humidities for A1, A2 and A3 storage conditions vary too widely between different situations to be represented by a single set of conditions.

METHOD 303

LOW TEMPERATURE

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METHOD 303

LOW TEMPERATURE

NOTE: *METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD.*

1. SCOPE

1.1. Purpose

The main objectives of low temperature tests are to determine if:

a. The safety of the materiel is affected as a result of exposure to low temperature, or

b. The materiel can be stored, manipulated and operated within the specified requirements during and after exposure to low temperature that it is expected to encounter during its service life, or

c. The materiel experiences physical damage during or after its exposure to low temperature.

1.2. Application

a. This Method is used when the requirements documents state that the materiel is likely to be deployed in regions in which the climatic conditions will induce low temperatures (below standard ambient) within the materiel. If the effects of low temperature on the materiel are being determined during other tests for the required extremes and durations (including manipulation), it is not necessary to perform this test.

b. Although not written for such, this Method may be used in conjunction with shock and vibration tests (AECTP 400) to evaluate the effects of dynamic events (e.g., shipping, handling, shock) on cold, embrittled materiel.

1.3. Limitations

a. This Method is not intended to be used to simulate temperature-altitude effects that will be experienced by aircraft-mounted equipment.

b. This Method does not address temperature cycling through 0°C.

c. This Method does not address the effects of snow, ice or wind as encountered during natural low temperature exposure.

d. This Method does not intentionally address the effects of frost, because this would require a controlled source of moisture.

1.4. Definition

For the purpose of this document, manipulation is defined as the actions necessary to convert the materiel from a storage to an operational configuration, operate it, and return it to its storage configuration.

2. TEST GUIDANCE

See General Guidance and Requirements, paragraphs 1 and 2.

2.1. Effects of the Environment

Exposure to constant or cyclic (diurnal) low temperatures may either temporarily or permanently impair the operation of materiel by changing the physical properties or dimensions of its construction materials. Examples of problems that could occur as a result of exposure to cold are as follows, but the list is not intended to be all-inclusive and some of the examples may overlap the categories.

2.1.1 Physical

a. Phase changes (solid/solid, solid/liquid/gas).

b. Dimensional changes.

c. Distortion, binding, failure of bearings, shafts and packings.

d. Failure of seals.

e. Differential thermal contraction, particularly non-metallic against metallic, e.g., explosives, propellants in cases.

f. Changes in physical properties such as modulus, strength and elongation (leading particularly to embrittlement).

g. Lubricant failure due to viscosity change.

h. Static fatigue of restrained glass.

i. Freezing (expansion) of water, and condensation of water vapor.

j. Failure of bonding materials.

k. Stiffening of shock and vibration mounts.

l. Difficulty of manipulation.

2.1.2. Chemical

Reduced rates of reaction:

a. Burning rates of explosives and propellants reduced.

b. Igniters failing to operate.

2.1.3. Electrical

a. Resistors and other components changing in value and life expectancy.

b. Variations in circuit characteristics.

c. Altering of operating/release margins of electrochemical devices.

d. Batteries generating insufficient power.

e. Breakdown due to shrinkage of insulation or potting.

f. Changes in performance of transformers.

g. Excessive static electricity.

h. Difficulty in obtaining or maintaining good earthing (grounding).

2.2 Choice of Test Procedure

(See General Guidance and Requirements, paragraphs 1 and 2.) There are three test procedures in this method: storage, operating and manipulating. All three tests can be conducted if appropriate.

2.2.1. Procedure I - Storage Test

This procedure is used to assess the possible effect of storage of the materiel at low temperatures upon its performance and safety in use. The test can be carried out in two different ways:

a. Exposure to an essentially constant low temperature.

b. Exposure to cyclic low temperature (change of at least 9°C as in category C2 of AECTP 200, Leaflet 2311) below freezing.

2.2.2. Procedure II - Operational Test

This procedure is used to assess the possible effect of exposure to low temperature upon the operational performance of the materiel and upon safety in use. This test will, in most cases, be preceded by a storage test, and may also be preceded by or combined with a manipulation test. The test can be carried out in two different ways as in paragraph 2.2.1.

2.2.3. Procedure III - Manipulation Test

For this test, the test item is exposed to the same temperatures as for the constant temperature operating test. This procedure is used to:

a. Test the suitability of the materiel for handling in operation, assembly, disassembly, and installation by personnel equipped to withstand cold, and

b. To determine if the materiel can be assembled and disassembled at low temperatures safely and without damage.

2.3. Choice of Test Parameters

(See General Guidance and Requirements, paragraphs 1, 2 and 4.)

The most significant parameters used in this test method are temperature and exposure time. It is also important in this test procedure to specify the operational configuration of the test item, as well as whether or not the test item is heat dissipating during operation. Although the natural low temperature environment is normally cyclic, in some instances it is acceptable to use a constant low temperature test. In those instances where design assessment suggests that exposure to varying low temperatures may be important, the appropriate cold cycles from AECTP 200, Category 230 are recommended. Typical low temperature data extracted from AECTP 200, Category 230 (for consideration if measured data are not available) are provided in Table 1. These data should not be used without reference to source documents (AECTP 200, Category 230 or equivalent national documents) that provide guidance on their significance. Consideration should be given to the need or otherwise for operation of materiel at very low temperatures, i.e., below -46°C.

Caution: *When temperature conditioning, ensure the total test time at the most severe temperature does not exceed the life expectancy of any material.* See General Guidance and Requirements, paragraph 4.

2.3.1. Storage test

Derive the time of materiel exposure to low temperatures from the deployment requirements, and consider it in conjunction with the materiel characteristics. There is evidence that prolonged storage of restrained glass and organic plastics may result in deterioration. Static fatigue of restrained glass, for example, has been documented[3,4] after long periods of low temperature exposure. Data from these sources suggest that the breaking stress for glass will be reduced by approximately 50% in 72 hours. For such material, a minimum storage test of 72 hours following stabilization of the test item is recommended. For other materials, there is no evidence to support deterioration following temperature stabilization. Prolonged storage testing following stabilization may not be necessary; a 4-hour soak following stabilization of the test item should be sufficient. If it is considered that thermo-mechanical stressing may present a significant problem, cyclic temperature testing may be appropriate. The number of cycles should be sufficient to reproduce the low temperature response of the previous cycle within 2°C. Use of a greater number of cycles may give information on low temperature aging characteristics of the materiel or, for example, on the effects of leakage around seals between dissimilar materials.

2.3.2. Operational Test

As a general rule, the operational test will take place after the storage, and during or after the manipulation test, but this may vary because of life cycle considerations. Although cyclic temperatures are normal, the application of cyclic testing at low temperature levels (except near the freezing point of water) rarely provides any known advantage over steady state testing. However, if the test item is exposed to temperature cycles, a minimum of three cycles will normally be required to achieve maximum response of the test item.

2.3.3. Manipulation Test

The conditions for this test will depend upon how the materiel is used and the test item configuration. The important issue is that the test item is exercised at the low operating temperature.

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[3] *Glass Engineering Handbook, 2nd Edition, E.B. Shand, 1958, McGraw-Hill Book Company, New -York.*

[4] *The Properties of Glass, 2nd Edition, G.W. Morey, 1954, Reinhold Publ.Corp.*

3. INFORMATION TO BE PROVIDED IN THE TEST INSTRUCTION

See General Guidance and Requirements, paragraphs 5 and 6.

4. TEST CONDITIONS AND PROCEDURES

See General Guidance and Requirements, paragraph 7 - 10, for test facility, test conditions and test control information.

4.1. Test Facility

See General Guidance and Requirements, paragraph 8.

4.2. Controls

See General Guidance and Requirements, paragraph 10.

4.3. Test Interruption

See General Guidance and Requirements, paragraph 11.

4.4. Procedures

The following test procedures, alone or in combination, (see Figure 1) may be used to determine the performance of the materiel in a cold environment. Conduct the operational checks after both the storage and manipulation tests for comparison with pretest data. For situations in which cyclic low temperatures are desired, replace the steady state steps with the cyclic temperature exposure related to the real life exposure of the materiel at the low anticipated temperature for either storage or operation (whichever is appropriate).

***NOTE**: Unless otherwise specified or required for operation or manipulation, opening of the chamber door at any point in these test procedures is not recommended because of possible frost formation and associated problems.*

4.4.1. Preparation For Test

Before starting any of the test procedures, determine the information specified in General Guidance and Requirements, paragraphs 5 and 6.1, and perform the test preparation procedure specified in General Requirements, paragraph 12. Ensure that any fluids included as part of the test item are those appropriate for the temperature range of the test.

4.4.2. Procedure I - Storage Test

Step 1. Place the test item in its storage configuration and install it in the test chamber. If appropriate, the configuration may include loading (actual or simulated) to simulate normal stacking configurations.

Step 2. Adjust the chamber air temperature to the required initial temperature for constant or cyclic temperature storage conditions.

Step 3a. For constant temperature: following temperature stabilization of the test item, maintain the storage temperature for a period as specified in the test plan.

Step 3b. For cyclic temperature: perform the required number of temperature cycles.

Step 4. If required, visually examine the test item to the extent practical, while at the lowest temperature from step 3.

Step 5. If low temperature operation with no manipulation (no reconfiguration for operation) is required, proceed to 4.4.3; if reconfiguration is necessary for low temperature operation, proceed to 4.4.4; otherwise, proceed to step 6 below.

Step 6. Stabilize the test item at standard ambient conditions.

Step 7. Visually examine the test item to the extent practical.

Step 8. If appropriate, conduct an operational check of the test item and document the results

4.4.3. Procedure II - Operational Test

4.4.3.1. Procedure IIa - Constant Temperature

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

Step 2. Visually examine the test item to the extent practical.

Step 3. Conduct an operational check of the test item and document the results.

Step 4. Stabilize the test item at standard ambient conditions.

Step 5. Visually examine the test item to the extent practical.

Step 6. Conduct an operational check similar to that in General Guidance and Requirements, paragraph 12, and document the results for comparison with the pretest data.

4.4.3.2. Procedure IIb - Cyclic Temperature

Step 1. With the test item in its operating configuration, adjust the chamber air temperature to the initial temperature of the specified cycle and maintain until the test item has stabilized.

Step 2. Expose the test item (non-operating) to the temperature level specified for the operational cycle for at least three cycles, or as necessary to obtain repeated test item response within 2°C.

Step 3. From the exposure data, determine the lowest response temperature of the test item. This will be the operational temperature for Step 4.

Step 4. Adjust the chamber air to the operational temperature. Maintain the chamber in a steady state condition until temperature stabilization of the test item has been achieved.

Step 5. Visually examine the test item to the extent practical.

Step 6. Conduct an operational check of the test item in accordance with the approved test plan, and document the results.

Step 7. With the test item not operating, stabilize the test item at standard ambient conditions.

Step 8. Conduct an operational check similar to that in General Guidance and Requirements, paragraph 12, and document the results for comparison with the pretest data.

NOTE: *During a long sequence of operations, temperature restabilization may be required at intervals.*

4.4.4. Procedure III - Manipulation Test

Step 1. With the test item in the test chamber in its storage configuration, stabilize the test item at its low operating temperature derived, if necessary, from 4.4.3.2.

Step 2. While maintaining the low operating temperature, place the test item in its normal operating configuration using one of the following options based on the type of test chamber available:

a. Option 1 - To be used when a "walk-in" type chamber is available: With personnel clothed and equipped as they would be in a low-temperature tactical situation, assemble or install the test item into its operational configuration as would be done in the field.

b. Option 2 - To be used when non-walk-in chambers are used: Perform the Option 1 procedure by reaching through chamber access holes or the open door while wearing heavy gloves such as would be required in service. (NOTE - Opening the chamber door is not recommended because it may cause frost to form on the test item as well as cause a gradual warming of the test item.) In order to maintain the test item external temperature within the required tolerance as specified in General Requirements, paragraph 7.3, limit the door-open periods by performing the manipulation in stages.)

Step 3. If operation of the test item is required at low temperatures, perform the checkout and document the results for comparison with General Requirements, paragraph 12 (Pretest Standard Ambient Check).

Step 4. Restabilize the test item at the low operating temperature.

Step 5. With the test item still in the chamber, repeat the options of Step 2 above while disassembling the test item and repacking it in its normal shipping/storage container(s), transit case, or other mode and configuration. It is not necessary to replace any stacking loads.

Step 6. Adjust the chamber air conditions to standard ambient and stabilize the test item.

Step 7. Visually examine the test item to the extent practical.

Step 8. Conduct an operational check of the test item similar to that in General Requirements, paragraph 12, and document the results for comparison with pretest data.

NOTE: *During a long sequence of operations/manipulations, temperature restabilization may be required at intervals.*

5. EVALUATION OF THE TEST RESULTS

See General Guidance and Requirements, paragraph 13.

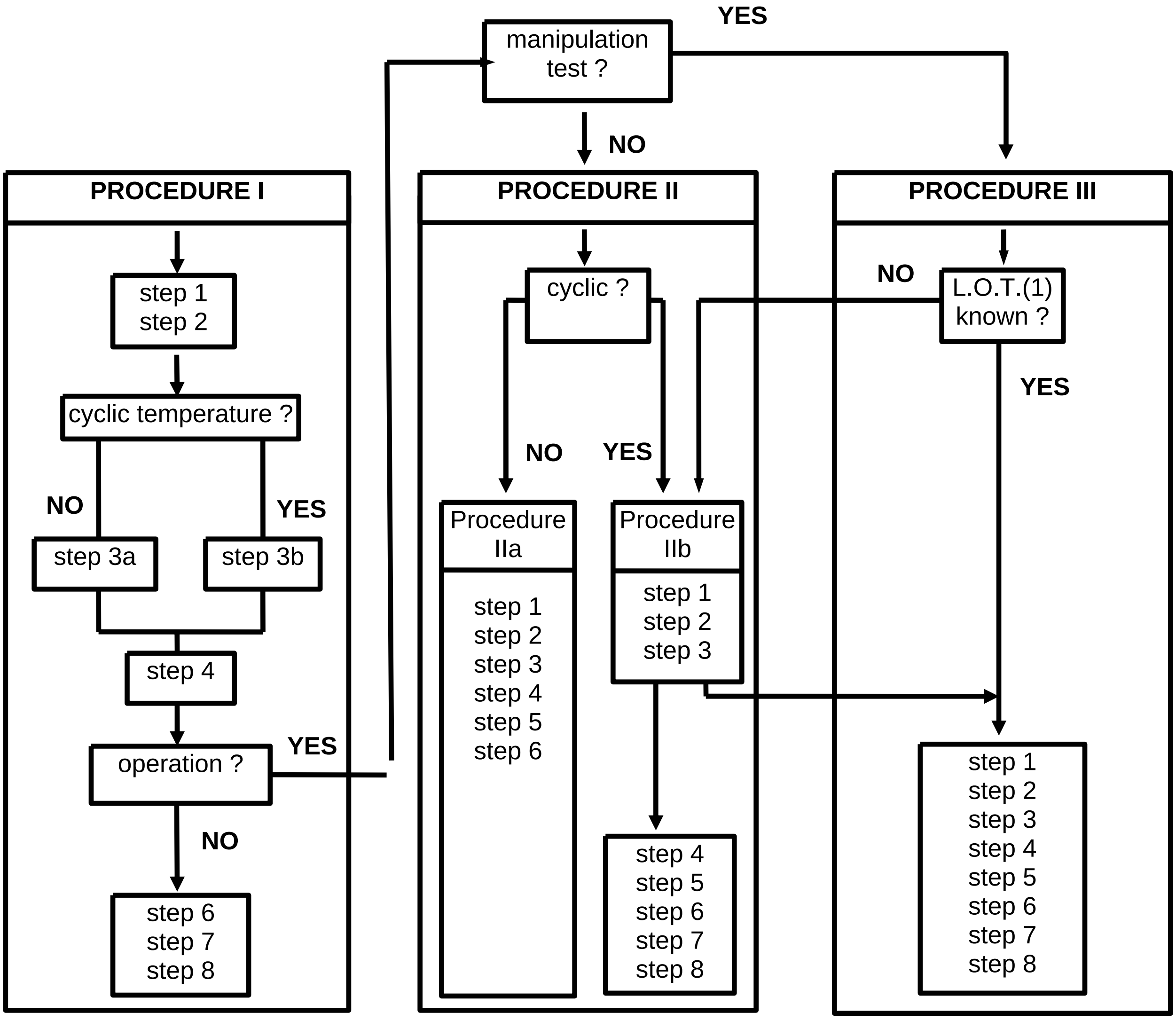
6. REFERENCES AND related DOCUMENTS

See General Guidance and Requirements, paragraph 14.

TABLE 1 - Typical low temperature data.
(from AECTP 200, Category 230)

Climatic Category (*)	Meteorological		Induced	
	Temperature (°C)	**Relative Humidity (%)**	**Temperature (°C)**	**Relative Humidity (%)**
C0	-6 to -19	Tending toward saturation	-10 to -21	Tending toward saturation
C1	-21 to -32		-25 to -33	
C2	-37 to -46		-37 to -46	
C3	-51		-51	
C4	-57		-57	

(*) These categories are described in AECTP 200, Category 230 and are comparable to those found in national standards.



(1) Low Operating Temperature

Figure 1 - Low Temperature Procedures

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METHOD 304

AIR-TO-AIR THERMAL SHOCK

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METHOD 304

AIR-TO-AIR THERMAL SHOCK

NOTE: *METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD.*

1. SCOPE

1.1. Purpose

The main objectives of the thermal shock test are to determine if:

a. The safety of the materiel is affected as a result of exposure to sudden, extreme changes of temperature.

b. The materiel can be handled and operated within the specified requirements during and after sudden temperature changes (greater than 10^{o}C per minute) likely to be associated with actual service conditions.

c The materiel experiences physical damage during or after experiencing temperature shock.

1.2. Application

This test method is used when the requirements documents specify that the materiel is likely to be deployed where sudden significant changes of air temperature may be experienced (see 2.3.1). This Method is only intended to evaluate the effects of sudden temperature changes of the outer surfaces of materiel, items mounted on the outer surfaces, or internal items situated near the external surfaces. Typically, this addresses:

a. The transfer of materiel between heated areas and low temperature environments.

b Ascent from a high temperature ground environment to high altitude via a high performance vehicle (hot to cold only).

c. Air drop at high altitude/low temperature from aircraft enclosures when **only** the external material (packaging or materiel surface) is to be tested.

This method may also be used to reveal safety problems and potential flaws in materiel normally exposed to less extreme conditions, as long as the design limitations of the materiel are not exceeded.

1.3. Limitations

a. This Method is not intended for materiel that will not experience sudden extreme air temperature changes because of its packaging, installed location, or other such configurations that would shield the materiel from significant temperature changes.

b. This Method is inappropriate if the actual transfer time in a service environment will not produce a significant thermal shock. Additionally, it is not to be used to assess performance characteristics after lengthy exposure to extreme temperatures, as are the low and high temperature methods.

c. This Method has not been designed to address the temperature shock experienced by materiel that is transferred between air and liquid or between two liquids, materiel that is exposed to rain following solar heating, or materiel that is exposed to heat from a fire and then cooled with water.

d. This Method does not address the thermal shocks produced by the internal generation of heat.

e This Method does not address the thermal shock caused by rapid warm-up by engine compressor bleed air.

f. This Method does not address aerodynamic heating or cooling due to wind.

2. TEST GUIDANCE

See General Guidance and Requirements, paragraphs 1 and 2.

2.1. Effects of the Environment

Sudden temperature changes may either temporarily or permanently impair the performance of the materiel by changing the physical properties or dimensions of its construction materials. Examples of problems that could occur as a result of exposure to thermal shock are shown below, but the examples are not intended to be comprehensive.

2.1.1. Physical

a. Shattering of glass vials and optical equipment.

b. Binding or slackening of moving parts.

c. Cracking of solid pellets or grains in explosives.

d. Differential contraction or expansion of dissimilar materials.

e. Deformation or fracture of components.

f. Cracking of surface coatings.

g. Leakage from sealed compartments.

h. Failure of insulation.

2.1.2. Chemical

a. Separation of constituents.

b. Failure of chemical agent protection.

2.1.3. Electrical

a. Changes in electrical and electronic components.

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

c. Excessive static electricity.

2.2. Test Procedure

(See General Guidance and Requirements, paragraphs 1 and 2.) There are two procedures. Procedure I employs constant temperature at each of the extreme shock conditions because, in many instances, the thermal shock itself so outweighs the other thermal effects that the test may be performed using two constant temperatures. This is particularly the case when more severe shocks are desired, such as for evaluation of safety or initial design and when extreme values will be used. When a careful simulation of a real environment is required, Procedure II can be used because the upper temperature follows part of an appropriate diurnal cycle. The test conditions that are used during either procedure are determined from:

a. The expected exposure temperatures in service.

b. The materiel's logistic or deployment configuration.

The function (operational requirement) to be achieved by the materiel and a definition of the circumstances responsible for the thermal shock should be determined from the requirements documents.

2.3. Choice of Test Parameters

(See General Guidance and Requirements, paragraphs 1-4.) 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 transfer between the two temperature extremes. The temperature of the test item before transfer must be the most realistic extreme that would be encountered during the specific operation. Response temperatures achieved when materiel is exposed to the conditions of the various climatic categories may be obtained from the test results of high temperature exposure for either the operational or storage configuration (see Method 302). The latter assumption must consider the induced effects of solar radiation during storage and transit in various climates.

2.3.1. Temperature Levels

Both the total temperature change expected in service and the materials involved must be evaluated to determine the need to perform this test. The temperature levels are determined in relation to the use of materiel that has been previously defined. They may be obtained from special measurements (response temperatures from the High and Low Temperature operational tests), or extracted or derived from AECTP 200, Leaflet 2311 or equivalent national standards. For safety or design evaluation, temperature levels may have more extreme values than these.

2.3.2. Transfer Time

The transfer time must reflect the time associated with the actual thermal shock in the life cycle profile. If the transfer takes more than one minute, the extra time must be justified.

2.3.3. Humidity

For most test programs, relative humidity is not controlled. Relative humidity may have a significant influence on some materiel (e.g., cellulosic materials that are typically porous, into which moisture can migrate and then expand upon freezing) during the thermal shock test. This must be considered and special measurements (if available) or the data of AECTP 200, Leaflet 2311 should be used as a basis.

2.3.4. Stabilization

Since this method is intended to evaluate those portions of materiel that can respond rapidly to external temperature changes, expose the test item to the temperature extremes for a duration representative primarily of the realistic worst case (life cycle profile), but also taking into account the time taken to achieve thermal stabilization of the areas on or near the external surfaces of the test item.

2.3.5 Number of Shocks

For a test item that is likely to be exposed only rarely to thermal shock, one shock is recommended for each appropriate condition. There is little available data to substantiate a specific number of shocks when more frequent exposure is expected. In lieu of better information, a minimum of three shocks should be applied at each condition, the number depending primarily on the anticipated service events.

2.4. Evaluation of Effects

The nature of this test precludes extensive performance evaluation while thermal shock conditions exist. Operational evaluation will, in most cases, be limited to irreversible effects or simple "go/no go" performance indications that can be quickly observed.

3. INFORMATION TO BE PROVIDED IN THE TEST iNSTRUCTION

In addition to that specified in General Guidance and Requirements, paragraphs 5 and 6, document the actual transfer times from the time that the chamber door is opened, to the time that the door of the second test section is closed.

4. TEST CONDITIONS AND PROCEDURES

See General Guidance and Requirements, paragraphs 7 - 10 for test conditions, test facility, and test control information.

4.1. Test Facility

See General Guidance and Requirements, paragraph 8.
Unless otherwise specified or impractical due to the thermal mass of the test item, the chamber(s) or compartments to be used must be equipped so that after transfer of the test item, the desired test air temperature within the chamber can be achieved within 5 minutes. Chamber airflows of up to 6 m/s may be required in order to optimize heat transfer rates.

4.2. Controls

See General Guidance and Requirements, paragraph 10.

4.3. Test Interruption

See General Guidance and Requirements, paragraph 11.

If an interruption occurs during the transfer, the test item must be re-stabilized at the previous temperature and then transferred.

4.4. Procedures

The procedures depicted in Figures 1 and 2 arbitrarily begin with the lower temperature, but could be reversed to begin with the higher temperature if it is more realistic. Specific points in Figures 1 and 2 (in parentheses) are referenced in the following text.

4.4.1. Preparation for Test

Before starting either of the test procedures, determine the information specified in General Guidance and Requirements, paragraphs 5 and 6.1, and perform the test preparation procedure specified in General Guidance and Requirements, paragraph 12.

4.4.2. Procedure I - Shock From Constant Extreme Temperatures (See Figure 1)

Step 1 With the test item in the chamber, adjust the chamber air temperature to the low temperature extreme specified in the test plan (a) at a rate not exceeding 3°C/minute. Maintain this temperature for a period as determined in the test plan (a-b).

Step 2. Transfer the test item in no more than one minute (b-c) to an atmosphere at temperature T2 that will produce the thermal shock specified in the test plan, and maintain this temperature as specified in the test plan (c-e).

Step 3. If required in the test plan, evaluate the effects of the thermal shock on the test item to the extent practical (see paragraph 2.4).

Step 4 If other cycles in reversed directions are required, transfer the test item to the T1 environment in no more than one minute (e-f) and stabilize as required in the test plan (f-b), evaluate the thermal shock effects (if required), and continue as in steps 2 and 3 above. If other one-way shocks are required, return the test item to the T1 environment at a rate not exceeding 3^{o}C/minute and repeat steps 1-3. If no other shocks are required, go to Step 5.

Step 5.. Return the test item to standard ambient conditions.

Step 6 Examine the test item and, if appropriate, operate. Record the results for comparison with pretest data.

4.4.3. Procedure II - Shock to/from Cyclic High Temperatures (See Fig. 2)

Step 1. With the test item in the chamber, adjust the chamber air temperature to the low temperature extreme specified in the test plan (a). Maintain this temperature for a period as determined in the test plan (a-b).

Step 2. Transfer the test item to the maximum air temperature of the high temperature cycle (c) (as specified in the test plan) in no more than one minute. As soon as the chamber door is closed and the high temperature is restored, cycle the chamber through part of the appropriate diurnal cycle until the chamber reaches the test item response temperature (d) (obtained according to Method 302, para 2.3.2). Maintain this temperature as specified in the test plan (d-e).

Step 3. If no other cycles are required, return the test item to standard ambient conditions and proceed to step 7; otherwise proceed to step 4.

Step 4. Transfer the test item to the lower temperature environment (f) in no more than one minute and stabilize as required in the test plan (f-h). If other cycles are required, proceed to step 6.

Step 5. If no other cycles are required, return the test item to standard ambient conditions, and proceed to step 7.

NOTE: *Unless the requirements documents indicate otherwise, if the test procedure is interrupted because of work schedules, etc., maintaining the test item at the test temperature for the period of the interruption will facilitate resumption of the test. If the temperature is changed, before continuing the test restabilize the test item at the temperature of the last successfully completed period before the interruption.*

Step 6 Repeat steps 2, 3 and 4 as specified in the test plan.

Step 7. Examine the test item and, if appropriate, operate. Record the results for comparison with pretest data.

5. EVALUATION of the TEST RESULTS

See General Guidance and Requirements, paragraph 13.

6. REFERENCES and RELATED DOCUMENTS

See General Guidance and Requirements, Paragraph 14.

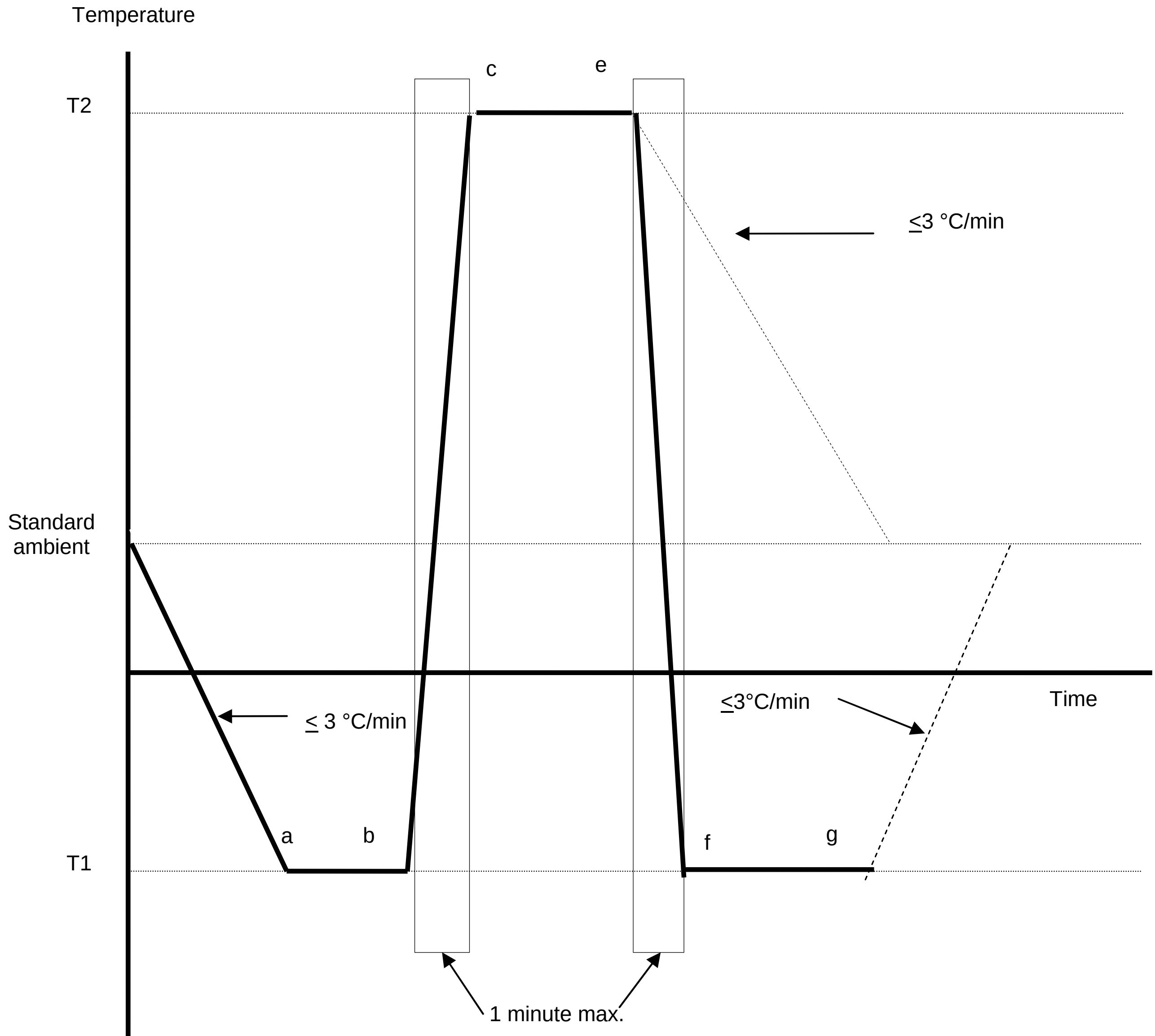

Figure 1. Shocks From Constant Extreme Temperature (Procedure I).

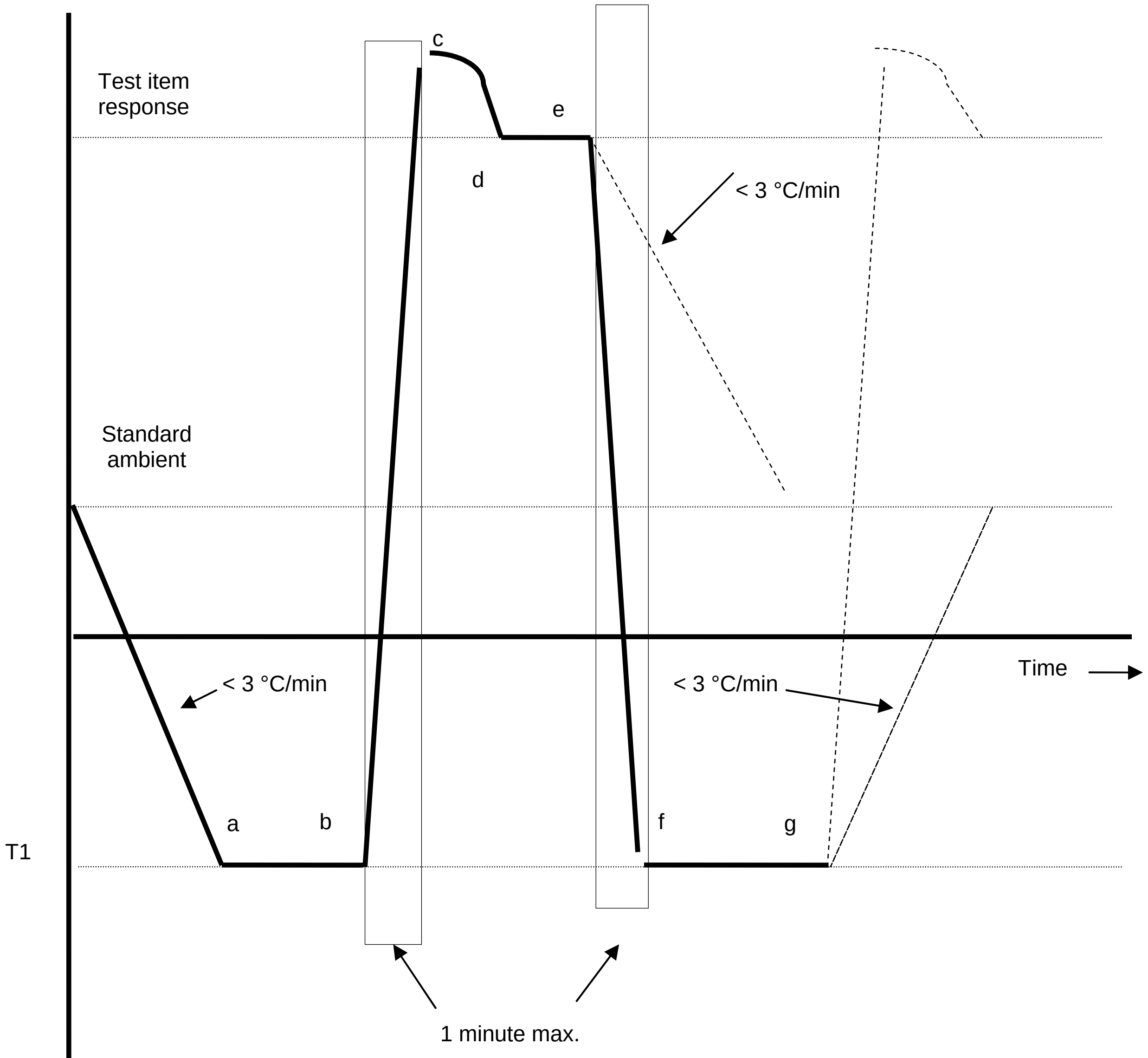

Figure 2. Shocks From Cyclic High Temperature (Procedure II)

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METHOD 305

SOLAR RADIATION

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ANNEX A

DETAILED GUIDANCE ON SOLAR RADIATION TESTING

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METHOD 305

SOLAR RADIATION

NOTE: *METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD.*

1. SCOPE

1.1. Purpose

The main objective of this solar radiation test is to determine the actinic (photodegradation) and heating effects of solar radiation on materiel when it is exposed to sunshine during operation or during unsheltered storage at ground level.

1.2. Application

This Method is applicable to materiel likely to be directly exposed to solar radiation. This Method is for use when close simulation of the spectral distribution of radiation is required such as for assessment of materiel degradation or a combination of degradation and/or thermal response. In certain cases where, for example, paint finishes with unusual characteristics have been applied, it may be necessary to use this Method to establish realistic response temperature cycles on a single item for application in high temperature tests of multiple copies. Once the temperatures have been measured, heating effects of solar radiation may be determined through the High Temperature test (Method 302). Further guidance on high temperature application is provided in Method 301, General Guidance and Requirements, paragraph 3.3. Because of lamp deterioration, this test is more expensive to perform than a high temperature test but may be necessary for determining the initial thermal response characteristics.

1.3. Limitations

This Method does not represent the heating that occurs in enclosed area storage. This test method does not consider all of the effects related to the natural environment (see Annex A, paragraph 7.2) and, therefore, it is preferable to test materiel at appropriate natural sites. This Method shall be used when the spectrum of the lamp bank has been measured and conforms to the spectrum identified in Table 1. Deviations from Table 1 may be justified if the test requirements are based on the tailoring process, or if a specific frequency band is of concern. Any deviation shall be detailed and justified.

NOTE: *This is a very specialized, potentially hazardous set of tests (see Annex A, paragraph 8). Experts in this area shall be consulted to define the test specifications. In particular the spectral distribution of light sources needs to be carefully considered with respect to spectral differences between different sources and their impact on specific materiel*

2. TEST GUIDANCE

See General Guidance and Requirements, paragraphs 1 and 2.

2.1. Effects of the Environment

Solar radiation has two significant types of effects on materiel: actinic and thermal.

2.1.1 Actinic Effects

Certain portions of the solar spectrum are known to cause degradation of materials. The full spectrum must be used to simulate adequately these actinic effects of solar radiation. Some examples of deterioration caused by actinic effects are:

a. Deterioration of natural and synthetic elastomers and polymers through photochemical reactions initiated by shorter wavelength radiation. High strength polymers such as Kevlar are noticeably affected by the visible spectrum.

b. Fading of fabric color.

c. Checking, chalking and fading of paints.

2.1.2. Heating Effects

The heating effects of solar radiation differ from those of high air temperature alone in that the amount of heat absorbed or reflected depends on the roughness and color of the surface on which the radiation is incident. In addition to the differential expansion between dissimilar materials, changes in the intensity of solar radiation may cause components to expand or contract at different rates, that can lead to severe stresses and loss of structural integrity. Other examples of heating effects include but are not limited to:

a. Jamming or loosening of moving parts.

b. Weakening of solder joints and glued parts.

c. Change in strength and elasticity.

d. Loss of calibration or malfunction of linkage devices.

e. Loss of seal integrity.

f. Changes in electrical or electronic components.

g. Premature actuation of electrical contacts.

h. Fading of component color codes.

i. Change in the properties of elastomers and polymers.

j. Blistering and scaling of paints and other finishes.

k. Softening of plastic materials.

l. Pressure variations.

m. Sweating of composite materials and explosives.

n. Difficulty in handling.

Table 1 - Test Spectral Distribution.

	SPECTRAL REGION				
CHARACTERISTICS	**ULTRAVIOLET**		**VISIBLE**	**VISIBLE/IR***	**INFRARED**
Bandwidth	0,28 µm to 0,32 µm	0,32 µm to 0,40 µm	0,40 µm to 0,64 µm	0,64 µm to 0,78 µm	0,78 µm to 3,00 µm
Irradiance	5 W/m^2	63 W/m^2	386 W/m^2	174 W/m^2	492 W/m^2
Tolerance	± 35%	± 25%	± 10%	± 10%	± 20 %

* Note: This bandwidth may apply to either the visible or the Infrared spectrum.

2.2. Choice of Test Procedure

(See General Guidance and Requirements, paragraphs 1 and 2.) Two test procedures are proposed: cycling and steady state. Either procedure may be used to determine actinic effects but procedure II reduces the test duration.

2.2.1 Procedure I - Cycling (Thermal Effects)

This procedure is primarily used to determine realistic response temperature cycles when the materiel is expected to withstand the heat of exposure in the open in hot climates and still be able to perform without degradation due to thermal effects both during and after exposure. Limited evaluation of actinic effects is possible. The solar radiation test (as opposed to the high temperature test) should be used when the materiel could be affected by differential heating or when the heating caused by solar radiation is unknown. After the induced temperatures have been determined, the high temperature test (with or without directional heating) could (for economic reasons) be substituted for this solar radiation procedure provided that actinic or thermal gradient effects are not important.

2.2.2 Procedure II - Steady State (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. When using this procedure, it is important that the temperature of the test item is representative that which it would experience under natural conditions (as simulated by the cyclic test of Procedure I). If necessary, a preliminary test should be carried out in accordance with Procedure I to determine the maximum response temperature of the materiel. The 4-hour “lights-off” period of each 24-hour cycle allows for test item conditions (chemical and physical) to return toward “normal” and provide some degree off thermal stress excercising.(see Annex A, ref 25, p 84 for a more detailed explanation).

2.3. Choice of Test Parameters

2.3.1 Temperature Levels

After having selected the most suitable test type for the desired objective, the maximum test temperature is defined. Three values are proposed for each type of test. They correspond to the maximum meteorological temperatures in the three climatic categories (A1, A2 and A3) of AECTP 200, Leaflet 2311. Figure 1 shows the daily cycle temperature and radiation variations corresponding to these three categories for Procedure 1. The maximum air temperature for the chamber shall be chosen according to the planned climatic categories of use of the materiel:

a. + 49°C when the materiel must be used and must operate correctly anywhere in the world.

b. + 44°C when the materiel is expected to be used in only categories A2 and A3 as defined by AECTP 200, Leaflet 2311.

c. + 39°C when the materiel is only to be used in the A3 category as defined by AECTP 200, Leaflet 2311.

Figure 2 shows the corresponding temperature and radiation levels for Procedure II.

2.3.2 Test Duration

The test durations are expressed in numbers of 24 hour cycles in both types of tests.

2.3.2.1 Procedure I (Fig. 1)

A minimum of 3 cycles of Fig. 1 is recommended. The variation in solar energy may be applied continuously or incrementally, with a minimum of 4 levels (preferably 8 levels) for each side of the cycle, provided that the total energy of the cycle is maintained. This number of cycles will usually produce a maximum response temperature in materiel. However, the test should be continued until the maximum temperature reached by the test item during one cycle and the subsequent cycle differs by less than 2^{o}C. If this procedure is used for evaluating actinic effects, each cycle represents one day of exposure to full sun, in mid-summer, in the appropriate climatic category. In the cooler, cloudier parts of each category, ten cycles might, for example, represent up to one summer of natural exposure. If more exact simulation is required, meteorological data for the particular areas under consideration should be consulted. This may include adjustment of solar energy, if appropriate, to account for latitude, altitude, month of anticipated exposure, or other factors (for example, a product exclusively used in northern areas, or exclusively used in winter months). Any deviation from the standard conditions must be detailed and justified.

2.3.2.2. Procedure II (Fig. 2)

It is normally recommended to use 10 cycles of Fig. 2 for materiel occasionally used outside (such as portable equipment). For materiel used permanently outside, use a test of 56 cycles or more. 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, as in the steady-state test, is approximately equal to 24 hours of the cycling test (20 hours of light and 4 hours of no light per cycle).

2.3.3. Test Item Orientation

The orientation of the test item relative to the direction of radiation will have a significant impact on the heating effects. In cases where several test item components are known to be sensitive to solar effects, the relative test item-solar source orientation may have to be adjusted to simulate a diurnal cycle. The direction of the radiation will also be dependent on the latitude of the expected location of the materiel.

2.3.4. Substrate

The test item should be mounted either on raised supports or on a substrate of specified properties, e.g., a layer of concrete of specified thickness or a sand bed of a conductivity and reflectivity representative of actual deployment, as provided in the requirements documents.

2.3.5. Solar Irradiance

Increasing the irradiance above the specified level is not recommended because of the danger of overheating and excessive degradation, 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. See Annex A, paragraphs 2.1 and 2.2.

2.4 Spectral Distribution - Sea Level v High Ground Elevations

At high ground elevations solar radiation contains a greater proportion of damaging UV radiation than at sea level. Although the internationally agreed spectrum shown in Table 1 is recommended for general testing, it is a closer representation of the real environment at 4-5 km above sea level. This standard spectrum may be used (unless other data are available) for both sea level and high ground elevation. If testing for sea level conditions using the data in Table 1, degradation during the test may be expected to proceed at a faster rate than if using the appropriate spectrum for sea level, and thus laboratory test exposure can be modified if there is adequate knowlege of the ground level spectrum.

3. INFORMATION TO BE PROVIDED IN THE TEST INSTRUCTION

In addition to General Guidance and Requirements, paragraphs 5 and 6, the following information is required:

a Orientation of the test item with respect to the solar source.

b. Position of the temperature sensors on/in the test item.

c. Test Item Temperature

d. Substrate characteristics.

4. TEST CONDITIONS AND PROCEDURES

4.1. Test Facility

(See General Guidance and Requirements paragraph 8.) The radiation sources consist of lamps reproducing the solar spectrum with irradiances and tolerances as indicated in Table 1 or as indicated in the test plan. Traditional sources are described in Annex A although the spectrum produced can only comply with the spectrum specified in table 1 by the use of filters. This list is not intended to exclude new lamps made available by advanced technology.

4.2. Controls

See General Guidance and Requirements, paragraph 10 and consider the following:

4.2.1. Temperature measurement

In order to adequately identify the temperature of the air surrounding the test item, it should be measured as close as possible to the test item making adequate provision for shielding from the effects of radiant heat, both from the lamps and from the test item. (see annex A, paragraph 5.3 for more explanations).

4.2.2. Measurement Of Solar Radiation

4.2.2.1. Instrumentation

Measurement of the total radiated energy can be made using a pyranometer or a pyrheliometer. The spectral distribution of the radiation may be measured approximately by using filters together with a pyranometer. Precise measurement of the radiation spectrum requires the use of a spectroradiometer that is more delicate to employ. (More details on the use of these instruments are given in Annex A, paragraphs 5.1 and 5.2.) Any other measuring instrument satisfying the required specifications may be used.

4.2.2.2. Measurement Accuracy

The required measurement accuracy of these different instruments is given in table 2.

4.2.2.3. Energy Distribution

Periodic inspection of the radiation produced by the test facility is imperative since the characteristics of radiation sources are numerous and change with time. Thorough checking of the spectral distribution, the intensity and uniformity shall be conducted as frequently as possible but at not more than 500-hour intervals. A check of the overall intensity and uniformity (that is much easier) shall be conducted before and after every test.

Table 2 - Instrument accuracy.

MEASUREMENT INSTRUMENT	PARAMETER MEASURED	ACCURACY
Pyranometer/Pyrheliometer	Total radiation (Direct & diffuse)	± 47 W/m^2
Spectroradiometer/Pyranometer & filters	Spectral distribution	± 5% of the reading

4.2.2.4. Long Wave Radiation

The value of 1120 W/m^2 measured between 0.28 μm and 3 μm shall include any radiation reflected from the test chamber walls and received by the equipment under test, but it should not include long-wave IR radiation greater than 3 μm.

4.2.2.5. Direction of Radiation

Where it could have a significant effect on the final heat balance, the equipment/radiation source shall be progressively adjusted to simulate the angular movement of the sun (i.e., 180^o in 12 hours). It should be noted that intensity measurements in AECTP 200, Leaflet 2311 refer to a flat horizontal surface, and this should be taken into account when the sun's angular movement is being simulated.

4.2.3. Surface Contamination

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

4.2.4. Air Velocity

The air velocity inside the enclosure must be between 0.25 m/s and 1.5 m/s to avoid unrealistic test item temperature reduction but still maintain the required air temperatures Test chambers providing cooling air may be used to prevent unrepresentative temperatures from being produced, but the guidance in paragraph 3 of Annex A should be strictly observed.

4.3. Test Interruptions

See General Guidance and Requirements, paragraph 11 and consider the following:

4.3.1. Undertest Interruptions

a. Procedure I (Cycling).

  (i) If an interruption occurs before 19 hours of the last cycle of procedure 1, the test item shall be restabilised at the conditions existing immediately before the point of interruption. Only when these conditions are met should the test timing be restarted.

  (ii) If an interruption occurs after 19 hours of the last cycle of procedure I, the test shall be considered complete. (At least 92% 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. Procedure II (Steady state). The test rationale is based on the total cumulative effect of the solar environment. Any undertest interruption should be followed by restabilization at the specified conditions and continuation of the test from the point of the interruption.

4.4. Procedures

See General Guidance and Requirements, paragraph 7.

4.4.1. Preparation for Test

Before starting any of the test procedures, determine the information specified in General Guidance and Requirements, paragraphs 5 and 6.1, and perform the test preparation procedure specified in General Guidance and Requirements, paragraph 12. For eventual comparison between pre- and post-test items, photographs of the test item and material samples should be taken.

4.4.2. Procedure I - Cycling. (Figure 1)

Step 1. Bring the air temperature in the enclosure to the minimum value of the temperature cycle at which radiation is non-existent. Measure the test item temperature.

Step 2. If necessary, create the initial relative humidity conditions specified by the test program.

Step 3. Conduct the required number of cycles during which temperature and solar radiation levels are changed in accordance with the schedule followed.

Step 4. Perform the operational checks on the test item at the times called for in the test program.

Step 5. At the end of the last cycle, allow the chamber to return to standard ambient conditions.

Step 6. Allow the test item to return to thermal equilibrium.

Step 7. Visually examine the test item to the extent practicable.

4.4.3. Procedure II - Steady State. (Figure 2)

Step 1. Bring the temperature in the enclosure up to the value specified in the test program. Measure the test item temperature.

Step 2. Adjust the solar radiation value to the value specified in the test program.

Step 3. Maintain these conditions for 20 hours.

Step 4. Stop the radiation for 4 hours while maintaining the temperature in the enclosure at the specified level.

Step 5. Repeat Step 2 to Step 4 for the number of cycles specified in the test program.

Step 6. If applicable, perform operational tests on the test item at the times called for in the test program.

Step 7. At the end of the last radiation period, allow the test item to return to standard ambient conditions.

Step 8. Conduct a thorough visual inspection and operational check, and document the results for comparison with pretest data.

5. EVALUATION OF THE TEST RESULTS

See General Guidance and Requirements, paragraph 13.

6. REFERENCES AND RELATED DOCUMENTS

See General Guidance and Requirements paragraph 14.

VALUES ARE FROM AECTP 200, Category 230 - Temperatures of categories A1, A2 and A3 in °C, solar radiation in W/m²

Time (h)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
A1	35	34	34	33	33	32	33	35	38	41	43	44	47	48	48	49	48	48	46	42	41	39	38	37
A2	33	32	32	31	30	30	31	34	37	39	41	42	43	44	44	44	43	42	40	38	36	35	34	33
A3	30	29	29	28	28	28	29	30	31	34	36	37	38	38	39	39	38	37	35	34	34	32	32	31
W	0	0	0	0	0	55	270	505	730	915	1040	1120	1120	1040	915	730	505	270	55	0	0	0	0	0

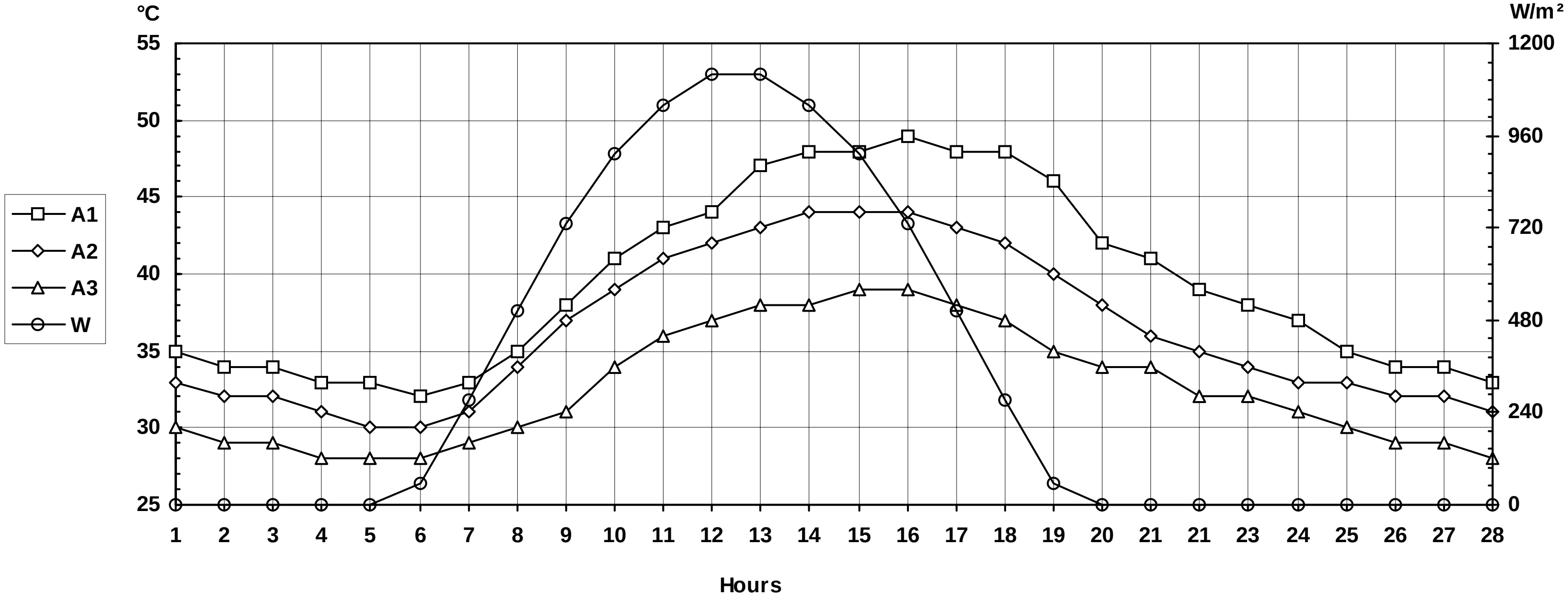

Fig 1. Procedure 1: cycling test
Temperatures in °C, solar radiation in W/m²

Time (h)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
A1	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49	49
A2	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
A3	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39
W	0	0	1120																			0	0	0

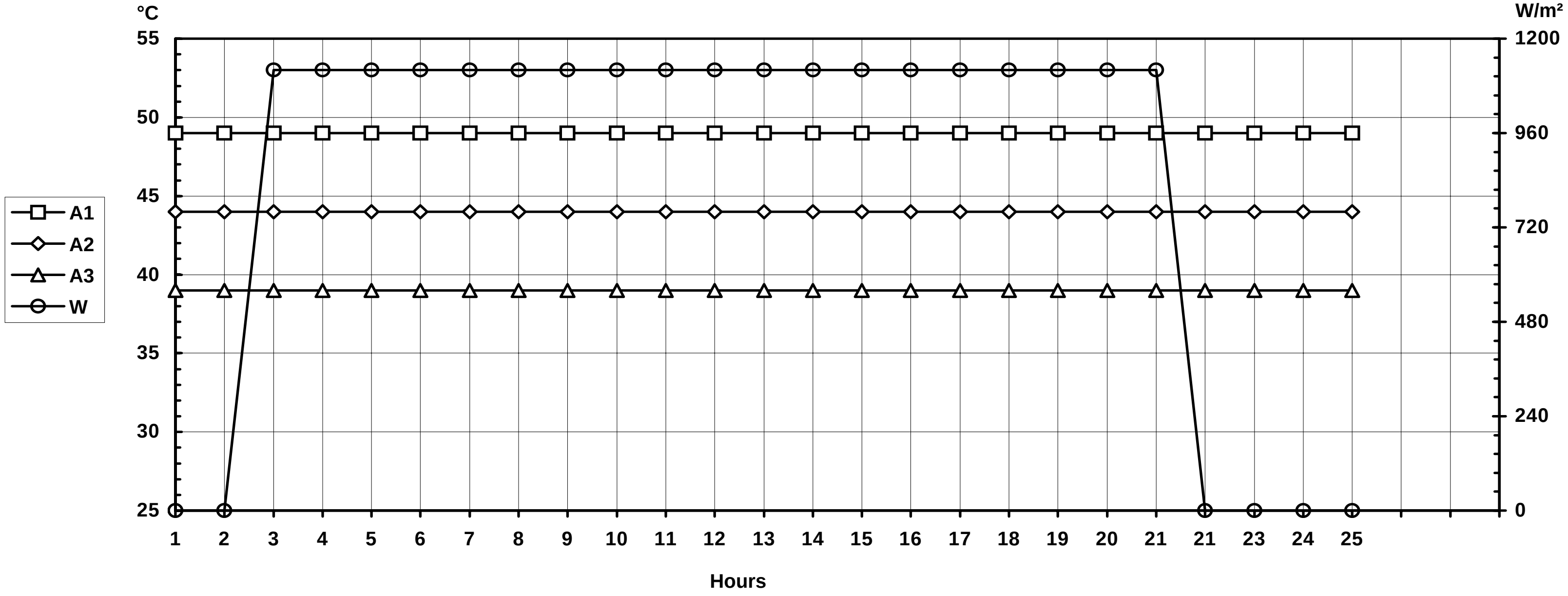

Fig. 2 Procedure 2: steady state test

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ANNEX A

DETAILED GUIDANCE ON SOLAR RADIATION TESTING

1. INTRODUCTION

This Annex describes methods of simulation designed to examine the effects of solar radiation on equipment. The main quantities to be simulated are the spectral energy distribution of the sun as observed at the Earth's surface and the intensity of received energy, in combination with controlled temperature conditions. However, it may be necessary to consider a combination of solar radiation - including sky radiation - with other environments, e.g., humidity, air velocity, etc.

2. IRRADIANCE AND SPECTRAL DISTRIBUTION

The effect of radiation on the materiel will depend mainly on the level of irradiance and its spectral distribution.

2.1. Irradiance

The irradiance by the sun on a plane perpendicular to the incident radiation outside the Earth's atmosphere at the mean Earth-sun distance is known as the solar constant 'I_0' (Ref 12). The irradiance at the surface of the Earth is influenced by the solar constant and the attenuation and scattering of radiation in the atmosphere. For test purposes, a maximum intensity of 1120 W/m^2 is specified to simulate the global (total) radiation at the surface of the Earth from the sun and the sky with the sun at zenith, based on a solar constant I_0 = 1350 W/m^2 (Ref 22). The true solar constant is thought to be about 1365-1370 W/m^2.

2.2. Spectral Distribution - Sea Level Versus High Altitude

At high altitude, solar radiation contains a greater proportion of damaging UV radiation than at sea level. The internationally agreed spectrum (see Table 1) recommended for general testing is a closer representation of the real environment at 4-5 km. This standard spectrum is recommended for use at both sea level and at high altitude.

3. OTHER ENVIRONMENTAL FACTORS TO BE CONSIDERED

Attention is drawn to the possible cooling effects of airflow over materiel. This can also result in misleading errors in open-type thermopiles used to monitor radiation intensity; ventilation of pyranometers may be necessary to keep the glass dome cool. An airflow of as little as one meter per second can effect a reduction in temperature rise of over 20%. In practice, high solar radiation conditions are rarely accompanied by complete absence of wind. It may be necessary, therefore, to assess the effect of different air velocities over materiel under test. The materiel specification should state any special requirements in this respect. It is essential, therefore, to measure and control the rate of airflow in order to maintain the required air temperature at the test item.

4. RADIATION SOURCES

4.1. General

The radiation source may comprise one or more lamps and their associated optical components, e.g., reflectors, filters, etc., to provide the required spectral distribution and irradiance. The high-pressure xenon arc lamp with filters can provide a good spectral match (Ref 1). Mercury vapor and xenon-mercury lamps have considerable deficiencies in matching that would lead to error (Refs 2, 5 and 6). If not already covered in test method characteristics of these sources, features of filters, optical arrangements, etc., are covered in the following paragraphs. Further information can also be found in Reference 2.

4.2. Tungsten filament lamps

Because of their deficiency of ultraviolet radiation, tungsten lamps are unsuitable for tests for degradation purposes. Serious discrepancies can also occur in results obtained in tests for thermal effects, unless the considerable difference in spectral energy distribution compared with natural solar radiation is taken into account. The major part of the radiant energy from the tungsten lamp is in the infrared range, with maximum intensity at about 1.0 μm, whereas approximately 5O% of solar energy is in the visible and ultraviolet bands, i.e., at wavelengths less than 0.7 μm. The quartz halogen-type of tungsten lamp has an improved consistency of performance during its life (Ref 4).

4.3 Xenon lamps

The configuration and size of the lamp(s) used will depend on the test required. The relative spectral distribution of the xenon arc radiation has been found to be substantially independent of lamp power (Annex A, reference 3). However, variation of lamp power will change the temperature of the electrodes and hence the spectral distribution of the electrode radiation. With long arc lamps, it is relatively simple to mask off the electrode radiation. The form of construction of the short arc lamp leads to considerably wider manufacturing variation compared with the long arc, a point particularly important when replacement becomes necessary. Routine replacement of either type of lamp will be needed, since the emission will change continuously with life, and there may be wide variations of the life characteristic from lamp to lamp.

4.4 Metal halide (HMI) lamps

Although this lamp imparts more energy in the ultraviolet range and low visible range than specified in table 1, it provides a good source for tests requiring attention to thermal effects, since the additional UV energy represents less than one per cent of the total energy, and tests for heating effects are generally sufficiently short in duration that actinic degradation will not be a concern. For testing actinic effects, the energy level in the heating range will be lower than specified, as the UV levels will be adjusted to table 1 levels. Since the energy level between 0.32 and 0.40 μm increases sharply as the lamp power level is reduced, power cannot be used to adjust overall energy levels once the desired distribution has been obtained.

4.5. Filters

Liquid filters have certain disadvantages such as the possibility of boiling, the temperature coefficient of spectral transmission, and long term drift in spectral character (Ref 7). The present preference is for glass filters to be used, although the characteristics of glass filters are not as accurately reproduced as those of a chemical solution filter. Some trial and error may be necessary to compensate for different optical densities by using different plate thicknesses (Ref 8). Glass filters are proprietary articles and manufacturers should be consulted concerning the choice of filters suitable for particular purposes. The choice will depend on the source and its methods of use. For example, a xenon source may be test-compensated by a combination of infrared and ultraviolet absorbing filters (Ref 8). Some glass infrared filters may be prone to rapid changes in spectral characteristics when exposed to excessive ultraviolet radiation. This deterioration may be largely prevented by interposing the ultraviolet filter between the source and the infrared filter. Interference type filters, that function by reflecting instead of absorbing the unwanted radiation, (thus resulting in reduced heating of the glass), are generally more stable than absorption filters.

4.6. Uniformity of Irradiance

Owing to the distance of the sun from the Earth, solar radiation appears at the Earth's surface as an essentially parallel beam. Artificial sources are relatively close to the working surface and means of directing and focusing the beam must be provided with the aim of achieving a uniform irradiance at the measurement plane within specification limits (i.e., 1120 W/m^2 (+10, -0 W/m^2)). This is difficult to achieve with a short-arc xenon lamp with a parabolic reflector because of shadows from the lamp electrodes and supports. Also, the incandescence of the anode can produce considerable radiation at a much lower color temperature, slightly displaced from the main beam, if only the arc itself is at the focus of the reflector. Uniform irradiation is more readily achieved with a long arc lamp mounted in a parabolic 'trough' type reflector. However, by employing very elaborate mounting techniques, it is possible to irradiate, with some degree of uniformity, a large surface by a number of short arc xenon lamps (Ref 9). It is generally advisable to locate radiation source(s) outside the test enclosure or chamber. This avoids possible degradation of the optical components, e.g., by high humidity conditions, and contamination of test items by ozone that has been generated by xenon and other types of arc lamps. Precise collimation of the radiation beam is not normally required except for testing special materiel such as solar cells, solar tracking devices, etc. However, some of the simulation techniques developed for space research purposes could be adapted for Earth-surface solar radiation studies (Ref 10).

5. INSTRUMENTATION

5.1. Measurement of Irradiance

The type of instrument considered most suitable for monitoring the irradiance is a pyranometer as used for measuring global (combined solar and sky) radiation on a horizontal plane. Two types are suitable for measuring radiation from a simulated solar source. Each depends for its operation on thermojunctions.

5.1.1. Moll-Gorczinski Pyranometer

The Moll-Gorczinski pyranometer consists of 14 constantan-manganin strips (10 x 1 x 0.005 mm) arranged so that their 'hot' junctions lie on a plane and are formed into a horizontal surface by means of a black varnish of low thermal conductivity. The 'cold' junction ends are bent down to make good thermal connections with a copper plate of large thermal capacity. The sensitive area is surmounted by two concentric glass hemispheres.

5.1.2. Eppley Precision Spectral Pyranometer

The sensor is a circular 50-junction wire wound plated (copper-constantan) thermopile, enclosed in concentric, clear-glass hemispheres, 30 mm and 50 mm diameter. The outer hemisphere is interchangeable with another, either of glass absorbing in particular wavelength bands, or with a deposited interference type filter, allowing the separation of radiation into well-defined wavelength intervals (see Ref 25).

5.1.3 Neither of these instruments is significantly affected by long-wave IR radiation emitted by the specimen or the test enclosure. A modification of the Moll-Gorczinski pyranometer, commonly known as the Kipp solarimeter, is the instrument used by meteorological services in many countries. The Eppley pyranometer is the one most widely used in the United States. The glass covers used in both these instruments will cut off radiation at wavelengths greater than about 3 μm; this is significant when unfiltered lamps are used and a correction factor would then be necessary. A useful survey of calibration techniques for solar pyranometers is given in Reference 11, (see also Ref 26). Further information will also be found in References 12 and 13.

5.2. Measurement of Spectral Distribution

Total intensity checks are readily made, but detailed checks on spectral characteristics are more difficult. Major spectral changes can be checked by inexpensive routine measurements, using a pyranometer in conjunction with selective filters (Ref 14). For checking the detailed spectral distribution characteristics of the facility, it would be necessary to employ sophisticated spectroradiometric instrumentation. However, there seems to be no practical instrumentation obstacle to prevent this calibration being done either as a service by the facility manufacturer or by a visit from a national calibration center. Correlation should be achieved between the filter/pyranometer and spectroradiometric methods at regular intervals (Ref 15 and 21). Changes in the spectral characteristics of lamps, reflectors and filters may occur over a period of time that could result in the spectral distribution being seriously outside the permitted tolerances. Manufacturing tolerances may mean that lamp replacement could result in unacceptable changes in both the level of irradiation and spectral distribution compared with that initially set up. Regular monitoring is therefore essential, but monitoring of the detailed spectral distribution within the test facility may not be possible while equipment is undergoing test. A method of measuring the intensity of radiation below 320 nm based on the exposure of polysulphone film and that would permit the monitoring of this wavelength range within the test facility is now established (Ref 23). (The technique is currently being considered as an ISO test method.)

5.3. Measurement of Temperature

Because of the high level of radiation, it is essential that temperature sensors are adequately shielded from radiant heating effects. This applies both to measuring air temperatures within the test enclosure and also to monitoring test item temperatures. For air temperature measurements, it is obviously impracticable to use the standard 'Stevenson' screen used for meteorological measurements of 'shade temperatures' since this is too cumbersome. A suitable alternative is a thermocouple freely mounted in a radiation shield comprising a vertical cupro-nickel tube (approximately 1.5 cm dia. by 7 cm long), surmounted by a spaced metal hood, polished on the inside surface and painted white on the outside. When monitoring test item temperatures, sensors, e.g., thermocouples, should be located on the inside surfaces of the external case and not be attached to the outside surfaces. Temperature-indicating paints and waxes are unsuitable for monitoring the temperature of irradiated surfaces, as their absorption characteristics will not be the same.

6. PREPARATION OF TEST FACILITY AND MATERIEL UNDER TEST

6.1 Test Facility

It must be ensured that the optical parts of the facility, lamps, reflectors, and filters, etc. are clean. The level of irradiation over the specified measurement plane must be measured immediately prior to each test. Any ancillary environmental conditions, e.g., ambient temperature, as well as air velocity and other parameters if specified, should be monitored continuously throughout the test.

6.2. Materiel Under Test

The method of mounting and the orientation of the test item relative to the direction of radiation will have marked influences on the heating effects. The test item will probably be required to be mounted either on raised supports or on a substrate of specified properties, e.g., a layer of concrete of specified thickness or a sand-bed of certain conductivity. All this and the attitude of the test item should be specified in the relevant specification. Special attention must be paid to the surface conditions of the test item to see that its finish is clean or in accordance with the relevant requirements. The heating effect on the test item will be largely affected by the condition of its external surfaces. Care must therefore be exercised in handling the test item, especially in avoiding oil films and in ensuring that the surface finish and its underlay are fully representative of production standards. Temperature sensors should be attached to the test item as required (but see also paragraph 5.3).

7. INTERPRETATION OF RESULTS

The test item specification should indicate the permitted changes in the external conditions and/or performance of the item under test after exposure to the required level of irradiation for certain durations. In addition to such mandatory requirements, the following aspects of interpretation may be considered:

7.1. Comparison with Field Experience

The effects of exposing material to solar radiation are well documented (Ref 16, 17) (see also paragraphs 7.2 and 7.3). Any marked differences between the expected effects and the behavior under test conditions should be investigated and the basic cause established, i.e., whether caused by the test equipment or procedure, or by some peculiarity in the test item.

7.2. Thermal Effects

The maximum surface and internal temperatures attained by materiel will depend on:

a. the temperature of the ambient air.

b. the intensity of radiation.

c. the air velocity.

d. the duration of exposure.

e the thermal properties of the materiel itself, e.g., surface reflectance, size and shape, thermal conductance, and specific heat.

Materiel can attain temperatures in excess of 60°C if fully exposed to solar radiation in an ambient temperature as low as 35 - 40°C. The surface reflectance of an object affects its temperature rise from solar heating to a major extent; changing the finish from a dark color, for example, to a gloss white will effect a considerable reduction in temperature. Conversely, a pristine finish designed to reduce temperature can be expected to deteriorate in time resulting in an increase in temperature (Ref 18). Most materials are selective reflectors, i.e., their spectral reflectance changes with wavelength. For instance, paints, in general, are poor infrared reflectors although they may be very efficient in the visible region. Furthermore, the spectral reflectance of many materials changes sharply in the visible (producing a color sensation to the human eye) and in the near infrared. It is important, therefore, that the spectral energy distribution of the radiation source(s) used in any simulated test should closely duplicate that of natural radiation.

7.3. Degradation of Materials

The combined effects of solar radiation, atmospheric gases, temperature, humidity changes, etc., are often collectively termed 'weathering,' and result in the 'ageing' and ultimate destruction of most organic materials (e.g., plastics, rubbers, paints, timber, etc.). Many materials that give satisfactory service in temperate regions have been found to be completely unsuitable for use under the more adverse conditions of the tropics. Typical effects are the rapid deterioration and breakdown of paints, the cracking and disintegration of cable sheathing, and the fading of pigments. The breakdown of a material under weathering usually results not from a single reaction, but from several individual reactions of different types occurring simultaneously, often with interacting effects (Ref 19 and 24). Although solar radiation, principally the ultraviolet, resulting in photo-degradation is often the major factor, its effects can seldom be separated in practice from those of other weathering factors. An example is the effect of ultraviolet radiation on polyvinyl chloride, where the apparent effects of ultraviolet radiation alone are small, but its susceptibility to thermal breakdown, in which oxygen probably plays a major role, is markedly increased. Unfortunately, artificial tests occasionally produce abnormal defects that do not occur under weathering. This can be often attributed to one or more of the following causes:

a. Many laboratory sources of ultraviolet radiation differ considerably from natural solar radiation in spectral energy distribution. In some cases (e.g. fluorescent lamps) the infrared energy of the source is significantly less than that of true solar radiation, resulting in a surface temperature during the test that is much lower than it would be in outdoor conditions.

b. When the intensity of ultraviolet, temperature, humidity, etc. are increased to obtain accelerated effects, the rate of the individual reactions (that occur under normal exposure conditions), are not necessarily increased to the same extent.

c. The artificial tests, in general, do not simulate all the natural weathering factors.

8. HAZARDS AND PERSONNEL SAFETY

8.1. General

The complex equipment employed for solar radiation testing purposes will necessarily call for operation and maintenance by a skilled test staff, not only to ensure the prescribed performance of the test, but also because of the various health and safety hazards that have to be considered.

8.2. Ultraviolet Radiation

The most obvious dangers that have to be guarded against are those associated with the harmful effects of high intensity radiation in the near ultraviolet region. In natural sunlight, the eyes are protected in two ways; the brightness of the sun makes it almost impossible to look directly at it, and the ultraviolet radiation is considerably attenuated by the atmosphere. These protections may not apply to artificial sources. The eyes must be protected by filtered goggles or viewing apertures, particularly when setting up the equipment (due to the point source and high UV component of these sources, sunglasses may increase the danger). All testing personnel should be warned that severe eye damage can result from only short exposure to unfiltered radiation from arc-type lamps. Serious erythema (sunburn) of exposed skin will also occur. Koller (Ref 4) states the ultraviolet radiation of sunlight is a major causal factor in cancer of the skin in the white population of the USA (see also Ref 27). The use of suitable protective clothing including protection of the head and hands is therefore highly recommended, even when working in test enclosures irradiated by filtered sources.

8.3. Ozone and Harmful Fumes

Another serious health hazard arising from the use of xenon and other arc lamps is the possible buildup of local toxic concentrations of ozone during the testing period. However, the maximum production of ozone occurs at the initial switching on of the lamp, and thereafter the hot envelope of the lamp tends to degrade the ozone back to oxygen. Where forced-air cooling is employed, this cooling air should be sucked out and removed from the building and not blown into the lamp housing. In this way, the ozone hazard can be largely eliminated. Suitable detecting and measuring equipment is commercially available (Ref 2O). The combined effects of heat and ultraviolet radiation on certain plastics (e.g., melamine laminates) may also produce toxic fumes. Particular care should therefore be taken in the choice of materials used in the construction of a test facility.

8.4. Risk of Lamp Explosions

The use of high-pressure xenon discharge lamps as the primary radiation source can also result in serious accidents unless a well-planned code of practice for the handling of these arc discharge tubes has been specified and is adhered to. All such lamps (whether hot or cold, used or new) have a liability to explode violently by reason of the considerable internal pressure (two to three atmospheres when cold, but up to twenty atmospheres when hot). There should be no visible dirt or oil on the envelope, so regular cleaning with detergent and alcohol is necessary using cotton gloves and face protection during such cleaning. When cold lamps are to be stored, the effects of explosion may be limited by two layers of 0.25 mm thick polycarbonate sheet. Particular care must be taken to limit the spread of chain reaction breakdowns in multi-lamp equipments. It is possible to use armor plate glass for the dual purpose of protection against lamp explosions and as a corrective filter. Individual lamp records should be kept as a matter of routine so as to be able to detect abnormal voltage/current behavior.

8.5. Electric Shock

Normal electric shock preventive measures must, of course, be adopted, particularly in the case of the high voltage igniter systems used with arc lamps. In some xenon lamps, the arc ignition pulse exceeds 60 kV, and an interlock system is therefore essential.

TABLE 1. Detailed spectral distribution of global radiation

SPECTRAL REGION	BANDWIDTH (μm)	IRRADIANCE (W/m^2)	IRRADIANCE (%)
Ultra-violet*	0.28 - 0.36 0.36 - 0.40	32 36	2.9 3.2
Visible	0.40 - 0.44 0.44 - 0.48 0.48 - 0.52	56 73 71	5.0 6.5 6.3
	0.52 - 0.56 0.56 - 0.64	65 121	5.8 10.8
**	0.64 - 0.68 0.68 - 0.72 0.72 - 0.78	55 52 67	4.9 4.6 6.0
Infra-red	.78 - 1.0 1.0 - 1.2 1.2 - 1.4 1.4 - 1.6 1.6 - 1.8 1.8 - 2.0 2.0 - 2.5 2.5 - 3.0	176 108 65 44 29 20 35 15	15.7 9.7 5.8 3.9 2.6 1.8 3.1 1.4
	Totals	1120	100.0

** Note: Radiation shorter than 0.30 μm reaching the Earth's surface is insignificant.*

*** This bandwidth may apply to either the visible or IR spectrum.*

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METHOD 306

HUMID HEAT

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METHOD 306

HIGH HUMIDITY

NOTE: *METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD.*

1. SCOPE

1.1. Purpose

The high humidity tests are used to determine the effects of high humidity and temperature on materiel in storage or use.

1.2. Application

This Method is applicable to materiel likely to be stored or used wherever high levels of relative humidity can exist, or to provide an indication of potential problems associated with humidity. Further information on high temperatures and humidity is provided in AECTP 200, Category 230.

1.3. Limitations

This Method does not consider all of the effects related to the natural environment and, therefore, it is preferable to test materiel at appropriate natural sites. Not all of the "aggravated" test procedures necessarily simulate any naturally-occurring climatic condition, but may have a relationship to high temperature and humidity conditions anticipated in enclosed areas. The relationship of the procedures in this Method to the effects on non-metallic materials has not been evaluated. This document does not address condensation resulting from changes of altitude for airborne equipment. Additionally, it does not include the synergistic effects of high humidity combined with biological and chemical contaminants, nor does it consider situations in which liquid water may be trapped within packages and retained for substantial periods.

2. TEST GUIDANCE

See General Guidance and Requirements, paragraphs 1 and 2.

2.1. Effects of the Environment

Humidity has physical and chemical effects on materiel; the temperature and humidity variations can also trigger condensation inside the materiel. Typical effects of humid heat include:

a Swelling or deterioration of materials due to water absorption.

b. Drop in mechanical strength.

c. Change in thermal and electrical characteristics of insulating materials.

d. Electrical short circuits due to condensation.

e. Seizing of moving parts due to corrosion and contamination of lubricants.

f. Galvanic corrosion of metals.

g. Micro-environments caused by trapped moisture.

h. Loss of elasticity.

i. Acceleration of chemical reactions.

j. Acceleration of biological actions.

k. Deterioration of electrical and electronic components.

Some of these effects can only be observed after a sufficient lapse of time or are simply initiated by humid heat.

2.2. Discussion

All of the procedures in this Method include a degree of compromise as explained below. It may be that a complete understanding of the test item in the service environment may only be possible by exposure to the actual service environment.

2.2.1. Synergism

The naturally-occurring, highly complex environment associated with the tropic and sub-tropic areas of the world and other areas in which combinations of high temperature and relative humidity are found, cannot be duplicated in a laboratory chamber. Bacteria, fungus, chemical contaminants, etc., combine to form an environment that is unique to warm, humid climates. Exaggerated synergistic effects can also exist within closed containers/spaces, and may include contamination from various sources.

2.2.2. Exposure duration

Two test duration approaches are included. The first is to expose the test item to realistic combinations of temperature and humidity for periods of time directly corresponding to the service exposure. While this has the advantage giving some correlation between laboratory and service results, test durations may become prohibitively long. The next alternative is to expose the test item to exaggerated temperature and humidity conditions for a relatively short test duration. This approach using test time compression has the disadvantage of not being able to determine if laboratory test results correspond to actual service exposure.

2.2.3. Test Time Compression

In some situations, equipment will be exposed to highly humid environments, occasionally or periodically rather than constantly. In these situations, a period of laboratory exposure may be equivalent to a greater period of service. Based on the life cycle environmental profile, the degree of time compression should be estimated in order to establish a realistic perspective for the laboratory test results.

2.3. Test Types

(See General Guidance and Requirements, paragraph 1.)
Two types of testing are available for this Method:

2.3.1. Test Type 1 - Cyclic

This test simulates the temperature and humidity variations for the number of 24-hour cycles specified in the test program. It represents the storage and transit cycles of the B2 (wet-hot) and B3 (humid-hot coastal desert) climatic areas detailed in AECTP 200, Leaflet 2311. The cycles proposed for conducting this test are the so-called "induced" conditions when the materiel is used or stored in these regions in places having little or no ventilation (closed light-duty shelter, for example), but are influenced by diurnal variations. Another cycle that is more severe than the induced cycles is also proposed. It is used when it is necessary to detect quickly the potential weak points in the materiel. The cyclic test is more suitable for revealing the effects of condensation and breathing (see Annex A).

2.3.2. Test Type 2 - Steady State

This test simulates the relatively stable temperature and humidity conditions of the natural environment observed in some warm tropical, wooded, and very rainy areas characteristic of the B1 (wet-warm) climatic area detailed in AECTP 200, Category 230. It is also used to simulate the conditions encountered inside certain poorly ventilated enclosed spaces. Steady state testing is more suitable for revealing the effects of absorption and adsorption phenomena (see Annex A).

2.3.3. Choice of Test Type

The choice of the test type and its associated parameters can be made based on the environmental requirements for the materiel, the zone and the expected use circumstances, the safety and criteria for acceptability of the materiel to be tested, and the expected duration of the exposure to humid heat. Test type 1 should be selected if the materiel is exposed to a cyclic thermal environment, and test type 2 when the thermal environment is essentially unchanging.

NOTE: *When making this choice it is important to review all the foreseeable cases of use of the materiel in order to select only the most severe environments/tests.*

2.4. Choice of Test Parameters

See General Guidance and Requirements, paragraphs 1-4.

2.4.1. Temperature-humidity

2.4.1.1. Cycling test

a. For the hot, humid climatic regions of the world, the cycle should be chosen from Table 1 for category B2 (cycle 1) and B3 (cycle 2), that represent diurnal temperature and humidity conditions encountered when the thermal effects of the sun must be considered, when humidity is high, and when ventilation is inadequate.

b The aggravated cycle (cycle 3) is shown in figure 1. This cycle does not attempt to simulate the meteorological cycle. It yields information more quickly on the effects of humid heat on materiel. The temperature and associated humidity levels are generally higher than those encountered in nature, and the duration of exposure to high humidity is longer in each cycle. This cycle helps to identify the parts of the materiel having potential weaknesses.

Table 1. Diurnal cycles for category "B" environmental conditions

Transit and Storage Conditions			
B2 (Cycle 1)		**B3 (Cycle 2)**	
Induced Air Temperature (^{o}C)	**RH (%)**	**Induced Air Temperature (^{o}C)**	**RH (%)**
33	69	35	67
32	70	34	72
32	71	34	75
31	72	34	77
30	74	33	79
31	75	33	80
34	64	36	70
38	54	40	54
42	43	44	42
45	36	51	31
51	29	57	24
57	22	62	17
61	21	66	16
63	20	69	15
63	19	71	14
62	20	69	16
60	21	66	18
57	22	63	21
50	32	58	29
44	43	50	41
38	54	41	53
35	59	39	58
34	63	37	62
33	58	35	63

2.4.1.2. Constant Temperature and Humidity Test

Relatively constant warm or hot highly humid conditions occur both naturally and as a result of inadequate ventilation in enclosed areas where cyclic solar loading is not a factor. For enclosed spaces, measured parameters should be used. For tests when measured data may not be available, the following parameters (from IEC Publication 68, Part 2.1, Test Ca) are recommended: Temperature: 55°C, Relative humidity: 95%. These parameters do not necessarily simulate any real environment, but will create a relatively severe environment that may be used to reveal potential problem areas.

2.4.2. Test Duration

Two methods for the determination of test duration are given. The first (preferred) method (paragraphs 2.4.2a & b) requires knowledge of chemistry together with some expertise in the type of materiel under consideration. The second method (paragraph 2.4.2c) involves an arbitrary choice of test duration from a table for which some guidance is given. It is recommended that the second method be used only if the relevant knowledge and/or expertise are not available, or it is not necessary to assess the life of the materiel.

NOTE: *For materiel that is expected to be used often, frequent test item checks are recommended (especially during long duration tests) for the early identification of problems, so that testing may be stopped without wasted test time. This approach is not recommended for materiel likely to be subjected to long, dormant periods.*

a. Materiel failures normally arise as a result of a chemical reaction or sequence of reactions sometimes associated with mechanical stress. In such a sequence, one chemical step is likely to determine the rate of the overall sequence. Where these criteria apply, the test duration should be derived as follows:

(1) Establish the likely failure modes.

(2) Determine the activation energies for the rate-determining chemical steps in these failure modes. (The activation energy controls the way in which a reaction rate varies with temperature.)

(3) Apply the lowest of these activation energies in the Arrhenius equation below:

$$\text{Acceleration factor} = \frac{k_1}{k_2} = e^{-\frac{E}{R}\left[\frac{1}{T_1} - \frac{1}{T_2}\right]}$$

where:

E = activation energy (J mol^{-1})
R = universal gas constant (8.314 J mol^{-1} K^{-1})
T_1 = test temperature (K)
T_2 = average storage temperature (K)
k_1 = rate of reaction at temperature T_1
k_2 = rate of reaction at temperature T_2

Acceleration factor = ratio of required storage life to test duration

If moisture penetration is assessed as being the rate-determining step and no measured activation energy is available for that particular system, a value for E of 70,000 J mol^{-1} is recommended. As written, this equation requires constant test and storage temperatures. Storage temperatures, however, may be averaged with little loss of accuracy, and a short computer program may be used to solve the Arrhenius equation where T varies cyclically.

b. In most cases, the test cycle conditions compare with the worst natural conditions. They can, therefore, only be considered an accelerated test when compared with average year-round conditions for the same climatic area. In such cases, acceleration factors of 2-5 are appropriate, the actual factor depending on the likely failure mode(s) (see above together with probability data given in AECTP 200, Category 230). Where all or most of the storage is to be in significantly less severe conditions than those of the test, higher acceleration factors are appropriate.

c. For cycle 3 (Figure 1: aggravated) - used primarily where insufficient information is available to carry out the analysis in 2.4.2a above, or where it is not necessary to assess the life of the materiel, arbitrary numbers of cycles are given in Table 2. Selection from these should consider the consequences of failure and the anticipated duration of exposure.

   (1) Time severity "A" is intended to demonstrate the short-term effects of a humid environment, including those arising from condensed surface moisture. It is, therefore, applicable to materiel that is normally protected, whether in a fully conditioned building or by a fully desiccated container, but that may be subjected to occasional exposure to high humidities outside their normal protected environment.

(2) Test severity "B" should be applied to equipment that is used in semi-protected conditions but that may occasionally be exposed to a humid atmosphere for longer periods of time. Severity "C" should be applied to materiel that is in exposed locations or subject to a humid atmosphere in its normal use location, e.g., field equipment, equipment mounted in unconditioned cabins, armored vehicle equipment, etc.

(3) Severity "D" is applicable mainly to package testing or materiel prepared for long-term storage, but the test duration may be extended to a period approaching real (life) time requirements derived as in 2.4.2a above.

Table 2. Durations

Severity	No. of Cycles
A	6
B	12
C	21
D	56

d If it is determined that the test item may become unsafe on exposure to high temperature and relative humidity conditions, consideration should be given to extending the length of the test and/or increasing the number of items to be tested.

3. INFORMATION TO BE PROVIDED IN THE TEST INSTRUCTION

See General Guidance and Requirements, paragraphs 5 and 6.

4. TEST CONDITIONS AND PROCEDURES

4.1. Test Facility

(See General Guidance and Requirements, paragraph 8.) The inside of the enclosure must be designed in such a way as to prevent condensation from falling on the test item from the ceiling or walls. The enclosure must be vented to the atmosphere to prevent pressure buildup inside the enclosure.

4.2. Controls

See General Guidance and Requirements, paragraphs 7 and 10, and:

a Monitoring and control of the humidity inside the test enclosure must be accomplished by using psychrometric systems or with sensors that are not affected by condensation.

b The speed of the air across the psychrometric sensors must be at least 4.5 m/s in order to achieve the required evaporation and sensor response. (Diffusers can be used to obtain this speed in the vicinity of the probe.) Deflectors or screens can be installed around the test item if necessary. In order to prevent heating of the psychrometer sensors, the sensors shall be either installed upstream of any fan used to create the air velocity, or far enough downstream to not be affected by fan heat.

c The humidity and temperature recordings shall be made from sensors separate from hose used to control the chamber environment.

d Water used for both generating humidity and for wet bulb socks must be essentially ee of contaminants. Follow the guidance provided in Method 301, paragraph 10.1c.

4.3. Test Interruptions

See General Guidance and Requirements, paragraph 11.

4.4. Test Procedure

See General Guidance and Requirements, paragraph 7.

4.4.1 Preparation for Test.

Before beginning the test, determine the information specified in General Guidance and Requirements, paragraphs 5 and 6.1, and conduct the test preparation procedure specified in General Guidance and Requirements, paragraph 12.

4.4.2. Procedure I - Cycling

This test consists of a 24-hour conditioning period (to ensure all items at any intended climatic location will start with the same conditions), followed by a repeating 24-hour temperature and humidity cycle for the number of cycles specified in the test plan.

Step 1 With the test item installed in the test chamber in its required configuration, adjust the temperature to 23 ±2°C and 50 ± 5% RH, and maintain for 24 hours.

Note: *This step may be omitted if the number of cycles to be carried out during the test is sufficient to make the conditioning irrelevant.*

Step 2 Adjust the temperature and relative humidity conditions to those specified for the minimum temperature of the appropriate cycle.

Step 3. Perform the required temperature and humidity cycle for the number of cycles specified in the test plan.

Step 4 Conduct test item performance checks as required by the test plan and at the specified temperature-humidity conditions, and record the results.

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

Step 6. Conduct an operational check and record the results for comparison with pretest data.

4.4.3. Procedure II - Steady State

This test consists of a 24-hour conditioning period (to ensure all items at any intended climatic location will start with the same conditions), followed by subjecting the test item to stabilized temperature and humidity conditions for a given period of time.

Step 1 With the test item installed in the test chamber in its required configuration, adjust the temperature to 23 ±2°C and 50 ± 5% RH, and maintain for 24 hours.

Step 2. Adjust the temperature and humidity levels to those specified.

Step 3 Maintain the required test conditions for the time specified in the test plan.

Step 4 If required, operate the test item and record the results.

Step 5 Stabilize the temperature and humidity at standard ambient conditions.

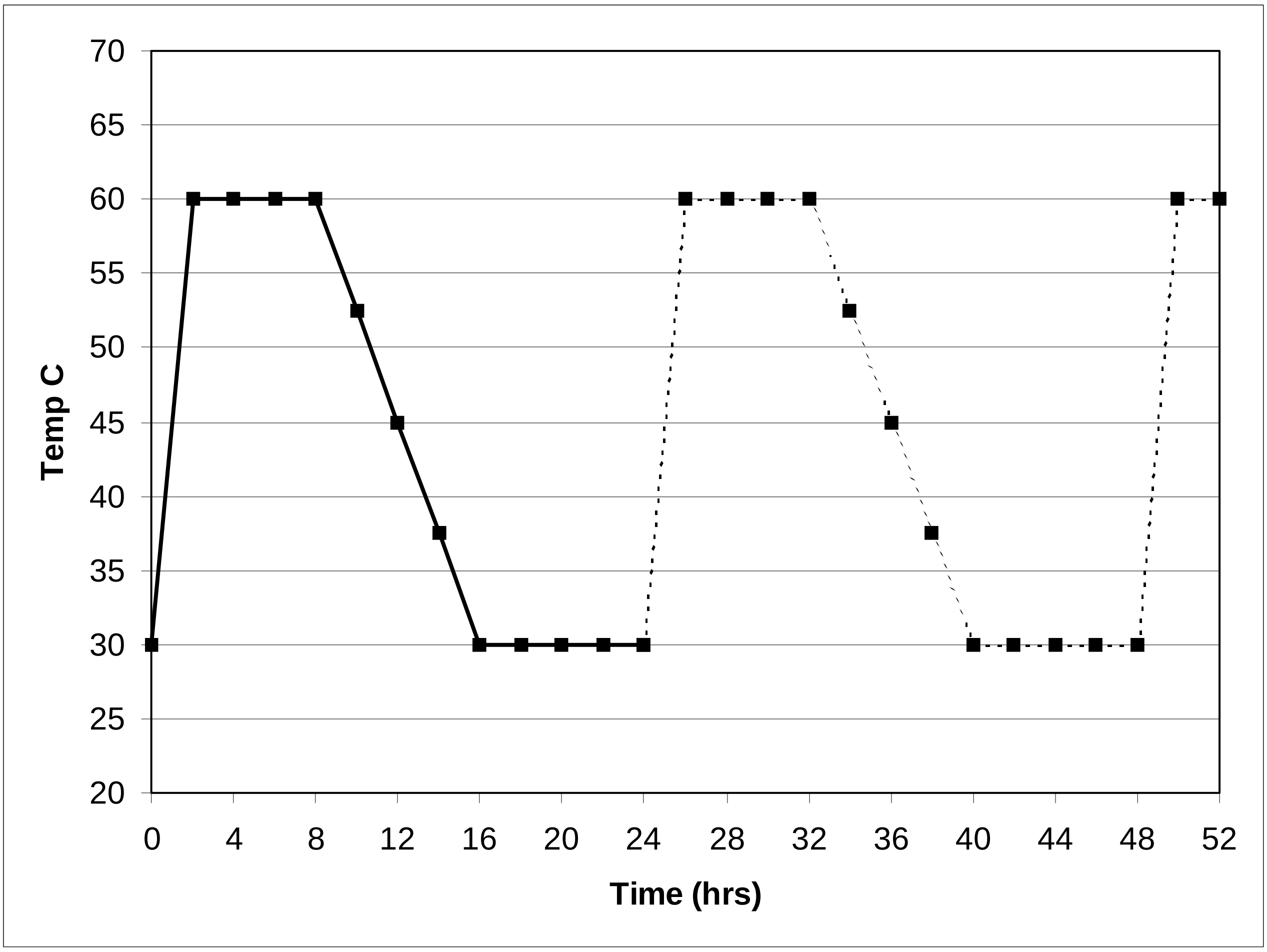
Step 6 Conduct an operational check and record the results for comparison with pretest data.

5. EVALUATION OF THE TEST RESULTS

See General Guidance and Requirements, paragraph 13.

6. REFERENCES AND RELATED DOCUMENTS

See General Guidance and Requirements, paragraph 14.



NOTE : Maintain the relative humidity at 95 ± 4% at all times except that during the descending temperature periods the relative humidity may drop to as low as 85%.

<u>**FIGURE 1. Aggravated Cycle (cycle 3).**</u>

ANNEX A

Physical Phenomena Associated With Humidity

1. Condensation

Condensation is precipitation of water vapor on a surface whose temperature is lower than the dew point of the ambient air. As a consequence, the water is transformed from the vapor state to the liquid state.

a The dew point depends on the quantity of water vapor in the air. The dew point, the absolute humidity and the vapor pressure are directly interdependent.

b. Condensation occurs on a test item when the temperature at the surface of the item placed in the test chamber is lower than the dew point of the air in the chamber. As a result, the item may need to be preheated to prevent condensation.

c. If the test item has a low thermal constant, condensation can only occur if the air emperature increases abruptly, or if the relative humidity is close to 100%.

d. Slight condensation may be observed on the inside surface of box structures resulting from a decrease in the ambient temperature.

e. Generally speaking, condensation can only be detected with certainty by visual inspection. This, however, is not always possible, particularly with small objects having a rough surface.

2. Adsorption

Adsorption is adherence of water vapor molecules to a surface whose temperature is higher than the dew point. The quantity of moisture that can adhere to the surface depends on the type of material, its surface condition, and the vapor pressure. An estimation of the effects due solely to adsorption is not an easy matter because the effects of absorption, which occurs at the same time, are generally more pronounced.

3. Absorption

Absorption is the accumulation of water molecules within a material. The quantity of water absorbed depends in part on the water content of the ambient air. The process of absorption occurs continuously until equilibrium is reached. The penetration speed of the molecules in the water increases with temperature.

4. Diffusion

Diffusion is the movement of water molecules through a material caused by a difference in partial pressures. An example of diffusion often encountered in electronics is the penetration of water vapor through organic coatings such as those on capacitors or semiconductors, or through the sealing compound in the box.

5. Breathing

Breathing is air exchange between a hollow space and its surroundings caused by temperature variations. This commonly induces condensation inside the hollow space.

METHOD 307

IMMERSION

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METHOD 307

IMMERSION

***NOTE**: METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD.*

1. SCOPE

1.1 Purpose

Immersion or fording tests are conducted to determine if materiel can withstand immersion or partial immersion in water and operate as required during or following immersion.

1.2 Application

This method is applicable to materiel that may be exposed to partial or complete immersion, with or without operation. The immersion test has traditionally been considered to be more severe than the rain test (Method 310) for determining the penetrability of materiel. The immersion test may, in some cases, be used to verify watertightness in lieu of a rain test provided that the materiel configuration would be the same for both situations and the method of water ingress is well understood. However, there are documented situations in which the impact of rain causes pumping of water across seals during the rain test that does not occur during the immersion test, as seals are held tight against the backing plate by static pressure. Therefore in most cases both tests should be carried out.

1.3 Limitations

Immersion tests are not intended to be used for buoyant items unless the life cycle profile identifies specific applications where restraints (including stacking) could hold the materiel under water.

2. TEST GUIDANCE

See General Guidance and Requirements, paragraphs 1 and 2.

2.1 Effects of the Environment

Penetration of water into materiel or packaging enclosures can result in problems such as:

a. Fouling of lubricants between moving parts.

b. Formation of electrically conductive paths that may cause electrical or electronic equipment to malfunction or become unsafe to operate.

c. Corrosion due to direct exposure to the water or to the relatively high humidity levels caused by the water.

d. Impairment of the burning qualities of explosives, propellants, fuels, etc.

e. Failure of vehicle engines to operate.

2.2 General

See General Guidance and Requirements, paragraphs 1 and 2.

2.3 Sequence

(See General Guidance and Requirements, paragraph 2.2.) Performing the immersion test before and after structural tests such as shock and vibration will aid in determining the test item's resistance to dynamic tests.

2.4 Choice of Test Parameters

(See General Guidance and Requirements, paragraphs 1-4.) This method incorporates the following variable parameters to be used as appropriate:

a. Conditioning temperature.

b. Depth of immersion or fording.

c. Duration of immersion.

d. Water temperature with respect to the test item temperature.

2.4.1 Conditioning

This test usually includes heating of the test item to establish a pressure differential (on cooling) to determine whether the seals or gaskets leak under relatively low pressure differential, and to induce expansion/contraction of materials.

a. Three options are provided for the conditioning of the test item:

  (1) 27°C above the water temperature to represent exposure to solar heating immediately prior to immersion.

  (2) 10°C above the water temperature to represent a typical temperature difference between materiel and water.

(3) Equal to the water temperature to represent situations in which little or no temperature differential exists. This may also be used for items for which large enough conditioning facilities are not available provided that the depth of immersion is adjusted to result in the same pressure differential.

b. It is recommended that the duration of conditioning immediately prior to immersion be at least two hours following temperature stabilization of the test item.

2.4.2 Depth of immersion

2.4.2.1 Complete immersion

For testing the integrity of a test item, a 1m representative covering depth should be chosen, or an equivalent pressure be applied. The relevant depth/pressure equation follows:

$$P = 9.8d$$

where d = depth of the water in meters, and

P = pressure in kPa.

NOTE: *The equivalent head of seawater is 0.975 times the head of fresh water for the same pressure difference.*

2.4.2.2 Partial immersion

Where materiel is unlikely to be completely immersed either due to anticipated water depths or to its ability to float, and being unlikely to be restrained, a partial immersion test may be appropriate. In this case, depths should be specified as being measured from the base of the materiel rather than from the top as in paragraph 2.4.2.1.

2.4.3 Depth of fording

The fording test may also be used to cover the requirements of STANAG 2805, "Minimum Fordability and Floatation Requirements for Tactical Vehicles and Guns, and Minimum Immersion Requirements for Combat Equipment Normally Installed or Carried in Open Vehicles or Trailers" in which the following depths are prescribed

2.4.3.1 Shallow fording

a. Tanks and armored cars.

(1) Light tanks and armored cars - 1m.

(2) Other tanks (slightly more ground compression) - 1.05m.

b. Vehicles under 2 ton payload - 0.5m

c. Other vehicles - 0.75m

2.4.3.2 Deep fording

It is essential that all tactical vehicles and guns, either with built-in waterproofing or by the use of waterproofing kits, should be able to deep ford six (6) minutes in fresh or salt water, to the depths indicated below (the depth to take into account ramp angle as well as wave height):

a. Fully enclosed armored vehicles should be able to deep ford to the top of the turret. (Alternatively, these vehicles to be fitted with flotation equipment.)

b. All other prime movers or self propelled guns, except trailed loads, should be able to deep ford 1.5m.

c. All trailers or towed guns should be capable of complete immersion. (Alternatively, these equipments should be capable of flotation.)

2.4.4 Materiel fording

Materiel designed to be transported on open vehicles and trailers (such as equipment trailers) should be capable of withstanding partial immersion as anticipated during fording exercises. Examples of fording depths for this type of materiel are as follow:

a. S-280 shelter: 53 cm

b. S-250 shelter: 76 cm

2.4.5 Duration of Immersion or Exposure

The duration of immersion should typify that anticipated during use. If this duration is unknown, a 30-minute immersion period is considered adequate to develop leakage if it is to occur. Fording durations (other than as specified in 2.4.3.2) should be a minimum of one hour, and may be extended if justified by the anticipated life cycle profile.

2.4.6 Temperature

Experience has shown that a temperature differential between the test item and the water can affect the outcome (leakage) of an immersion test. Increasing the test item temperature above the water temperature may be more realistic and will give a more reliable verification of its watertightness. Establishing a specific temperature differential for fording tests is often impractical due to the size of the materiel.

3. INFORMATION TO BE PROVIDED IN THE TEST INSTRUCTION

In addition to the information specified in General Guidance and Requirements, paragraphs 5 and 6, the water and test item temperatures are required, as well as fording/immersion depths and durations.

4. TEST CONDITIONS AND PROCEDURES

See General Guidance and Requirements, paragraphs 7 - 10, for test facility, test conditions and test control information.

4.1 Test Facility

In addition to that specified in General Guidance and Requirements, paragraph 8, the following apply:

a For immersion tests, in addition to a chamber or cabinet capable of conditioning the test item to the required temperature, the required test apparatus should include a water container that can achieve a covering depth of 1m (or other required depth) of water over the uppermost point of the test item and maintain the test item at that depth. To represent greater depths, it may be necessary to apply air pressure to the surface of the water.

b. For fording tests, the facility should be equipped with a tie-down capability to prevent buoyant test items from floating.

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

4.2 Controls

See General Guidance and Requirements, paragraph 10.

4.3 Test Interruption

(See General Guidance and Requirements, paragraph 11.) Treat an interruption that results in less severe conditions than specified as a "no test." The test item should be dried and the entire test procedure repeated from the beginning. Any failure discovered during an undertest condition should be treated as a failure. If more severe conditions than intended are applied and a failure results, the test shall be repeated, if possible, on a replacement item. If no failure occurs, the test need not be repeated.

4.4 Procedure

See General Guidance and Requirements, paragraph 6.2.

4.4.1 Preparation for Test

Before starting the test procedure, determine the information specified in General Guidance and Requirements, paragraphs 5 and 6.1, and perform the test preparation procedure specified in General Guidance and Requirements, paragraph 12.

***NOTE**: No sealing, taping, caulking, etc., shall be used except as required in the design specification for the test item.*

a When testing a shipping/storage container or transit case without the test items enclosed, if possible, remove all dunnage, packing, padding material, etc., that may absorb water, before the test so that leakage can be detected. This option may not provide an adequate test of the container if the seals are not representatively stressed because of the absence of the contents.

b Items that may experience immersion when mounted on or secured to a carrying platform should be secured representatively. If representative of the real life situation, stacking is an acceptable method of restraining items under water.

4.4.2 Procedure I - Immersion

Step 1 If weight gain is likely to be an acceptable method of determining leakage, weigh the test item.

Step 2 Three times immediately before the test, open and close (or remove and replace) any doors, covers, etc., that would be opened during normal use to ensure that any seals are functioning properly and are not adhering to the sealing surfaces.

Step 3 Measure and record the immersion water temperature.

Step 4 Condition the test item as in 2.4.1 and record the conditioning temperature and duration. The test item's sealed areas (where appropriate) shall remain open throughout the conditioning cycle. Also, materiel occasionally incorporates valves or venting devices that may or may not be opened in normal service use. If the test item incorporates such devices, open them throughout the conditioning portion of the test.

Step 5 Close all sealed areas and valves; assemble the test item in its test configuration and, as quickly as possible, immerse the test item in water so that the uppermost point of the test item is 1 ± 0.1m below the surface of the water, or as otherwise required by the test plan. The orientation of the test item should represent that of its expected in-service orientation. If several orientations are possible, the most vulnerable shall be selected for this test.

Step 6 Following a 30-minute immersion period (or as otherwise specified in the test plan), remove the test item from the water, wipe the exterior surfaces dry (giving special attention to areas around seals and relief valves) and, if applicable, equalize the air pressure inside by activating any manual valves.

Step 7 If appropriate, re-weigh the test item.

Step 8 Open the test item and examine the interior and contents for evidence of and quantity of leakage, and for probable areas where the leakage occurred.

Step 9 If appropriate, conduct an operational check of the test item.

4.4.3 Procedure II - Fording

The fording test may be conducted in one of two ways: by towing or driving the test item through water at the appropriate depth, or by securing the test item in a tank and flooding the tank to the required depth.

Step 1 If weight gain is likely to be an acceptable method of determining leakage, weigh the test item

Step 2 With the test item in its fording configuration, ensure that any drain plugs or apparatus are closed, and either:

a. tow or drive the test item into the water at the required depth or,

b secure the test item in a watertight tank.

In either case, the orientation of the test item should represent that of its expected in-service orientation, including the angle of entry and exit during fording. If several orientations are possible, the worst case shall be selected for this test.

Step 3 If using the tank method, flood the tank to the required height above the bottom of the test item.

Step 4 Maintain the test item in the water for a duration as determined in paragraph 2.4.4.

Step 5 Either remove the test item from the water or drain the water from the facility, and inspect the interior of the test item for evidence of free water.

Step 6 Measure and record the amount of free water, and the probable point(s) of entry. If appropriate, re-weigh the test item.

5. EVALUATION OF TEST RESULTS

In addition to that specified in General Guidance and Requirements, paragraph 13, any evidence of water penetration into the test item following this test must be assessed for its short and long term effects. Consideration should be given to the effects of free water as well as to the increase of relative humidity in closed containers following the evaporation of any free water.

6. REFERENCES AND RELATED DOCUMENTS

See General Guidance and Requirements, paragraph 14.

STANAG 2805, Minimum Fordability and Floatation Requirements for Tactical Vehicles and Guns, and Minimum Immersion Requirements for Combat Equipment Normally Installed or Carried in Open Vehicles or Trailers for Mobile Equipment.

METHOD 308

MOULD GROWTH

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METHOD 308

MOULD GROWTH

NOTE: *METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD.*

1. SCOPE

1.1 Purpose

The purpose of this mould growth test is to assess the extent to which the materiel will support mould growth or how the mould growth may affect performance or use of the materiel. The term "mould" as used throughout this document is synonymous with "fungus." The primary objectives of the mould growth test are to determine:

a If the materials comprising the materiel, or the assembled combination of same, will support mould growth and, if so, what species. (See table 1 for the types of moulds.)

b How rapidly moulds will grow on the materiel.

c How any mould growth affects the materiel, its mission, and its safety for use following the growth of mould on the materiel.

d. If the materiel can be stored effectively in a field environment.

e. If there are simple reversal processes, e.g., wiping off mould growth.

1.2 Application

Since microbial deterioration is a function of temperature and humidity and is an inseparable condition of hot-humid tropics and the mid-latitudes, it must be considered in the design of all standard, general-purpose materiel. This method is used to determine if mould growth will occur and, if so, how it may degrade/impact the use of the materiel.

Note: *1. This test procedure and the accompanying preparation and post-test analysis involve highly specialized techniques and potentially hazardous organisms. Only technically qualified personnel (e.g., microbiologists) should perform the test.*

2. Although the basic (documented) resistance of materials to mould 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 can result in the growth of fungus on materiel that would otherwise be considered resistant. Care must therefore be exercised when using documented evidence to justify waiving laboratory or natural environment tests.

1.3 Limitations

This test is designed to 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.

2. GUIDANCE /REQUIREMENTS

(See General Guidance and Requirements, paragraphs 1 and 2.)

2.1 Effects of Mould Growth.

Mould growth impairs the functioning or use of equipment by changing its physical properties.

2.1.1 Detrimental effects

The detrimental effects of mould growth are summarized as follows:

2.1.1.1 Direct attack on materials

Nonresistant materials are susceptible to direct attack as the moulds break the materials down and use them as nutrients. This results in deterioration affecting the physical properties of the material. Examples of nonresistant materials are:

a Natural material. Products of natural origin are most susceptible to this attack.

   (1) Cellulosic materials (e.g., Wood, paper, natural fiber textiles, and cordage).

   (2) Animal-based and vegetable-based adhesives.

   (3) Grease, oils, and many hydrocarbons.

   (4) Leather.

b. Synthetic materials:

  (1) PVC formulations (e.g., those plasticized with fatty acid esters).

  (2) Certain polymers (e.g., polyesters, polyurethane and some polyethers).

  (3) Plastics that contain organic laminating materials or fillers.

  (4) Paints and varnishes that contain susceptible constituents.

2.1.1.2 Indirect attack on materials

Damage to mould-resistant materials results from indirect attack when:

a Mould growth on surface deposits of dust, grease, perspiration, and other contaminants (that find their way onto materiel during manufacture or accumulate during service) causes damage to the underlying material, even though that material may be resistant to direct attack.

b. Metabolic waste products (i.e., organic acids) excreted by mould cause corrosion of metals, etching of glass, or staining or degrading of plastics and other materials.

c The products of mould growth on adjacent materials that are susceptible to direct attack come in contact with the resistant materials.

2.1.2 Physical interference

Physical interference can occur as follows:

a. Electrical or electronic systems. Damage to electrical or electronic systems may esult from either direct or indirect attack. Mould growth can form undesirable electrical conducting paths across insulating materials, for example, or may adversely affect the electrical characteristics of critically adjusted electronic circuits.

b. Optical systems. Damage to optical systems results primarily from indirect attack. The mould growth can adversely affect light transmission through the optical system, block delicate moving parts, and change non-wetting surfaces to wetting surfaces with resulting loss in performance.

2.1.3 Health and aesthetic factors

Mould growth on materiel can cause physiological problems (e.g., allergies) or be so aesthetically unpleasant that the users will be reluctant to use the materiel.

2.2 Choice of Test Parameters

(See General Guidance and Requirements, paragraphs 1-4.)

The essential parameters for defining the test include temperature and humidity, test duration, and test item configuration.

2.2.1 Temperature and humidity

Since the combination of temperature and humidity is critical to microbial growth, it is essential that these be maintained as specified in the procedure.

2.2.2 Test duration

Twenty-eight days is the minimum test period to allow for mould germination, breakdown of carbon-containing molecules, and degradation of material. Since indirect effects and physical interference are not likely to occur in the relatively short time frame of the mould test, extension of the exposure period to 84 days should be considered if a greater degree of certainty (less risk) is required in determining the existence or effect of mould growth.

2.3 Choice of Test Mould

Two groups of moulds (U.S. and European) are commonly used and are listed in table 1. One group or the other should be used *in toto*, and adjusted, if necessary, as in 2.3b. The U.S.' five species of test moulds are included in the U.S. National standard on environmental testing, MIL-STD-810, and seven in the European standards. These organisms were selected because of their ability to degrade materials, their worldwide distribution, and their stability. To aid in selection of a species to supplement the selected group, the organisms have, where possible, been identified with respect to the materials to which they are known to attack, and must be selected accordingly.

a. Because the test item is not sterile before testing, other microorganisms will be present on the surfaces. When the test item is inoculated with the selected group of moulds, both these and the other organisms will compete for available nutrients. It is not surprising to see organisms other than the test moulds growing on the test item at the end of the test.

b. Additional species of moulds may be added to those required in this test method. However, if additional moulds are used, their selection shall be based on prior knowledge of specific material deterioration. For example, penicillium funiculosum can be employed because of its known specificity for degrading textiles.

Table 1. Test moulds

Mould	**Mould Sources Identification n$^{o.}$**		**Standard**	**Materials Affected**
	USDA(1)	**ATCC(2)**		
Aspergillus niger	QM 458	ATCC 6275	Eur.	textiles, vinyl, etc. Resistant to tanning salts
Aspergillus terreus	QM 82j	ATCC 10690	Eur.	haversack, paperboard, paper
Paecilomyces varioti		IAM 5001	Eur.	plastics, leather
Penicillium funiculosum		IAM 7013(3)	Eur.	textiles
Penicillium ochro-chloron	QM 477	ATCC 9112	Eur.	plastics, textiles
Scopulariopsis brevicaulis		IAM 5146	Eur.	rubber
Trichoderme viride		IAM 5061	Eur.	plastics, textiles
Aspergillus flavus	QM 380	ATCC 9643	U.S.	leathers, textiles
Aspergillus versicolor	QM 432	ATCC 11730	U.S.	leather
Penicillium funiculosum	QM 474	ATCC 11797	U.S.	plastics, cotton fabric.
Chaetomium globosum	QM 459	ATCC 6205	U.S.	cellulose
Aspergillus niger	QM 386	ATCC 9642	U.S.	conformal coatings and insulation

1/ U.S. Department of Agriculture
Northern Regional Research Center
ARS Culture Collection
1815 North University Street
Peoria, Illinois 61604
(The mould may be distributed in a lyophilized state or on agar slants.)

2/ American Type Culture Collection
12301 Parklawn Drive
Rockville, Maryland 20852

3/ Institute of Applied Microbiology
Univ. Of Tokyo
Tokyo, Japan

(See General Guidance and Requirements, paragraphs 1 and 2.)
In addition to the sequence guidance provided in General Guidance and Requirements, paragraph 2.2, the following is applicable: This method should not be conducted after a salt fog (Method 309) test or a sand and dust test (Method 313). A heavy concentration of salt may affect the germinating mould growth, and sand and dust can provide nutrients, thus leading to a false indication of the biosusceptibility of the test item.

3. INFORMATION TO BE PROVIDED IN THE TEST INSTRUCTION

In addition to that specified in General Guidance and Requirements, paragraphs 5 and 6.2, record the following information:

a Evidence of mould growth on the control cotton strips at the 7-day check and at the end of the test (see paragraph 4.4.7).

b Location of mould.

c. Narrative description of growth, including colors, areas covered, growth patterns, and density of growth (and photographs, if necessary). (See table 2.)

d. Effect of moulds on performance or use:

  (1) As received from chamber.

  (2) After removal of mould, if appropriate.

e Physiological or aesthetic considerations.

f Types of moulds used.

4. TEST PROCEDURES

See General Guidance and Requirements, paragraphs 7 - 10.

4.1 Test Facility

See General Guidance and Requirements, paragraph 8. Also see Annex A of this method for pre-test and post-test decontamination guidance

In addition to the standard requirements for test chambers, the following apply to chambers to be used for mould tests:

a Construct the chamber and accessories in such a manner as to prevent condensation from dripping on the test item.

b Filter-vent the chamber to the atmosphere to prevent the buildup of pressure and release of spores into the atmosphere.

c Monitoring and control of the humidity inside the test enclosure must be accomplished with psychrometric systems or with sensors that are not affected by condensation.

d The speed of the air across the psychrometric sensors must be at least 4.5 m/s in order to achieve the required evaporation and sensor response. (diffusers may be used to obtain this speed in the vicinity of the probe.) Deflectors or screens can be installed around the test item if necessary. In order to prevent heating of the psychrometer sensors, the sensors shall either be installed upstream of any fan used to create the air velocity or far enough downstream not to be affected by fan motor heat.

e The humidity and temperature recordings shall be made from sensors separate from those used to control the chamber environment

4.2 Controls (See also paragraph 4.4.)

In addition to that provided in general guidance and requirements, paragraph 10, the following controls apply to this test:

4.2.1 Humidity

In addition to the requirements appropriate for Method 506, humid heat, determine the relative humidity 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 condensation.

a. When the wet-bulb control method is used, clean the wet-bulb assembly and install a new wick for each test.

b In order to produce the evaporation necessary for sensor measurement of wet bulb temperature, the air velocity across the wet bulb shall not be less than 4.5 meters per second.

c Because heat from fan motors may affect temperature readings, do not install wet- and dry-bulb sensors close to the discharge side of any local fan or blower used to create the requirement of 4.2.1b.

4.2.2 Air circulation

Maintain free circulation of air around the test item and keep the contact area of fixtures supporting the test item to a minimum.

4.2.3 Steam injection

Do not inject steam directly into the test chamber working space where it may have an adverse effect on the test item and microbial activity.

4.2.4 Chemicals

Unless otherwise specified:

a. All reagents shall conform to the specifications of the committee on analytical reagents of the American Chemical Society, where such specifications are available.

b. References to water shall be understood to mean water essentially free of contaminants. Follow the guidance in Method 301, paragraph 10.1c.

4.3 Test Interruption

(See General Guidance and Requirements, paragraph 11.)

The mould 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 ten days of the test, the test should be restarted from the beginning with either a new or cleaned test item

b If the interruption occurs late in the test cycle, examine the test item for evidence of mould growth. If the test item is biosusceptible, there is no need for a retest. If the controls exhibit viable growth but there is no evidence of mould growth on the test item, follow the guidance given below.

    (1) Lowered temperature. A lowering of the test chamber temperature generally will retard mould growth. If 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. If not, see (3) below.

    (2) Elevated temperature. Elevated temperatures may have a drastic effect on mould growth. A complete re-initiation of the test is required if:

        (a) The temperature exceeds 40°C, or

        (b) The temperature exceeds 31°C for 4 hours or more, or

        (c) There is evidence of deterioration of the mould growth on the control strips.

Otherwise, reestablish test conditions and continue the test from the point of interruption.

(3) Lowered humidity. A complete retest is required if:

    (a) The relative humidity drops below 50%, or

    (b) The relative humidity drops below 70% for 4 hours or more, or

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

Otherwise, reestablish test conditions and continue the test from the point of interruption.

4.4 Procedure

4.4.1 Cleaning

Although it is preferable to use a new test item, the same test item as used in other tests may be used. If cleaning is required, conduct the cleaning at least 72 hours before test initiation in order to allow evaporation of any volatile materials. Cleaning should follow typical production cleaning methods. The test item shall be prepared in accordance with 4.4.6.1. Place new cotton control strips in the test chamber and inoculate both the test item and the controls with the test moulds.

4.4.2 Water Purity

Water used for generating humidity and for wet bulb socks must be essentially free of contaminants. Follow guidance provided in Method 301, paragraph 10.1c.

4.4.3 Miscellaneous

a. This method is designed to provide optimal climatic conditions and all of the basic inorganic minerals needed for growth of the mould species used in the test. The group of mould species was chosen for its ability to attack a wide variety of materials commonly used in the construction of military materiel. Optional species may be added to the inoculum if required (see paragraph 2.3b).

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 The specified temperature of 30 ± 1°C, is most conducive to the growth of the test moulds.

e Control items specified in paragraph 4.4.5 are designed to:

(1) Verify the viability of the mould spores used in the inoculum.

(2) Establish the suitability of the chamber environment to support mould growth.

f. Although this procedure can provide information on the susceptibility of materials to mould growth, the testing of materials and piece parts will not reveal potential mould growth situations. These can result due to the complexities involved in assemblages. Examples are induced conditions created by coatings and protective wrappings, deterioration of protective coatings due to bimetallic reactions, and other situations that would not be encountered with the testing of components

4.4.4 Test Preparation

a Preparation of mineral salts solution

(1) 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 sulphate heptahydrate ($FeSO_4 \cdot 7H_2O$)	0.002g
Zinc sulphate heptahydrate ($ZnSO_4 \cdot 7H_2O$)	0.002g
Manganous sulphate monohydrate ($MnSO_4 \cdot H_2O$)	0.001g
Distilled water	1000ml

(2) The pH of the mineral salts solution must be between 6.0 and 6.5.

b Preparation of mixed spore suspension

***Note - Precautions**: Although the exact strains of moulds 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 for safety should be employed. Also, the tests should be conducted by personnel trained in microbiological techniques.*

(1) Use aseptic techniques to prepare the spore suspension containing at least the test moulds determined from paragraph 2.3.

(2) Maintain pure cultures of these moulds 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. Prepare the mineral salts agar by dissolving 15.0g of agar in a liter of the mineral salts solution described in paragraph 4.4.5.2a.

***Note:** Do not keep the stock cultures for more than 4 months at $6^o \pm 4^oC$; after that time, prepare subcultures and use them for the new stocks.*

(3) Verify the purity of mould cultures before the test.

(4) Make subcultures from the pure stock cultures and incubate them at $30^o \pm 1^oC$ for 10 to 21[*] days.

Most moulds will develop within 10 to 14 days and may show signs of deterioration after longer incubation. Some moulds such as chaetomium globosum require 21 days or longer to develop.

(5) Prepare a spore suspension of each of the required test moulds by pouring into one subculture of each mould 10ml of an aqueous solution containing 0.05g per liter of a nontoxic wetting agent such as sodium dioctyl sulphosuccinate (sulfosuccinate) or sodium lauryl sulphate (sulfate).

(6) Use a rounded glass rod or a sterilized platinum or nickel chrome wire to gently scrape the surface growth from the culture of the test organisms.

(7) Pour the spore charge into a 125ml capped erlenmeyer flask containing 45ml of water and 50 to 75 solid glass beads, 5mm in diameter.

(8) Shake the flask vigorously to liberate the spores from the fruiting bodies and to break the spore clumps.

(9) Filter the dispersed mould spore suspension into a flask through a 6mm layer of glass wool contained in a glass funnel.

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

(10) Centrifuge the filtered spore suspension and discard the supernatant liquid.

(11) Re-suspend the residue in 50ml of water and centrifuge. Wash the spores obtained from each of the moulds in this manner at least three times (until the supernatant is clear).

(12) Dilute the final washed residue with mineral salts solution in such a manner that the resultant spore suspension shall contain 1,000,000 ± 20% spores per milliliter as determined with a counting chamber.

(13) Repeat this operation for each organism used in the test.

(14) Perform a viability check for each organism in accordance with paragraph 4.4.5.1.

(15) Blend equal volumes of the resultant spore suspension to obtain the final mixed spore suspension.

Note: The *spore suspension should be prepared fresh. If not freshly prepared, it must be held at* $6^o \pm 4^o$*c for not more than 14 days.*

4.4.5 Control Items

Two types of control tests are required. Using the procedure of 4.4.5.1, verify the viability of the spore suspension and its preparation. Using the procedure of 4.4.5.2, verify the suitability of the chamber environment.

4.4.5.1 Viability of Spore Suspension

a. Before preparing the composite spore suspension, inoculate sterile potato dextrose or another nutrient agar plates with 0.2 to 0.3ml of the spore suspension of each of the individual mould species. Use separate agar plates for each species.

b. Distribute the inoculum over the entire surface of the plate.

c. Incubate the inoculated potato dextrose agar plate at 30 ± 1^oC for 7 to 10 days.

d. After the incubation period, check the mould 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.*

4.4.5.2 Test Chamber Environment

a. Prepare the following solution:

   (1) 10.0g glycerol.

   (2) 0.1g potassium dihydrogen orthophosphate (KH_2PO_4).

   (3) 0.1g ammonium nitrate (NH_4NO_3).

   (4) 0.025g magnesium sulphate (sulfate) heptahydrate ($MgSO_4 \cdot 7H_2O$).

   (5) 0.05g yeast extract.

   (6) distilled water to a total volume of 100ml.

   (7) 0.005g of a nontoxic wetting agent such as sodium dioctyl sulphosuccinate (sulfosuccinate) or sodium lauryl sulphate (sulfate).

   (8) HCl and NaOH to adjust the final solution pH to 5.3.

b. Prepare control strips from unbleached, plain weave, 100% cotton cloth that has been cut or torn into strips about 3cm wide. The strips shall be devoid of fungicides, water repellents, and sizing additives. To aid in removing any possible treatment materials, boiling in distilled water is recommended. Dip the strips 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. Ensure that the strips have been thoroughly wetted

c. 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.

d. These strips are installed and inoculated along with the test item to ensure that proper conditions are present in the incubation chamber to promote mould growth.

4.4.6 Test Performance

4.4.6.1 Preparation for Incubation

Step 1. Assure that the condition of the test items 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 mould test to allow for evaporation of volatile materials.

Step 2 Install the test item in the chamber or cabinet on suitable fixtures, or suspended them from hangers.

Step 3. Hold the test item in the operating chamber (at 30 ± 1°C and a RH of greater than 90% but less than 100%) for at least 4 hours immediately before inoculation.

Step 4. Inoculate the test item and the cotton fabric chamber control items with the mixed mould 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 that are exposed during use or maintenance. If the surfaces are non-wetting, spray until drops begin to form on them.*

Step 5. In order for air to penetrate, replace the covers of the test items without tightening the fasteners.

Step 6. Start incubation immediately following the inoculation

4.4.6.2 Incubation of the test item.

Step 1. Except as noted in Step 9 below, incubate the test items at constant temperature and humidity conditions of 30 ± 1°C and a relative humidity above 90% but below 100% for the test duration (28 days, minimum).

Step 2.After 7 days, inspect the growth on the control cotton strips (paragraph 4.4.5.2.b) to verify 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 fungus. 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.

Step 3. If the cotton strips show satisfactory fungus growth after 7 days, continue the test for the required period from the time of inoculation as specified in the test plan. If there is no increase in fungus growth on the cotton strips at the end of the test as compared to the 7-day results, the test is invalid.

4.4.7 Inspection.

At the end of the incubation period, inspect the test item immediately. If possible, inspect the item within the chamber. If the inspection is conducted outside of the chamber and is not completed in 8 hours, return the test item to the test chamber or to a similar humid environment for a minimum of 12 hours. Except for hermetically sealed materiel, open the test item enclosure and examine both the interior and exterior of the test item. Record the results of the inspection.

4.4.8 Operation/Use.(To be conducted only if required)

If operation of the test item is required (e.g., electrical materiel), conduct the operation during the inspection period specified in paragraph 4.4.7. Ensure personnel with appropriate knowledge of the test item are available to aid in exposing its interior surfaces for inspection and in making operation and use decisions. Disturbance of any fungus growth must be kept to a minimum during the operational checkout.

Warning: *Because of the potential hazardous nature of this test, operation/use by personnel with appropriate knowledge of the test item will be performed under the guidance of technically qualified personnel (e.g., microbiologists). Appropriate personal protective equipment (PPE) must be worn.*

4.4.9. Decontamination

Because of the potentially hazardous nature of this test, extreme caution must be taken to ensure that the test item, the PPE and the test facility are properly decontaminated. Annex A provides guidance on a procedure for decontamination.

5. EVALUATION OF THE TEST RESULTS

In addition to General Guidance and Requirements, paragraph 13, the following information is provided to assist in the evaluation of the test results.

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

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

    (1) The extent of growth on susceptible components or materials. Use table II as a guide for this evaluation but any growth must be completely described.

    (2) The immediate effect that the growth has on the physical characteristics of the materiel.

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

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

c. Evaluate human factors effects (including health risks).

6. REFERENCE AND RELATED DOCUMENTS.

MIL-STD-810F, Test Method Standard for Environmental Engineering Considerations and Laboratory Tests.

TABLE 2 - Evaluation Scheme for Visible Effects.[1]

Amount of Growth	Rating	Comments
None	0	Substrate is devoid of microbial growth.
Trace	1	Scattered, sparse or very restricted microbial growth.
Light	2	Intermittent infestations or loosely spread microbial colonies on substrate surface. Includes continuous filamentous growth extending over the entire surface, but underlying surfaces are still visible.
Medium	3	Substantial amount of microbial growth. Substrate may exhibit visible structural change.
Heavy	4	Massive microbial growth.

[1] Use this scheme as a guide, but exceptions may occur that require a more specific description

ANNEX A

DECONTAMINATION OF TEST EQUIPMENT AND TEST ITEMS AFTER EXPOSURE TO FUNGUS

1. Decontamination of test equipment, materials, and test items that have been subjected to a fungus test is paramount when the test items are to be sent back to the users, manufacturer, or material management office for further evaluation or reuse. Many test items are too expensive to scrap and must be decontaminated.

    a. Decontamination and disinfection of the test chamber

        (1) Initially, good housekeeping procedures should be followed for all testing, especially those tests involving live cultures.

        (2) Prior to any testing, the climatic chamber should be thoroughly cleaned inside with a hot, soapy water (or Lysol®-type cleaner) solution.

        (3) With no items in chamber, high heat (at least 60°C/140°F) is applied for at least 2 hours (no humidity required). Cool the chamber to ambient prior to placing the test items in the chamber for fungus testing.

        (4) After testing is complete and the items have been examined/pictures taken, the items and the chamber can be initially sterilized with high heat as above and at least 90% relative humidity for at least 2 hours. The humidity keeps the surfaces wet until the spores are destroyed. (NOTE: The items must be able to withstand the high temperature chosen for initial sterilization without damage. Check the test item user's manual for the storage temperature before proceeding). After heat sterilization, the chamber can be washed with a sodium or calcium hypochlorite solution at 5000 ppm concentration (wear appropriate personal protective equipment [PPE] when using any chemical solutions). A phenolic disinfectant spray can also be used. Copious flushing with water to rinse the chamber is needed to limit the chlorine contact on the metals surfaces.

        (5) If the test items are washable, follow the instructions for each item and launder in a machine, if possible.

        (6) If the items cannot be washed with a solution, wipe with a damp cloth that has been sprayed with a phenolic solution (disinfectant spray) and label the items appropriately with precautions on handling items that have been subjected to fungus testing. Personnel trained in microbiological techniques and who conduct these tests should have general operating procedures in place for handling fungus cultures and test items after exposure.

METHOD 309

SALT FOG

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METHOD 309

SALT FOG

NOTE: *METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD.*

1 SCOPE

1.1 Purpose

This salt fog test is designed to give a set of repeatable conditions to determine the relative resistance of materiel to the effects of an aqueous salt atmosphere.

1.2. Application

All military materiel will be exposed to some form of salt during its life cycle that may affect its performance. The primary value of the proposed test procedure lies in testing coatings and finishes on materiel. Additionally, it can be used to locate potential design problems such as incompatible materials.

1.3. Limitations

a. It should be noted that the test has limitations regarding the simulation of real life conditions and successful compliance with the test does not guarantee that particular items of materiel will satisfactorily resist all saline conditions to which they may be subjected in service. In particular the procedure does not duplicate all the effects of a marine atmosphere and it has not been demonstrated that a direct relationship exists between the salt fog test corrosion and corrosion occurring in the natural environment. There is no quantitative relationship between time spent in the chamber and time in the field, so the test has proven to be generally unreliable for predicting the service life of different materials or coatings.

b. This test is not a substitute for evaluating corrosion caused by humidity and fungus because their effects differ from salt fog effects and this test is not intended for testing piece parts such as bolts, wires, transistors and integrated circuits, and material coupons.

2. TEST GUIDANCE

See General Guidance and Requirements, paragraphs 1 and 2.

Salt is one of the most pervasive chemical compounds in the world. It is found in the oceans, the atmosphere, ground surfaces, and lakes and rivers. It is impossible to avoid exposure to salt. In coastal regions, this exposure is intensified; in a marine environment the exposure reaches a maximum. The procedure can be used in a relatively short period of time to locate potential problem areas, design flaws, incompatibility of materials, etc., that are exacerbated by exposure to a salt atmosphere.

2.1 Effects of the Environment

The effects of exposure of materiel to an environment in which salt is present can be divided into three broad categories: physical effects, chemical effects, and electrical effects. The following examples of problems that could occur as a result of exposure to such an environment are not intended to be all-inclusive, and some of the examples may overlap the categories. They do indicate the importance of the test item adequately simulating the system (i.e. the materiel in it’s intended service role) such that the important effects of exposure are tested.

2.1.1 Physical

a. Clogging or binding of moving parts of mechanical components and assemblies.

b. Blistering of paint as a result of electrolysis.

2.1.2 Chemical

a. Corrosion due to electrochemical reaction.

b Accelerated stress corrosion.

c. Formation of acidic/alkaline solutions following salt ionization in water.

2.1.3 Electrical

a. Impairment of electrical equipment due to salt deposits.

b Production of conductive coatings.

c. Attack of insulating materials and metals.

2.2 Test Procedure

See General Guidance and Requirements, paragraphs 1 and 2.

2.3 Sequence

(See General Guidance and Requirements, paragraph 2.2.) Sand and dust testing should not precede salt fog testing because dust deposits may inhibit salt corrosion. Salt fog testing should not come before mould (fungus) or humidity testing because salt deposits may inhibit mould growth, nor should it precede humidity tests because residual salt deposits could accelerate chemical reactions.

2.4 Choice of Test Parameters

(See General Guidance and Requirements, paragraphs 1-4.) Variations for the test procedure are limited to the salt concentration, test duration, the cycling of exposure and drying periods, and the salt composition. Test item configuration is also an important factor to consider.

2.4.1 Salt composition

Studies have shown that, for the purpose of evaluating corrosion, a sodium chloride solution provides as realistic effect as any synthetic seawater solution (reference a., paragraph 7). Do not use sodium chloride containing anti-caking agents because such agents may act as corrosion inhibitors.

2.4.2 Salt concentration

Concentrations exceeding 20% are known to occur.. However the testing community have standardised on a 5 ± 1% solution because test results have shown this to be an effective test concentration to demonstrate the ability of material to resist corrosion (Reference B)..

2.4.3 Cycling

Experience has shown that alternating periods of salt fog exposure and drying conditions provides a more realistic exposure and a higher damage potential than does continuous exposure to a salt atmosphere. Because the rate of corrosion is much higher during the transition from the wet to dry, it is critical to closely control the rate of drying if corrosion levels from test to test are to be compared. The test item should be dried for at least 24 hours unless there is clear (and documented) evidence that the materiel is dry in less time. For large or complex items this drying time may need to be longer than 24 hours 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.

2.4.4 Salt Solution pH

Temperature affects the pH of a salt solution, that has been made from water saturated with carbon dioxide at room temperature. If the pH of the solution is adjusted at room temperature and then the solution atomised at 35°C, the pH of the collected solution will be higher due to loss of carbon dioxide. Therefore pH adjustment should be by one of the following methods.

a. Take a 50 ml sample of the salt solution and boil for 30 seconds. Cool the sample and determine the pH. When the pH of the salt solution is adjusted to 6.6 to 7.2 by this procedure, the pH of the atomised and collected solution at 35°C will come within this range.

b. Heat the salt solution to boiling and then cool to 35°C and hold at this temperature for 48 hours. Adjust the pH of the solution and it will not materially change when atomised at 35°C.

c. Heat the water from which the salt solution will be made to 35°C or above to expel the carbon dioxide. Adjust the pH of the solution and it will not materially change when atomised at 35°C.

2.5 Test item configuration.

The configuration and orientation 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 specified, configure the test item and orient it as would be expected during its storage, shipment, or use. The listing below offers the most likely configurations that materiel would assume when exposed to a corrosive atmosphere. For test purposes, choose the most severe/critical configuration.

a. In a shipping/storage container or transit case.

b. Outside of its shipping/storage container but provided with an effective environmental control system that partly excludes the salt fog environment.

c. Outside of its shipping/storage container and set up in its normal operating mode.

d. Modified with kits for special applications or to compensate for mating components that are normally present, but are not used for this specific test.

3 INFORMATION TO BE PROVIDED IN THE TEST INSTRUCTION

In addition to that specified in General Guidance and Requirements, paragraphs 5 and 6, measure the salt solution fallout rate (ml/cm^2/h), pH and specific gravity.

4. TEST CONDITIONS AND PROCEDURES

See General Guidance and Requirements, paragraphs 7 - 10, for test facility, test conditions and test control information.

4.1 Test Facility

See General Guidance and Requirements, paragraph 8.

The apparatus used in performing the salt fog test in this method is described as follows:

a. A test chamber with:

(1) Supporting racks designed and constructed so that they will not affect the characteristics of the salt fog. Construct all parts of the test chamber and the supporting racks that come into contact with the test item with material that will not cause electrolytic corrosion. Do not allow condensation 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. Vent the exposure chamber to prevent pressure buildup.

(2) The capability to maintain temperatures in the exposure zone at 35°C. This temperature shall be controlled continuously during the test. The use of immersion heaters within the chamber exposure area for the purpose of maintaining the temperature within the exposure zone is prohibited. The temperature of 35°C has been historically used and was selected as a standard to enable operation of a salt fog test chamber in almost any part of the country with a simple heating setup. It also eliminates the need for cooling (refrigeration) (reference c).

(3) A salt solution reservoir and dispenser made of material that is nonreactive with the salt solution, e.g., glass, hard rubber, or plastic, and that will not influence the pH. The reservoir provides a continuous supply to a tank normally (but not necessarily) situated inside the test section in which the salt solution level is held reasonably constant. The atomizers are connected to this tank.

(4) A means for injecting the salt fog into the test chamber and an input air humidifier to minimize clogging of the nozzles. 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. The facility must be designed to provide the required atomization distribution and fallout.

(5) 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.

(6) A compressed air supply that will maintain constant air pressure for the continuous, uniform atomization of the salt solution.

b. A salt fog fallout such that each receptacle collects from 1 to 3 ml of solution per hour for each 80 cm^2 of horizontal collecting area (10 cm diameter).

***NOTE**: The apparatus described in IEC Publication 68, test Ka is among those that satisfy these requirements.*

4.2 Controls

In addition to that specified in General Guidelines and Requirements, paragraph 10, the following controls apply to this test:

a. Compressed air: 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) (see table 1).

Table 1 - 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

b The salt solution is to be heated to within ±6°C of the test section temperature before injection into the test section.

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

d Chamber operation verification: Immediately before the test, and with the exposure chamber empty, all test parameters shall be adjusted to those required for the test. These conditions shall be maintained for at least one 24-hour period (or until proper operation and salt fog collection can be verified). The fallout rate and pH must be measured at the end of this initial period. Monitor and record the temperature imediately prior to testing, and at least every two hours thereafter.

e. Water used for this test must be essentially free of contaminants. Follow the guidance provided in Method 301, paragraph 10.1c.

4.3 Test Interruption

See General Guidance and Requirements, paragraph 11.

4.4 Procedure

4.4.1. Pretest information

See General Guidance and Requirements, paragraphs 5 and 6.1.

4.4.2. Preparation of Salt Solution

Prepare the required solution by dissolving 5 parts by weight of salt in 95 parts by weight of water. In the anhydrous state, the sodium chloride should not contain more than 0.5% of total impurities nor more than 0.1% of sodium iodide. It should contain essentially no nickel or copper. Maintain the solution within the required specific gravity range by using the measured temperature and density of the salt solution (figure 1). Maintain the pH of the salt solution, as collected as fallout in the exposure chamber, between 6.5 and 7.2 with the solution temperature at +35^{o}C. Only diluted chemically pure hydrochloric acid or sodium hydroxide shall be used to adjust the pH. Make the pH measurement electrometrically or colorimetrically. 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.

4.4.3. Preparation for Test

Perform the pretest standard ambient check as specified in General Guidance and Requirements, paragraph 12. Handle the test item as little as possible, particularly on the significant surfaces, and prepare it for test immediately before exposure. Unless otherwise specified, test items shall be free of surface contamination such as oil, grease, or dirt, that could cause dewetting. Do not include the use of corrosive solvents, solvents that deposit either corrosive or protective films, or abrasives other than a paste of pure magnesium oxide in the cleaning methods.

4.4.4. Test conduct

Step 1. With the test item installed in the test chamber in its specified configuration (or as otherwise specified in the requirements documents), adjust the test chamber temperature to 35^{o}C and condition the test item for at least 2 hours before introducing the salt fog.

Step 2. Continuously atomize the required salt solution into the test chamber for a period of 24 hours or as specified in the test plan. Measure and document the salt fog fallout throughout each 24-hour atomization period. The fallout shall be as specified in 4.1b. The frequency of sampling should be sufficient to ensure that the fallout is maintained but the rate of corrosion will accelerate if the sample is allowed to dry significantly while the spray is off. If fallout quantity requirements are not met, that interval must be repeated. Measure the pH at least once during each spraying period. Care should be taken to ensure that there is consistency in this activity if comparative tests are to be conducted.

Step 3. Dry the test item at standard ambient temperatures and a relative humidity of 50 ± 5 % for 24 hours or as otherwise specified in the test item specification (see paragraph 2.4.3). Minimize handling the test item or adjusting any mechanical features during the drying period.

Step 4. Repeat steps 1-3 once or as otherwise required to reach the cycles specified in the test plan.

Step 5. At the end of the drying period, unless otherwise specified, operate the test item and document the results for comparison with pretest data.

Step 6. Visually inspect[5] the test item for any changes (see para 2.1) to the extent practical. To aid in examination, a gentle wash in running water (38°C maximum) may be used.

Step 7. Complete any further inspections or operational checks and document the results for comparison with pretest data.

5. EVALUATION OF THE TEST RESULTS

In addition to General Guidance and Requirements, paragraph 13, 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.

6. REFERENCEs AND Related DOCUMENTS

See General Guidance and Requirements, paragraph 14.

a International Electrotechnical Commission (IEC), Publication 68, Basic Environmental Testing Procedures for Electronic Components and Electronic Equipment, 1974.

b. Methodology Investigation on Evaluation of Test Procedures Used for Salt Fog Tests, U.S. Army Test and Evaluation Command Project No. 7-CO-PB7-AP1-018, July 1979.

c Junker, V.J., The Evolution of USAF Environmental Testing, AFFDL-TR-65-197, October 1965.

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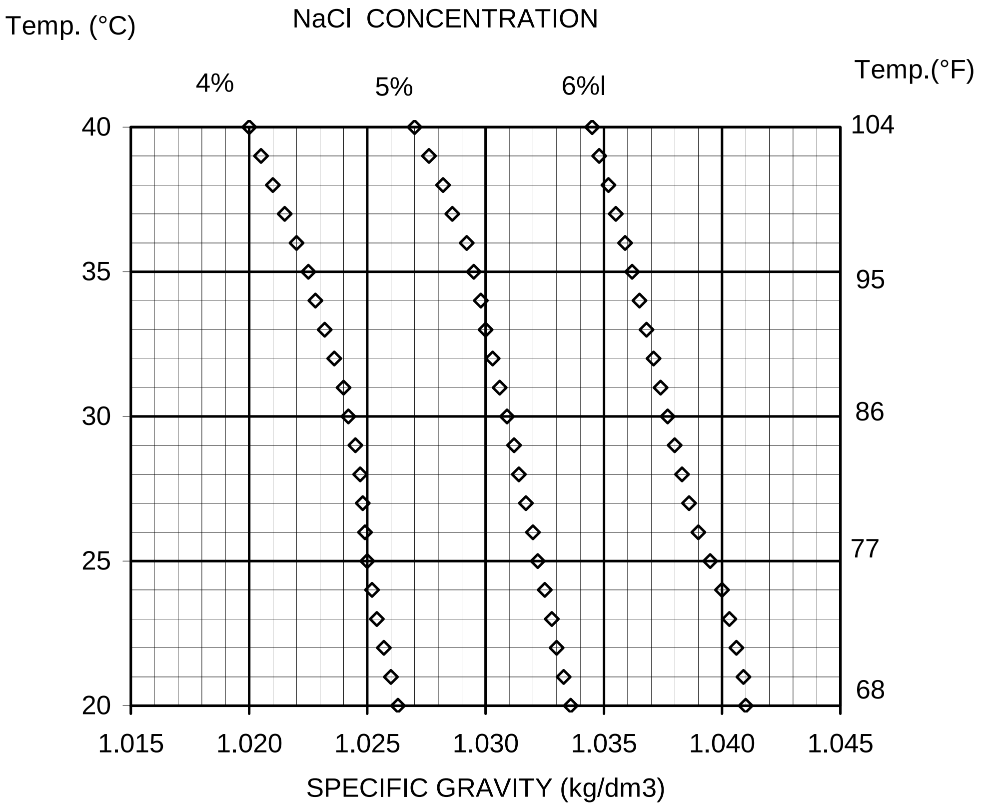
[5] *Visual examination of the test item should consider high stress areas; contact of dissimilar metals; electrical/electronic components; metallic surfaces; enclosed volumes where condensation may occur; components provided with corrosion protection coatings; cathodic protection systems, and mechanical systems subject to malfunction if clogged or coated with salt deposits.*


Temp. (°C)
NaCl CONCENTRATION
Temp.(°F)
4%
5%
6%l
40
35
30
25
20
104
95
86
77
68
1.015
1.020
1.025
1.030
1.035
1.040
1.045
SPECIFIC GRAVITY (kg/dm3)

INTENTIONALLY BLANK

METHOD 310

RAIN AND WATERTIGHTNESS

TABLE OF CONTENTS

METHOD 310

RAIN AND WATERTIGHTNESS

NOTE: *METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD. ADDITIONALLY, ANNEX A CONTAINS GUIDANCE ON TAILORING AND SPECIAL CONSIDERATIONS FOR PERFORMING THE FOLLOWING TEST PROCEDURES.*

1. SCOPE

1.1 Purpose

These tests are conducted to determine with respect to rain, water spray or dripping water:

a. The effectiveness of protective covers, cases, packaging, or seals;

b. The capability of the materiel to satisfy its performance requirements during or following exposure;

c. The physical deterioration of the materiel due to wetting/moisture ingress;

d. The effectiveness of the water removal systems.

1.2 Application

This method is applicable to materiel that may be exposed to rain, water spray or dripping water. The immersion test (Method 307) was traditionally considered to be more severe than the rain test for determining the penetrability of materiel. The immersion test may, in some cases, be used to verify watertightness in lieu of a rain test provided that the materiel configuration would be the same for both situations and the method of water ingress is well understood. However, there are documented situations in which the impact of rain causes pumping of water across seals that does not occur in the immersion test because the seals are held tight against the backing plate by the static pressure. In most cases it is more appropriate to carry out both tests.

1.3 Limitations

These test procedures are not suitable for:

a. Determining the effects of rain erosion;

b. Determining the atmospheric rain effects on propagation of electromagnetic radiation, light, etc.;

c. Evaluating the adequacy of aircraft windshield rain removal devices;

d. Evaluating materiel exposed to only light condensation drip rates (lower than 140 L/m^2/hr) caused by an overhead surface. For this case the aggravated humidity cycle of Method 306 will induce a significant amount of free water on both inside and outside surfaces;

e. Evaluating the effects of pressure washers or decontaminations devices.

2. TEST GUIDANCE

See Method 301, paragraphs 1 and 2.

2.1 Effects of the Environment

Rain (when falling, upon impact, and as deposited water), water spray and dripping water have a variety of effects on materiel. Examples of effects resulting from exposure to these environments are as follows. The list is not intended to be all-inclusive and some of the examples may overlap the categories.

a. In the atmosphere, it:

  (1) Inhibits visibility/detectability through optical devices.

  (2) Decreases effectiveness of personnel in exposed activities.

b. After deposition and/or penetration, it:

  (1) Degrades the strength/causes swelling of some materials.

  (2) Increases weight.

  (3) May freeze, which can cause delayed deterioration and malfunction by swelling or cracking of parts, or binding of moving parts.

  (4) Causes high humidity which can, in time, encourage corrosion and mould growth.

  (5) Reduces the burn rate of propellants.

  (6) Modifies thermal exchanges.

(7) Can render an electrical or electronic apparatus inoperative or dangerous.

(8) Can cause flash flooding, which may result in an immersion environment.

2.2 Choice of Test Procedure

(See Method 301, paragraphs 1 and 2.)

Three test procedures are provided in this method.

2.2.1 Procedure I – Rain and Blowing/Driving Rain

The Rain and Blowing Rain test is appropriate if the anticipated environment includes rain or rain combined with wind. The Driving Rain test set-up attempts to simulate blowing rain by using a pressurised nozzle arrangement but is not recommended unless facility limitations preclude wind generation, since the effects of impact velocity may not be properly addressed.

2.2.2 Procedure II – Exaggerated Rain

This procedure is not intended to simulate natural rainfall but is recommended when:

a. Large (shelter-size) materiel is to be tested and a blowing-rain facility is unavailable or impractical;

b. A high degree of confidence in the watertightness of materiel is desired;

c. The materiel will be exposed to non-natural sprays, such as road-spray or sprinkler systems;

d. The flux density of water impacting upon the item will be more severe due to extreme wind or motion of the item (eg. An item attached to the exterior of a vehicle during a normal rainfall will experience a more intense rate of rain impact due to the velocity of the vehicle).

2.2.3 Procedure III – Drip

This procedure is appropriate when materiel is not expected to be exposed to rain, but may be exposed to dripping/falling water from severe condensation or leakage from overhead surfaces.

2.3 Sequence

(See Method 301, paragraph 2.3.)

This Method is applicable at any stage in the test program, but its effectiveness is maximised if it is performed towards the end of the test program since the synergistic effects of the other tests can affect seal integrity of an enclosure.

2.4 Choice of Test Severities

(See Method 301, paragraphs 1-4.)

Variables include the test item configuration, rainfall rate, duration of exposure, wind velocity, test item exposure surfaces (orientation), and the water temperature with respect to the test item temperature.

2.4.1 Rainfall rate

For Procedure 1, the rainfall rate and duration should be tailored to address the anticipated deployment locale, material commodity, and mission criticality. Only when rainfall intensity-frequency-duration curves, commodity failure modes, material criticality, or mission location/duration are unavailable or not well understood, are the rates and durations suggested in Figure 1 recommended. Figure 1 includes 3 parts: an extreme 5-minute rainfall at an intensity of 14 mm/min, 25-minute rainfall at 8 mm/min, and 2-hour rainfall 1.7 mm/min. These parts, combined as one test, provide survival confidence for stationary materiel exposed for an extended period in the worst locations of the world (Reference A). Procedure 1 can consist of one or more parts as required to address specific commodity, materiel/usage or criticality issues. Small and localized rain bursts, such as during a thunderstorm, produces the heaviest rainfalls over a few hours or less, represented by the highest and mid intensity rates in Figure 1. These parts address the ability of materiel to withstand heavy storms and adequately dissipate and drain away water, and could be omitted if for example the item will not be operated in heavy rain. The lower intensity long duration portion represents steady-state rain, which addresses failures such as material soaking up water over a long period of time, or the gradual buildup of water inside an item with inadequate drainage. This part could be omitted if these issues do not affect the materiel. Care must be exercised to ensure that the test adequately assesses the commodity, usage and environment over the anticipated life cycle. Further information and guidance regarding rainfall rates may be obtained from Annex A and leaflet 2311.

For Procedure II, the suggested spray rate is 40 mm/min. Tailoring is not recommended unless the specific reasons for tailoring are fully understood, as this test has been traditionally used to provide materiel confidence.

The recommended drip rate for Procedure III is 280L/m^2/hr (4.67mm/min) for an exposure duration of 15 minutes. The intention of Procedure III is to ensure that the item will survive droplets of water falling onto it at any particular location and consequently this procedure is an aggravated test whereby droplets fall repeatedly over the entire surface of the test item. This can cause difficulties with small items that are not able to drain away the flow of water produced by multiple drips. When evaluating equipment exposed only to light (lower than 140 L/m^2/hr) condensation drip rates caused by an overhead surface, the aggravated humidity cycle of Method 306 may induce similar levels of surface water. In such cases, effects of internal condensation and the lack of drop impact and splash must be considered. For known conditions where a 280 L/m^2/hr drip rate cannot occur, the product may be tested by reducing the drip rate and proportionately increasing the test duration. For example, for a product exposed only to 140 L/m^2/hr, the rate may be appropriately reduced if the duration of the test is extended to 30 minutes to ensure the equivalent volume of water falls on the product.

2.4.2 Exposure duration

The exposure duration should be determined from the life cycle profile but should not normally be less than that specified in the individual procedures. This duration is representative for a stationary item exposed for 10 years in the worst locations of the world. For materiel liable to accidental exposure, lower intensities or shorter durations may be appropriate.

With certain materials, the water penetration and thus the degradation is more a function of time (length of exposure) than the volume or rain/drip rate. For any materiel made of material that may absorb moisture, the duration of the test may have to be significantly extended to reflect the real life cycle. For items that do not absorb water there is likely minimal value in exceeding the recommended durations, however the duration may be extended where concern exists.

2.4.3 Droplet size

Although nominal drop-size spectra exist for instantaneous rainfall rates, natural rain varies intensity from moment to moment and hence these instantaneous spectra are effectively meaningless. For Procedure I and Procedure II, droplet sizes should not be smaller than approximately 0.5 mm in diameter which is considered to be a mist or drizzle rather than rain, or larger than 4.5 mm. For Procedure III, polyethylene tubing sleeves added to the dispensing tubes (ref Figure 3) will increase the droplet size to its maximum. Procedure III is not meant to simulate rain but rather droplets of condensation or overhead leakage, and therefore droplets may be larger than 4.5 mm in diameter.

NOTE: *Observations have shown that water droplets introduced into a high velocity air stream tend to break up over distance (Reference B.). It is recommended that the droplets be introduced as close as possible to the test item while assuring the droplets achieve the required velocity prior to impact with the test item, where applicable.*

2.4.4 Wind velocity

Rainfall accompanied by winds of 18 m/s is not uncommon during storms. This velocity is recommended unless otherwise specified or vertical rain conditions are required. Gusts exceeding 24 m/s can be associated with these winds and may be required in the test plan. Unless otherwise specified, the wind need only be applied during the 2-hour steady-state rainfall. Where test facility limitations preclude the simulation of wind, the test setup shown in Figure 4 may be used.

2.4.5 Test item exposure surface(s) (orientation)

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. Orient the test item such that the most vulnerable surfaces face the driving rain. Rotate the test item as required to expose all vulnerable surfaces or openings, with attention to locations where pooling of water may occur.

2.4.6 Temperature

Experience has shown that a temperature differential between the test item and the rain water can affect the results of a rain test. For nominally sealed items, increasing the test item temperature approximately 10°C above the rain water temperature at the beginning of each exposure period will subsequently produce a negative pressure inside the test item, and will provide a more reliable verification of its watertightness.

3. INFORMATION TO BE PROVIDED IN THE TEST INSTRUCTION

In addition to the information specified in Method 301, paragraphs 5 and 6, the following are required:

a. Rainfall, spray, or drip flow rate(s) at exposure surface;

b. Exposure duration;

c. Water temperature;

d. Test item preheat temperature;

e. Exposure surfaces detailed with respect to (a) and (b);

f. Wind velocity, operational time, and direction with respect to (e).

4. TEST CONDITIONS AND PROCEDURES

See Method 301, paragraphs 7-10, for test facility, test conditions and test control information.

4.1 Test Facilities

See Method 301, paragraph 8. Unless otherwise specified, water used for rain tests can be from local water supply systems and shall be free from particles that can block the nozzle or tubing apertures. For the drip test, it is recommended that water from this source be filtered using a fine sediment filter to ensure particulate buildup does not block the tubing. A water-soluble dye such as fluorescein may be added to the rainwater to aid in locating water leaks. No rust or corrosive contaminants shall be imposed on the test item by the test facility. The facility temperature need not be controlled, as the water introduced as rain will significantly affect it.

4.1.1 Procedure I - Rain and Blowing/Driving Rain

The rain facility shall have the capability of producing falling rain accompanied, if required, by wind at the velocity specified. Where facility limitations preclude the generation of wind, the facility shall be capable of producing rain using the arrangement of the nozzles around the test item as shown in Figure 4. In this case, the rainfall rate will need to be increased on the appropriate materiel surface(s) to represent the effective rainfall rate that would be induced by the wind (See Annex A for details). The rain is to be produced by a water distribution device of such design that the water is homogeneously distributed in the form of droplets having a diameter range predominantly between 0.5 and 4.5 mm (see paragraph 2.4.3). Spray nozzles, or the apparatus shown in Figure 2 (with the polyethylene tubing removed), are suggested. If a dispenser is used for steady state rain, the height of the dispenser shall be sufficient to ensure that the drops approach terminal velocity (approximately 9 m/s). The wind source shall be capable of producing a horizontal wind velocity of at least 18 m/s.

4.1.2 Procedure II – Exaggerated Rain

The spray is to be produced by a water distribution device such that the water impacting the materiel is a steady spray pattern of homogeneous droplets predominantly in the range specified in paragraph 2.4.3. The nozzles used shall be arranged to ensure homogeneous wetting of the test item surfaces; one such arrangement is depicted in Figure 5. A minimum operating pressure of 377 kPa is recommended to produce the desired effects.

4.1.3 Procedure III - Drip

The dispenser arrangement shall allow a flow rate of not less than 280 $l/m^2/h$, but without coalescence of the drips into a stream. Alternative dispenser designs are shown in Figures 2 and 5, but other configurations may be used provided the spacing, rate, and size of individual drops are equivalently maintained. Either arrangement shown in Figure 2 is recommended over that of Figure 5 due to the simplicity of construction, maintenance, cost and reproducibility of tests. The polyethylene tubing ensures maximum droplet size. Use a drip height representative of the actual situation being simulated; unless otherwise specified, one meter is suggested. The drip area of the dispenser should be large enough to cover the entire top surface of the test item. The dispenser shown in Figure 5 requires accurate leveling together with extensive cleaning and maintenance to ensure consistency of the drip pattern. It is recommended that de-ionised or distilled water be used to minimize contamination of the test facility, and that the test item and the dispenser be covered to prevent accumulation of dust that could clog the dispenser holes. Since facility imperfections or small amounts of contamination can affect the test, control the flow rate either by introducing water through a flow meter (preferred) or by controlling the depth of the water in the drip dispenser (after verifying that the selected depth produces the required flow) to ensure the proper drip rate.

4.2 Controls

In addition to the controls specified in Method 301, paragraph 10, verify that the rainfall/spray rate and wind velocity at the position of the test item are correct before placement of the test item in the test facility. It may be necessary to measure the rainfall rate without the wind in order to ensure accurate measurement. Ensure that only separate (or discrete) drops are issuing from the dispenser. Where nozzles are used, it is not correct to measure the spray pattern of each nozzle independently as any overlap or excess spacing would not be found. Additionally, the pressure shall be at least the minimum necessary to maintain a homogeneous pattern distribution. Once the spray pattern and rate have been verified, it may be sufficient to verify the water pressure immediately before subsequent tests, so long as none of the variables of the test have been altered. For Procedure III, the flow rate must be confirmed before and after the test to ensure test tolerances are met from beginning to end of test.

4.3 Test Interruption

See Method 301, paragraph 11.

4.4 Test Procedures

4.4.1 Test Preparation

Before starting the test, determine the information to be documented in accordance with Method 301, paragraphs 5 and 6.1, and perform the pretest standard ambient check specified in Method 301, paragraph 12. If wind is required, position the wind source with respect to the test item in accordance with para 2.4.5.

NOTE: *No sealing, taping, caulking, etc., shall be applied to the test item except as required by the design specification for the test item. Unless otherwise specified, test items shall be free of surface contamination such as oil, grease or dirt, which could cause dewetting.*

4.4.2 Procedure I – Rain and Blowing/Driving Rain

Step 1. For materiel intended to be opened during use or for field maintenance, open the test item.

Step 2. Heat the test item to a higher temperature than the rain water such that the test item temperature has been stabilized at 10 ± 2°C above the rain water temperature at the start of each exposure to the rain (see paragraph 2.4.6).

Step 3. Install the test item in the rain test facility in the required test configuration. Position the test item so that when steady state or wind-driven rain is initiated, rain will be sprayed over the specified surfaces of the test item.

Step 4. Start the rain and, if appropriate, the wind at the velocity specified in the test plan, and maintain the prescribed rainfall conditions for the specified duration.

Step 5. If an operational check is required, operate the test item for the last 10 minutes (or as otherwise specified) of the rain duration selected for Step 4.

Step 6. Examine the test item for water within one hour of completion of exposure. If possible, examine the test item in the test chamber; otherwise remove the test item from the test facility and conduct a visual inspection. Dry the exterior surface of the test item before opening for internal inspection. If a noticeable amount of free water has penetrated the test item, judgment regarding potential safety hazards shall be made before operating the test item. It may be necessary to empty water from the test item to prevent a safety hazard. Record the approximate quantity and location of any free water found inside the test item, and identify probable area(s) of ingress.

Step 7. Repeat steps 1 through 6 for all faces of the test item that could be exposed to blowing or steady state rain.

Step 8. If required, operate the test item to demonstrate compliance with the requirements document, and document the results.

4.4.3 Procedure II – Exaggerated Rain

Step 1. Install the test item in the test facility in normal operational configuration.

Step 2. Position the nozzles as required by the test plan or as indicated in paragraph 4.4.1 and Figure 5.

Step 3. If practical, heat the test item to a higher temperature than the rain water such that the test item temperature has been stabilized at 10 ± 2°C above the rain water temperature at the start of each exposure to the rain (see paragraph 2.4.6).

Step 4. Unless otherwise specified, spray individually or in any combination all exposed surfaces of the test item with water for 40 minutes per face.

Step 5. Inspect the interior of the test item for evidence of free water. Estimate the water volume and the probable point of entry, and document.

Step 6. If required following removal of any free water, operate the test item to demonstrate compliance with the requirements documents, and document the results. Be aware of any potential electrical safety hazard.

4.4.4 Procedure III – Drip

Step 1. Heat the test item to a higher temperature than the rain water such that the test item temperature has been stabilized at 10 ± 2°C above the rain water temperature at the start of each exposure to the rain (see paragraph 2.4.6).

Step 2. Install the test item in the test facility in accordance with the test plan, in its operational configuration with all connectors and fittings engaged.

Step 3. Subject the entire top surface of the test item to water droplets falling from specified height measured from the upper main surface of the test item at the specified uniform rate for 15 minutes or as otherwise specified.

Step 4. At the conclusion of the exposure period, examine the test item in the test facility if possible. Dry the test item externally and remove sufficient panels or covers to allow the interior to be inspected.

Step 5. Visually inspect the test item for evidence of water penetration. Estimate the amount of any water inside the test item, and estimate the probable point of entry, and document.

Step 6. Conduct an operational check of the test item as specified in the test plan and document the results, but be aware of potential electrical hazards.

5. EVALUATION OF THE TEST RESULTS

In addition to the failure criteria specified in Method 301, paragraph 13, particular attention should be given to swelling which may cause the materiel to exceed its specified design tolerances or cause binding and/or distortion. Weight increases may indicate absorption or ingress to hidden crevasses, which may later lead to material delamination, degradation, or structural damage. In some cases, it may be insufficient to test operability of the materiel after exposure, and may be critical to test the operability of the item during exposure. Additionally, based on a risk assessment of the consequences of water penetration, determine if one of the following is applicable:

a. Watertight: any evidence of water penetration into the test item enclosure following the rain test shall be considered a failure;

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

   (1) There is no immediate or anticipated long-term effect of the water on the operation of the materiel;

   (2) The test item in its operational configuration (transit/storage case open or removed) can successfully complete the aggravated temperature/humidity procedure of method 306.

This quantity of water is approximately the quantity required to raise the relative humidity of one cubic foot of air at standard ambient conditions to saturation at 49°C. The 49°C value is realistic for equipment exposed to higher temperature and solar radiation effects.

Greater water penetrability may be acceptable, provided the above conditions are met and it can be proven that safety, operability, and survivability are not affected.

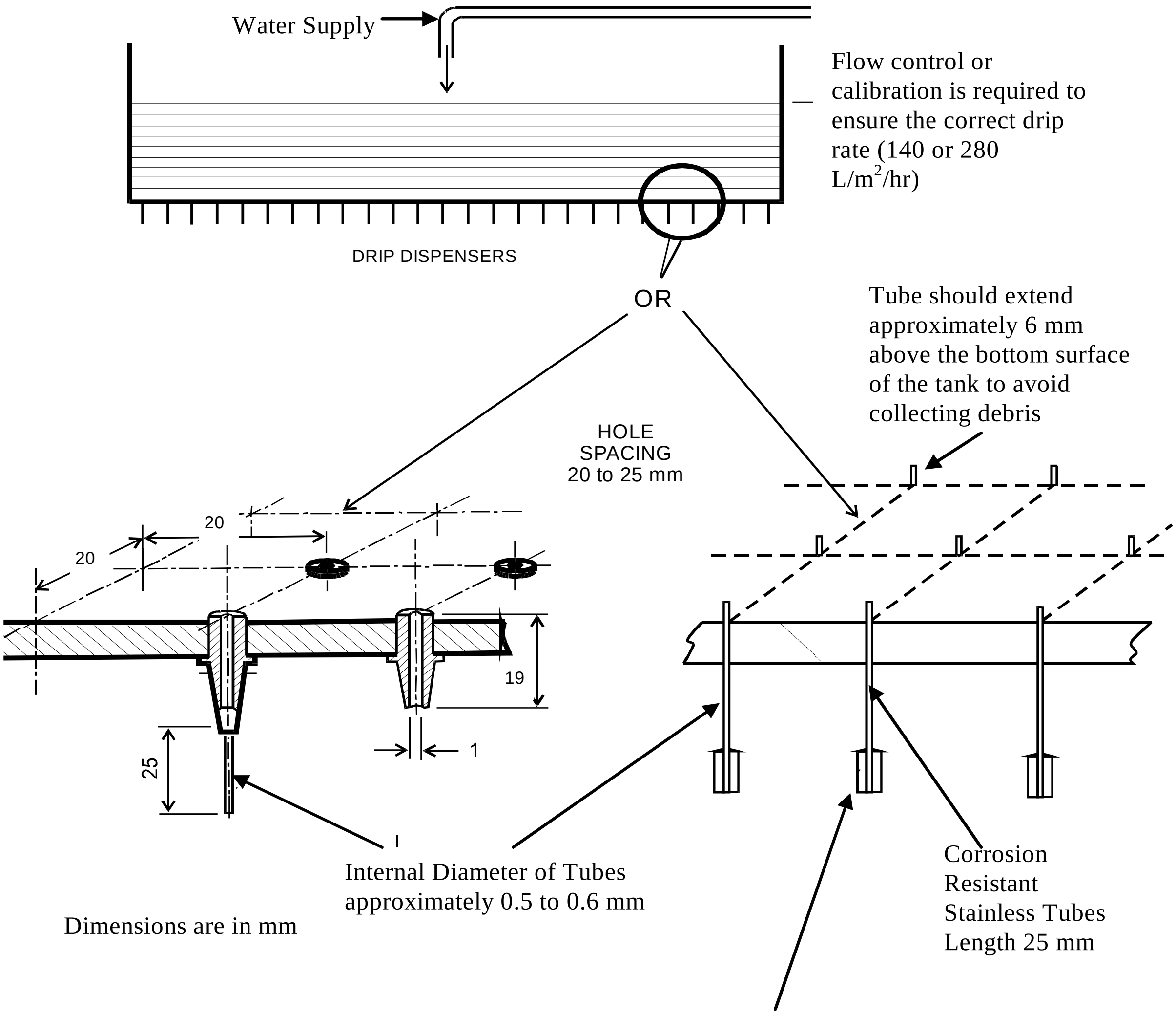
6. REFERENCES AND RELATED DOCUMENTS

See Method 301, paragraph 14.

A. Kaddatz, J., “NATO Rain Characterisation and Procedure Development”, QETE Project A011401, Canadian Department of National Defence, 2003.
B. Rogers, R. R., “Short Course in Cloud Physics,” Pergamon Press, Oxford; 1979.
C. Moriceau J. Etude Technique No. 749/84/SEM, DGA/LRBA, Vernon, France

Test Level	**Rate**	**Duration**	**Wind Velocity**
Extreme	**14 mm/min**	**5 min**	**If specified**
High	**8 mm/min**	**25 min**	**If specified**
Steady-State	**1.7 mm/min**	**120 min**	**18 m/s**

Figure 1: Procedure I, Recommended Rainfall Test Levels



Flow control or calibration is required to ensure the correct drip rate (140 or 280 L/m^2/hr)

Tube should extend approximately 6 mm above the bottom surface of the tank to avoid collecting debris

Internal Diameter of Tubes approximately 0.5 to 0.6 mm

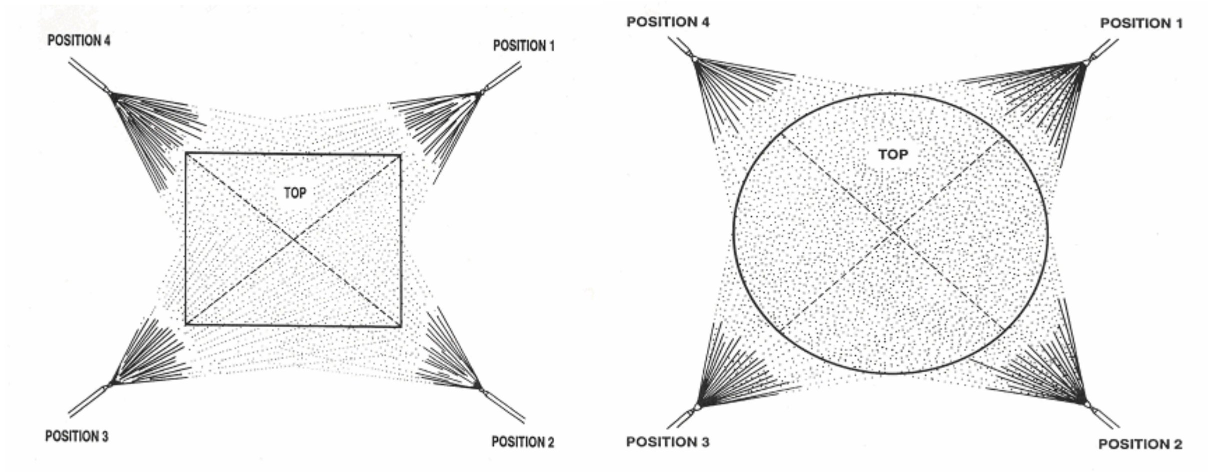
Dimensions are in mm

Corrosion Resistant Stainless Tubes Length 25 mm

Polyethylene or similar flexible sleeve 5 mm long by 5mm outside diameter, placed over ends of tubing to increase drop size. It should extend 2.5 mm beyond the bottom of the tubing.

Remove for rain tests.

Figure 2. Sample facility setup for rain or drip test



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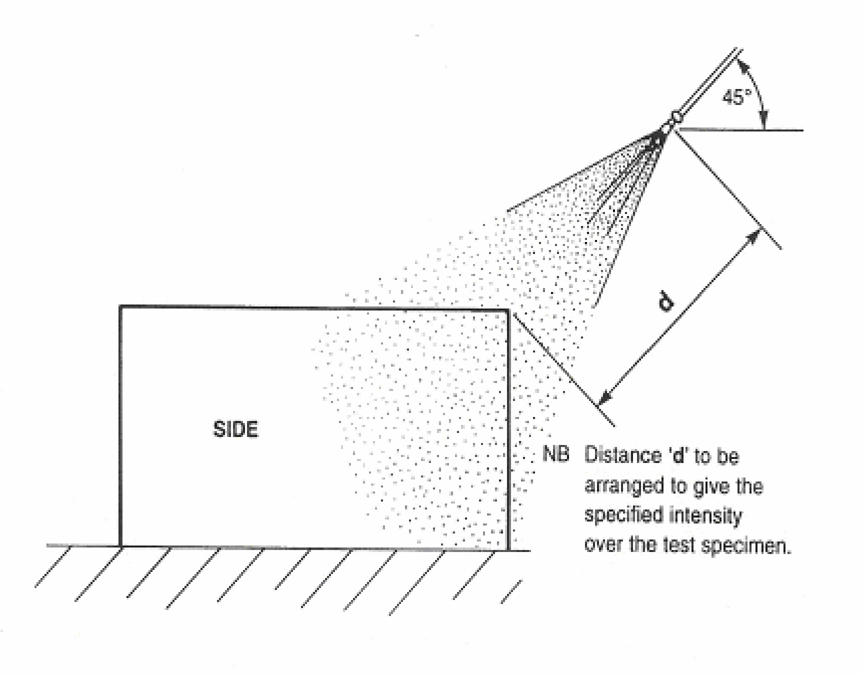
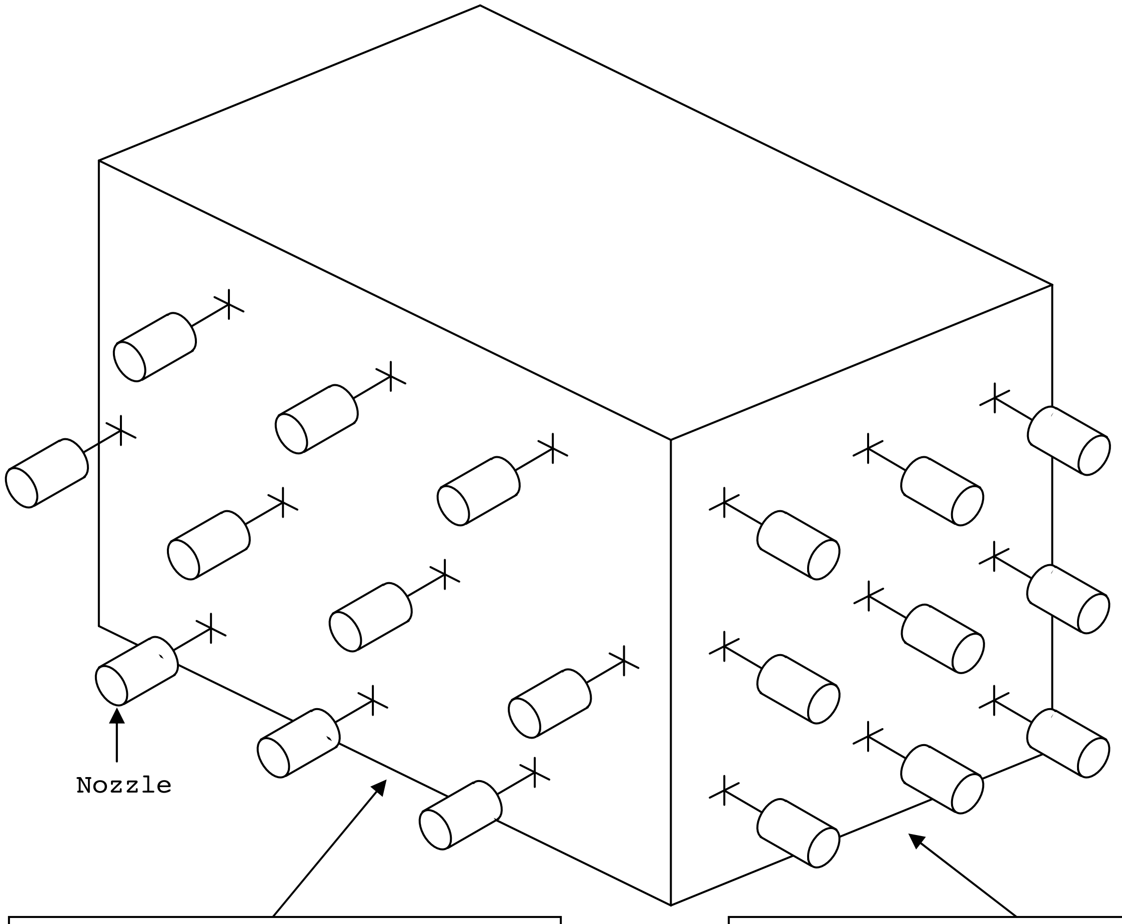


Figure 3. Nozzle arrangement for Procedure I, where wind is unavailable.



Circular Pattern Nozzles:
Use array of nozzles based on equilateral triangular spacing for minimal variance in spray distribution.

Square Pattern Nozzles:
Use array of nozzles based on square spacing for minimal variance in spray distribution.

*Adjust spacing and standoff as necessary to achieve spray overlap.

Note: Ensure nozzles are perpendicular to the surface(s), and situated such that each surface including top surface (and especially vulnerable areas) is sprayed.

Figure 4. Typical nozzle arrangement for Procedure II.

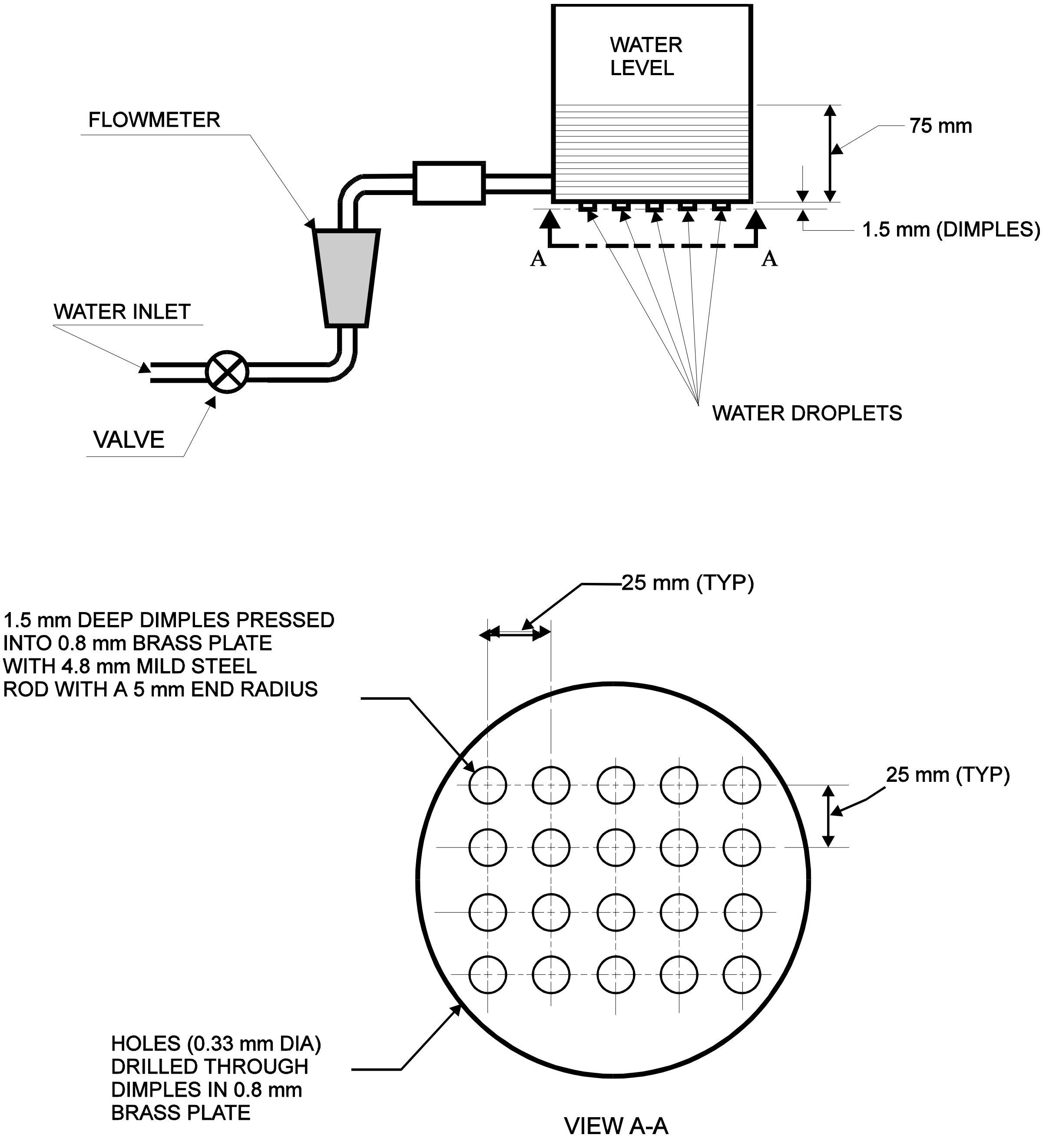


Figure 5. Details of alternative dispenser for drip test, Procedure III.

ANNEX A

DETAILED GUIDANCE FOR TAILORING RAIN

1. INTRODUCTION

This Annex provides additional information to aid in tailoring the rain and blowing/driving rain test procedures.

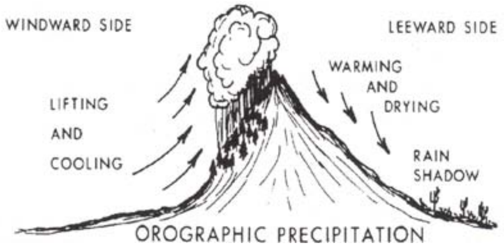
2. INTENSITY VS DURATION

2.1 Types of Rain

Rainfall is often classified according to the process causing the uplift of air initiating the rain formation; there are three main types of rain that are not mutually exclusive, and these are known as orographic, cyclonic, and convective (Reference A and Reference B).

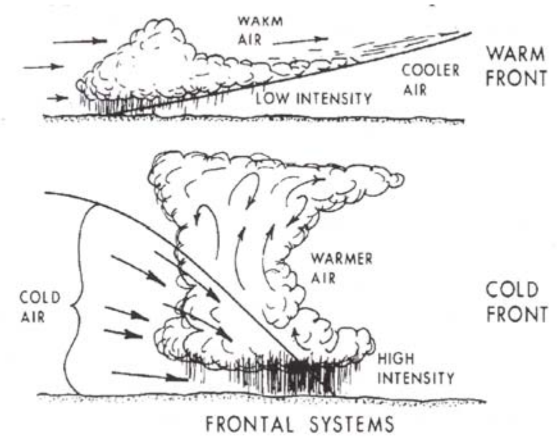
2.1.1 Orographic Rain

With orographic rain, the main cause is the forced ascent of moist air over high ground. The enhanced precipitation is often due to raindrops falling into the large amounts of low cloud formed by this ascent, giving rise to the 'seeder/feeder' mechanism. Orographic precipitation is often responsible for high monthly and annual rain amounts; however, windward slopes are also prone to very extreme amounts when affected by tropical storms. Due to the high rainfall on the windward slope of a mountain, the leeward side will often have lower precipitation; this condition is known as the "shadow effect".



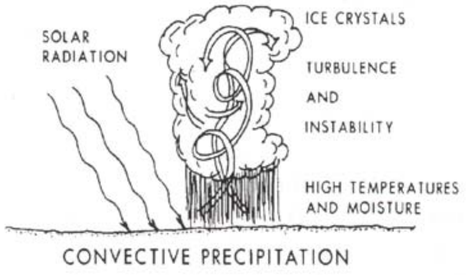
2.1.2 Cyclonic Rain

With cyclonic rainfall, large scale uplift is associated with features of the general weather situation, such as fronts and depressions. Tropical cyclones are responsible for most of the extreme amounts for a few hours to a few days.



2.1.3 Convective Rain

Convective rain falls from a cumuliform cloud with an unstable air mass, where columns of cloudy air can rise, and rapidly form raindrops. Rainfall intensity is typically greater than for cyclonic or orographic rain, but individual areas of rain are generally small (20km diameter or less), with dry areas close by. This type of rain produces the heaviest rainfalls over periods of a few hours or less. Although heavy winds are often associated with convective rain, these typically do not occur at the core of the storm where the rain is heaviest, since the causation for heavy rain is the strong downdraft.



2.2 Measuring Rainfall Intensity

Instantaneous rainfall intensity cannot be measured directly, but rather is an average value calculated as the volume of water per unit surface impact area per unit time (eg $mm^3/mm^2/min$ or $L/m^2/hr$). The measurement units can be simplified to specify rate in depth of water per unit time (eg mm/min), as is often the case in this test method. The volume of water collected is measured using a fluidic measurement unit (eg mL), converted to mm^3, divided by the surface area of the opening to the collection container, and finally divided by the time of collection. A common apparatus for measuring rainfall intensity is the tipping bucket rain gauge, however tipping buckets may not have the capacity to measure 14mm/min, and will almost certainly not be able to measure 40mm/min.

2.3 Intensity-Frequency-Duration (IFD) Curves

Due to the different types of rainfall, shorter rainfalls are often more intense. Climatologists and meteorologists often present this information in a simple diagram, known as IFD curves. These curves show the relationship between the intensity and duration, for different return periods. A sample IFD curve is shown in Figure 1. IFD curves will differ from one location to the next due to the differences in geographic features that influence the causation of the rainfall.

Standard practices for rain data collection do not often include gathering data for durations of less than one hour. When IFD curves are not available for short durations, the intensities for durations less than 1 hour may be estimated from the 1-hour value (Reference C), as shown in Table 1. These average ratios have been developed empirically from hundreds of station-years of records.

Table 1: Ratios for Estimating Short Duration Rainfall Rates from 1-Hour Value

Duration (minutes)	5	10	15	30
Ratio (n-minutes to 60-minutes)	3.48	2.70	2.28	1.58

Thus, if the 100-year one-hour rainfall rate is 102 mm/hr (1.7 mm/min), the 100-year ten-minute rainfall rate would be 275 mm/hr (4.6 mm/min). Caution must be exercised when using this approach. In regions where most of the rainfall occurs in connection with thunderstorms, the above ratios would tend to yield values that are too low; in regions where most of the rainfall results from orographic influences with little severe convective activity, these ratios might tend to yield values that are too high.

Alternatively, the IFD curve can be derived if the mean and standard deviation of annual extreme rainfall rates for various durations are known, by analyzing the data as a Gumbel double exponential distribution (Note: the Gaussian/Normal distribution does not apply and consequently the data is not entirely contained within ±3 standard deviations).

Using the method suggested in Reference D,

$$x = \overline{x} + K(T)s$$

where x is the exceedance value, $\overline{x}$ and s are the mean and standard deviation of the annual extreme rainfalls, T is the return period, and $K(T)$ is defined by:

$$K(T) = \frac{-\sqrt{6}}{\pi}\left(0.5772 + \ln\ln\frac{T}{T-1}\right)$$

3. RISK ASSESSMENT

3.1 Return Period

One traditional convention for expressing frequency of occurrence is the return period, which is an average of the length of time between rainfall rates of a specific magnitude. For example, the 100-year rainfall rate occurs, on average over a large period of time (a millennium), every 100 years. This does not mean that if the event occurs on a given year that it cannot occur the following year.

An alternate approach to expressing this value is to state that there is a 1 in 100 (1%) chance that a rainfall of this magnitude could occur any given year. By applying annual probabilities in succession, the resulting probability of occurrence increases. Figure 2 relates the anticipated design life to the required return period rainfall that must be selected, in order to achieve a given probability of success. Success is defined as the condition in which the specified rainfall rate is not exceeded during the design life (duration of exposure) of the materiel.

Consequently, for a materiel intended for a field exposure of 10 years, the 100-year return period rainfall must be used to provide 90% confidence that the item will not experience rain more intense than the test condition. This success probability was used to derive the recommended values in the rain and blowing/driving rain test procedure.

3.2 Percentage Frequency of Occurrence

Another method traditionally used to express rainfall rate is the frequency of occurrence (Reference B, Reference E and Reference F). Caution must be exercised when interpreting data that uses the term frequency. Some sources refer to the percentage of time that rainfall is exceeded when raining (ie. Rainfall rate greater than some threshold value - the threshold is dependent upon the source of the data); others reference the general percentage of time that the rainfall rate is exceeded, including time when it is not raining (ie. Rainfall rate = 0 mm/min). This information is extremely useful for determining if the rain test is applicable or for determining operational failure criteria, however it can be misleading to define survivability failure criteria to rates that are exceeded only 0.5% of the wettest month, as this may be equivalent to annually receiving up to 3.65 hours of rain (during the specified month) in which the rainfall rate exceeds this threshold. If there is little variance in the precipitation patterns throughout the year, this could mean the materiel will experience up to 43.8 hours annually at this intensity.

4. RECORD INTENSITIES

The intensities associated with the maximum observed rainfalls (Reference C) have been enveloped by the equation:

$$R = 60.4T^{-0.525}$$

where R is the rainfall rate in mm/min and T is the duration in minutes.

The most intense 100-year return period (10 year design life, 90 % confidence) rainfalls have been estimated to occur in Hawaii and Puerto Rico (Reference G and Reference H), and these values were selected as the recommended test rain rates.

Figure 3 shows the recommended 100-year rainfall rates in comparison with the maximum observed intensities.

5. DROP SIZE

The velocity of water droplets is dependent upon the drop size. This is due to the fact that the air resistance is proportionate to the square of the velocity. Conversely, the velocity is dependent upon the effective surface area that this resistance acts upon which changes as the drop deforms slightly.

5.1 Natural Raindrop Size

Natural raindrop velocities for various drop sizes are shown in Table 2. Note that these values are approximate estimates only, and do not need to be matched precisely.

Table 2: Approximate Terminal Velocity Associated with Various Drop Sizes

Drop Diameter (mm)	Droplet Terminal Velocity (m/s)
0.5	2
1	4
2	6.5
3	8
4	9

Where droplets are formed and allowed to fall naturally for the rain/blowing rain procedure, the test facility must be sufficient in height to ensure terminal velocity of the droplets is reached before impact upon the test item. Test facilities using pressurised water may not require as much height, as the droplets will leave the spray nozzle with some initial velocity.

Drop sizes greater than 4.5 mm do not typically occur in natural rainfall, as droplets of this size will tend to break up during their descent, either due to air resistance or collision with other droplets.

5.2 Drip Test Drop Size

Since the drip test is not to simulate rain, the droplets do not need to reach terminal velocity. It is possible to achieve larger droplet sizes, since the air resistance may not be sufficient to cause them to break up. The largest drop size that can be achieved without coalescence is recommended.

6. MOTION AND FLUX DENSITY

The flux density of water droplets on the vertical surfaces of the materiel may be increased in situations where either wind or motion is involved.

6.1 Wind

Wind will increase the horizontal rate of water impact on vertical surfaces. Windward surfaces will receive:

$$R_{eff} = R_{nominal}\sqrt{1+\frac{v^2}{u^2}}$$

Where R_{eff} is the effective rainfall rate impacting upon the windward vertical surface (mL/m^2/min)
$R_{nominal}$ is the vertical rainfall rate without wind (mL/m^2/min)
v is the velocity of the wind (m/s)
u is the vertical velocity of rain droplets (m/s)

6.2 Motion

Where materiel is in motion, the rate of water impact upon the front of the materiel will increase proportionately to the square of the velocity. This is especially important on equipment mounted to the exterior of surface vehicles. For example, a vehicle traveling at 25 m/s (90kph), the rate of surface impact on the front of the materiel can be increased by over 4 times the nominal rainfall rate.

The effective rainfall rate can be calculated:

$$R_{eff} = R_{nominal}\sqrt{1+\frac{v^2}{u^2}}$$

Where R_{eff} is the effective rainfall rate impacting upon the forward surface (mL/m^2/min)
$R_{nominal}$ is the vertical rainfall rate (mL/m^2/min)
v is the velocity of the vehicle (m/s)
u is the vertical velocity of rain droplets (m/s)

The theoretical angle of impact can be calculated $\theta = \tan^{-1}(v/u)$ where θ is the angle measured with respect to the horizontal plane.

Where wind and motion exist simultaneously, v in the above equations is the net vector summation of the vehicle speed and wind speed.

For example, for a materiel mounted to the exterior of a typical land vehicle travelling 100kph (27.8m/s) in rainfall of 2mm/min intensity and a head wind of 65kph (18m/s), the resultant effective rainfall rate is:

$$R_{eff} = R_{nominal}\sqrt{1+\frac{(v_{vehicle}+v_{wind})^2}{u^2}}$$

$$R_{eff} = 2\sqrt{1+\frac{(27.8+18)^2}{9^2}}$$

$$R_{eff}=10.4\text{mm/min}$$

Simultaneously, the wind velocity should be increased to 45.8 m/s ($v_{vehicle}$ + v_{wind}) which may help alleviate concerns regarding impact velocity.

7. ALTITUDE

Rainfall at altitudes of up to 4 km (13000ft) may be 25-30% higher than rainfall rates at sea-level (Reference A and Reference B). Above this altitude, the precipitation will be consist partly or fully of snow or hail.

8. TEST SETUP CONSIDERATIONS

8.1 Manifold Size

The test setup must be of sufficient size to produce the desired effect. In procedures where wind is involved, the rate of water impacting upon the windward surface is increased as is described in para. 6.1; the cause for this increase originates from the fact that the wind is collecting droplets that would normally fall off to the side of the materiel and pushing them into the vertical surface. As such, there must be sufficient droplets falling to the side of the materiel during testing to recreate this phenomenon.

The required manifold extension, measure from the side of the materiel, is dependent upon the resultant angle of the driving rain, which is in turn dependent upon the wind velocity. The minimum required extension is:

$$d = h \cdot \frac{u}{v}$$

where h is the vertical distance between the apparatus producing the droplets and the lowest point on the test item (m)
u is the vertical velocity of falling rain (m/s)
v is the wind speed (m/s)

8.2 Pressurised Test Equipment

8.2.1 Nozzle Selection

Nozzle selection is not an exact science. Although nozzle companies publish flow/pressure/spray angle tables for each nozzle, even the nozzles that suggest they produce even distributions may in fact have a fallout rate directly under the nozzle that is significantly higher than the average over the spray area. Trial-and-error may be required to determine the optimum nozzle. Contrary to intuition, larger capacity nozzles may cause lower rainfall rates due to an increase in the spray angle, which will increase the impact surface area.

8.2.2 Nozzle Arrangement

For nozzles that produce a round spray pattern, an equilateral triangle manifold arrangement will result in the most even spray distribution. Nozzles that produce a square spray pattern will be most effective on a square grid arrangement.

8.2.2 Nozzle Spacing

It has been observed that using nozzles that produce a fraction of the required fallout rate, and providing significant overlap, may result in a more even and consistent spray distribution than selecting nozzles that produce the desired rainfall rate and spacing them with small overlap. Additionally, this will help ensure the rainfall rate is consistent regardless of the vertical distance away from the nozzle.

8.2.3 Nozzle Operating Pressure

For procedures involving pressurised water, a minimum pressure (dependent upon selected spray nozzle) is required to maintain a homogeneous spray pattern and prevent (non-obvious) streaming. Increased pressure will result in smaller droplet size, and consequently the lowest practical operating pressure is recommended. At certain pressures, some nozzles may be subject to sputtering due to resonance of the vane or some other design factor. This pressure region should be avoided, since results may lack reproducibility due to the chaotic variance. Particular attention should be given to external variables that may influence water pressure (eg flushing lavatory).

9. REFERENCES AND RELATED DOCUMENTS

A. DEF STAN 00-35 (Part 4) Chapter 6-01

B. MIL-HDBK-310

C. WMO No. 168, Guide to hydrological practices: data acquisition and processing, analysis, forecasting and other applications (5th Ed.), 1994.

D. Hogg, W.D. and Carr, D.A. Rainfall Frequency Atlas for Canada, Canadian Government Publishing Centre, 1985.

E. AECTP 200, Leaflet 2311.

F. Tattleman, Paul. A Climatological Model for 1-min Precipitation Rates.

G. Technical Paper No. 43, Rainfall-Frequency Atlas of the Hawaiian Islands, US Department of Commerce Weather Bureau, 1962.

H. Technical Paper No. 42, Generalized Estimates of Probable Maximum Precipitation and Rainfall-Frequency Data for Puerto Rico and Virgin Islands, US Department of Commerce Weather Bureau, 1961.

D. Moriceau J. Etude Technique No. 749/84/SEM, DGA/LRBA, Vernon, France

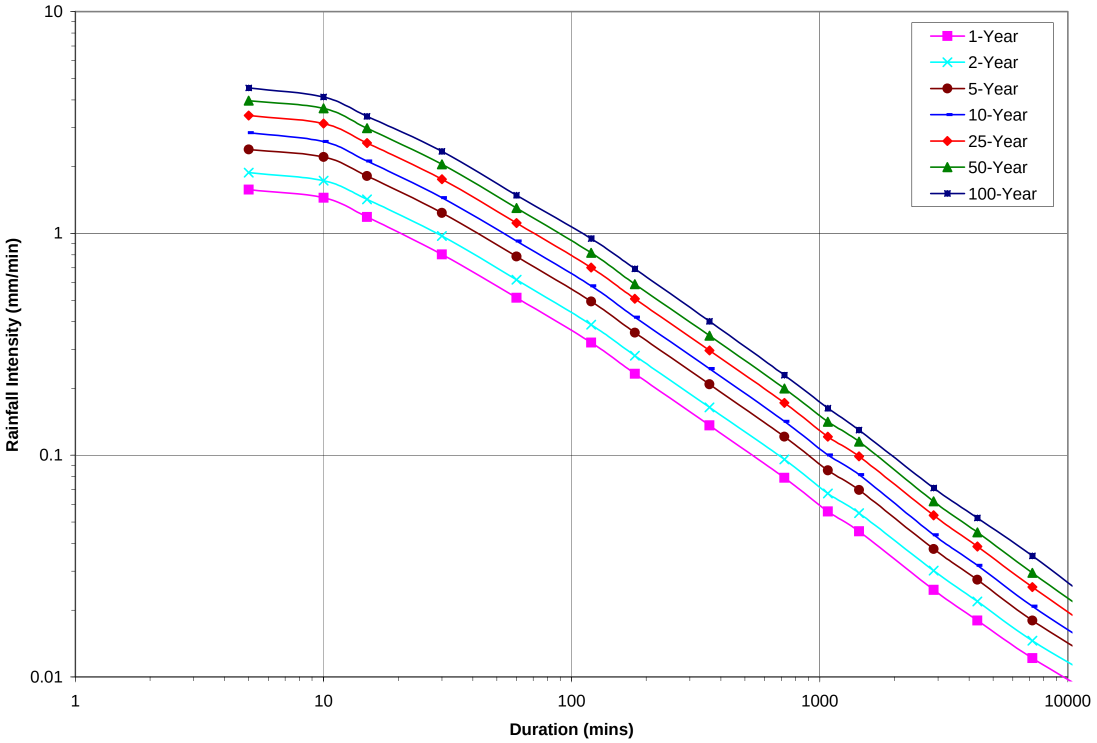
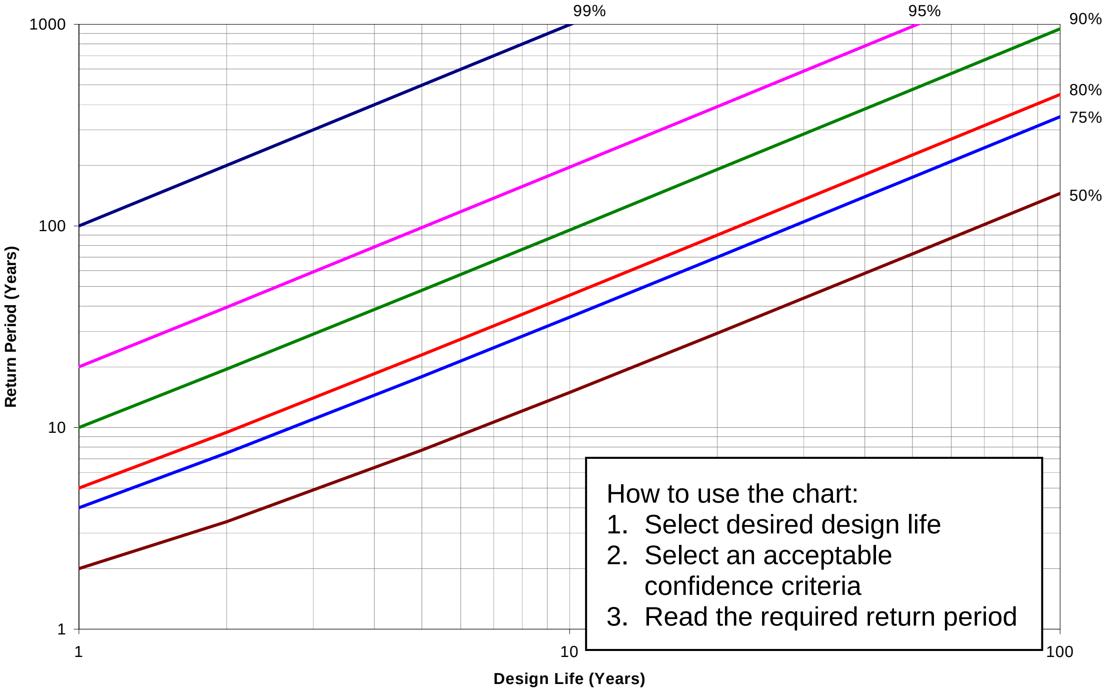


Figure 1: Sample IFD Curve



How to use the chart:
1. Select desired design life
2. Select an acceptable confidence criteria
3. Read the required return period

Figure 2: Risk Assessment Diagram

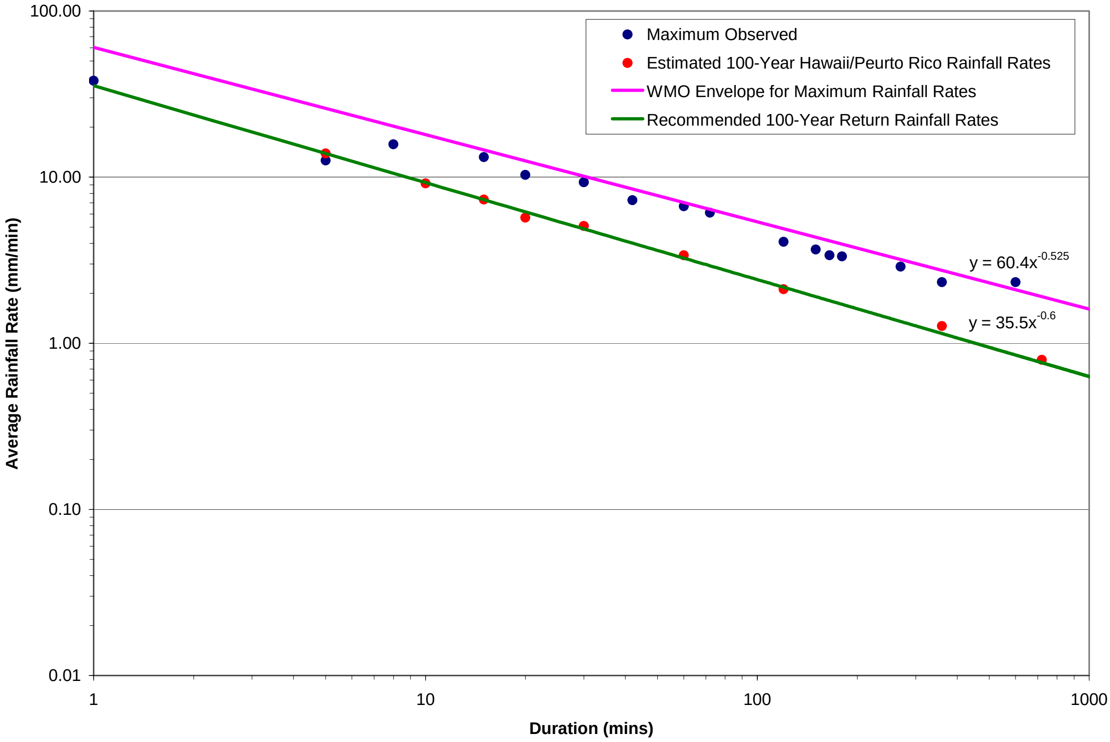


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Figure 3: Maximum Observed and Recommended 100-Year Rainfall Rates

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METHOD 311

ICING

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METHOD 311

ICING

NOTE: *METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD.*

1. SCOPE

1.1 Purpose

The icing test is conducted to evaluate the effect of icing on the operational capability of materiel. This Method also provides tests for evaluating the effectiveness of de-icing equipment and techniques, including prescribed means to be used in the field.

1.2 Application

a. This Method is applicable to materiel that may be exposed to icing such as produced by freezing rain or freezing drizzle (see paragraph 2.1.1 below).

b. This Method can be used for ice accretion from sea splash or spray, but the ice thicknesses may need to be modified to reflect the lower density of the ice.

1.3 Limitations

This Method does not simulate snow conditions or ice build-up on aircraft flying through supercooled clouds. Although frost occurs naturally, the effects are considered less significant and are not specifically addressed in this Method. This Method may not be suitable for the assessment of aerial/antenna performance, (i.e., rime ice saturated with air causes substantial signal reflection). For optional tests for testing vehicle windscreens/windshields, see EEC Directive 78/317/EEC (reference a). Also, this Method does not address icing effects from falling, blowing or recirculating snow and wet snow or slush. These are considered less severe than those in paragraph 2.2.

2. TEST GUIDANCE

See Method 301, paragraphs 1 and 2.

2.1 Ice Formation

2.1.1 Principal causes

A build-up of ice occurs in four principal ways:

a. From rain, drizzle or fog falling on materiel whose surface temperature is at or below freezing;

b. From sublimation;

c. From freezing rain or freezing drizzle falling on materiel at or near freezing, or

d. From sea spray and splash that coats materiel when the materiel temperature is below freezing.

2.1.2 Types of ice

(See Reference b)

Two types of ice are commonly encountered: rime ice (opaque/granular) and glaze ice (clear/smooth). Published extremes for ice accretion may be used for calculating design and structural evaluations, but are not considered practical for establishing test conditions due to the large thicknesses involved, unless the test is intended to provide practical confirmation of design calculations.

a. Rime ice: A white or milky and opaque granular deposit of ice formed by a rapid freezing of supercooled water drops as they impinge upon an exposed object. Rime ice is lighter, softer and less transparent than glaze. Rime is composed essentially of discrete ice granules and has densities ranging from 0.2 g/cm^3 (soft rime) to almost 0.9 g/cm^3 (hard rime). Factors that favour rime formation are small drop size, slow accretion, a high degree of supercooling, and rapid dissipation of latent heat of fusion. The opposite effects favour glaze formation.

(1) Hard rime: Opaque, granular masses of rime deposited chiefly on vertical surfaces by dense, supercooled fog. Hard rime is more compact and amorphous than soft rime, and builds out into the wind as glazed cones or feathers. The icing of ships and shoreline structures by supercooled spray from the sea usually has the characteristics of hard rime.

(2) Soft rime: A white, opaque coating of fine rime deposited chiefly on vertical surfaces, especially on points and edges of objects, generally in supercooled fog. On the windward side, soft rime may grow to very thick layers, long feathery cones, or needles pointing into the wind and having a structure similar to that of frost.

b. Glaze ice: A coating of ice, generally clear and smooth but usually containing some air pockets, formed on exposed objects by the freezing of a film of supercooled water vapour. Glaze is denser, harder and more transparent than rime. Its density may be as high as 0.9 g/cm^3. Factors that favour glaze formation are large drop size, rapid accretion, slight supercooling, and slow dissipation of heat of fusion. The opposite effects favour rime formation. Glaze occurs when rain or drizzle freezes on objects, and is clear and nearly as dense as pure ice. Since glaze ice is more difficult to remove, it is structurally a more significant factor and will be the focus of this test.

2.2 Effects of the Environment

Ice formation can impede materiel operation and survival and affect the safety of operating personnel by creating, as example, the following problems:

a. Binding moving parts together.

b. Adding weight to radar antennas, aerodynamic control surfaces, helicopter rotors, etc.

c. Increasing footing hazards for personnel.

d. Interfering with clearances between moving parts.

e. Inducing structural failures.

f. Reducing airflow efficiency as in cooling systems or filters.

g. Impeding visibility through windshields and optical devices.

h. Affecting transmission of electromagnetic radiation.

i. Providing a source of potential damage to equipment from the employment of mechanical, manual, or chemical ice removal measures.

j. Reducing efficiency of aerodynamic lifting and control surfaces; and

k. Reducing (aircraft) stall margins.

2.3 Test Procedure (See Method 301, paragraphs 1 and 2.)

When an icing test is deemed necessary, the procedure included in this Method is considered suitable for most materiel.

2.4 Choice of Test Severities

(See Method 301, paragraphs 1 - 4.)

The test variables are test item configuration and orientation, air and test item temperature, water delivery method, droplet size, and ice thickness. The values chosen for the variables are primarily dependent on the intended use of the materiel.

2.4.1 Configuration and orientation

The following factors are to be considered:

a Should the test item receive icing on all sides and on top?

b. Should the test item be in its deployment configuration? If required, perform tests in other configurations such as for shipping or outside storage.

2.4.2 Test temperature

Test temperatures that may be used to produce the required environmental conditions are recommended in the test procedure. The recommended temperatures of the chamber and water may have to be adjusted for different size facilities to prevent premature freezing of the water droplets before they come in contact with the test item. However, the initial test item temperature should not be below 0^{o}C to allow water to penetrate (cracks, seams, etc.) prior to freezing.

2.4.3 Water delivery rate

The objective is to produce a clear, uniform coating of glaze ice. Any delivery rate that produces a uniform coating of glaze ice is acceptable. A water delivery rate of 25 mm/h has been suggested in the test procedure and is based on data from previous testing.

2.4.4 Water delivery method

Any of the following water delivery systems can be used as long as the water is delivered as a uniform spray:

a Nozzle arrays directing spray to the top, sides, front and rear of the test item.

b. Nozzle arrays that direct spray straight down onto the test item. Sidespray coverage is achieved by using wind or an additional hand-held nozzle. If wind is used it should be the minimum necessary to maintain uniform ice accretion.

c. A single nozzle directing the spray over the appropriate surfaces of the test item.

2.4.5 Droplet Size

The droplet size range may have to be adjusted for different size facilities. A fine spray in the range of 1.0 to 1.5 mm diameter nominal droplet size has produced satisfactory icing in some facilities.

2.4.6 Ice Thickness

Unless specifically measured data for the anticipated situation are available, the following ice thicknesses are recommended (reference c):

a. 6 mm - represents general conditions, light loading

b. 13 mm - represents general conditions, medium loading

c. 37 mm - represents heavy ground loading and marine mast loading

d. 75 mm - represents extremely heavy ground loading and marine deck loading.

2.5 Operational Considerations

a. Some materiel covered with ice may be expected to operate immediately without first undergoing de-icing procedures; other materiel would not be expected to operate until some form of de-icing has taken place (e.g., aircraft ailerons (flaps) prior to flight).

b. Ice removal, if required, may include built-in ice-removal systems, prescribed means that could be expected to be employed in the field, or a combination of these.

c. The correct operation of anti-ice systems such as pre-heated surfaces.

3. INFORMATION TO BE PROVIDED IN THE TEST INSTRUCTION

In addition to the information derived from Method 301, paragraph 6, the following are required:

a. Ice thickness to be applied.

b. Ice removal method(s) (if employed).

c. Any variations from recommended test temperatures and droplet sizes.

d. Surfaces of the test item to which ice is to be applied.

e. Velocity of any wind used.

4. TEST CONDITIONS AND PROCEDURES

See Method 301, paragraphs 7 - 10, for test facility, test conditions and test control information.

4.1 Test Facility

In addition to having the characteristics specified in Method 301, paragraph 8, the chamber and drainage system should be arranged to minimize the collection of puddles/ice in the chamber. It is not necessary to use de-ionized or distilled water for this test. No rust or corrosive contaminants shall be imposed on the test item by the test facility.

4.2 Controls

See Method 301, paragraph 10.

4.3 Test Interruptions

See Method 301, paragraph 11.

4.4 Procedure

4.4.1 Preparation for Test

Before starting any of the test procedures, determine the information to be documented from Method 301, paragraphs 5 and 6.1, and perform the pretest standard ambient checkout specified in Method 301, paragraph 12. In addition:

a. Clean all outside surfaces of any contamination not present during normal operation. Even thin films of oil or grease will prevent ice from adhering to the test item and change the test results.

b. To facilitate measurement of ice thickness, depth gauges such as copper bars or tubes of an appropriate size shall be mounted in places where they will receive the same general waterspray as the test item. It is recommended that the gauges be mounted on the test item, particularly for large or rounded items where this may be the only way of verifying the thickness on the item. Other suitable thickness measurement techniques may be used.

NOTE: *Since artificially produced ice accretion rates tend to depend upon the distance between the test item and the spraying system, structures with large height variations, such as antenna masts, should have test bars placed at the different heights.*

c Water used in the spray system should be cooled to between 0^{o}C and 3^{o}C.

d. If difficulty is experienced in producing a satisfactory layer of glaze ice, it may be necessary to vary one or more of the parameters, i.e., water or test item temperature, spray rate, distance between the nozzles and the test item, etc.

4.4.2 Test Procedure.

Step 1. Place the test item in the chamber and arrange the nozzles to produce ice on specified surfaces.

Step 2. Stabilize the test item temperature at 0^{o}C (-0/+2^{o}C).

Step 3. Deliver a uniform precooled water spray for 1 hour to allow water penetration into the test item crevices/openings (although a water temperature of 0-3^{o}C is ideal, a water temperature of 5^{o}C and a water delivery rate of 25 mm/h has proven satisfactory).

Step 4. Adjust the chamber air temperature to -10°C or as specified and maintain the waterspray rate until the required thickness of ice has accumulated on the appropriate surfaces. Wind or a side spray may be used to assist accumulation of ice on the sides of the test item.

NOTE: *It may be easier to stop spraying during the temperature reduction to facilitate temperature adjustment and to minimize frosting of test chamber refrigeration coils.*

Step 5. Maintain the chamber air temperature for a minimum of 4 hours to allow the ice to harden. Examine for safety hazards and, if appropriate, attempt to operate the test item. Document the results (with photographs if necessary).

Step 6. If the specification allows ice removal, remove the ice. Limit the method of ice removal to that determined in paragraph 4, e.g., built-in ice removal systems, plus expedient means that could be expected to be employed in the field. Note the effectiveness of ice removal techniques used.

Step 7. Examine for safety hazards and, if appropriate (and possible), attempt to operate the test item at the specified low operating temperature of the materiel.

Step 8. If required, repeat steps 4 through 7 to produce other required thicknesses of ice.

Step 9. Stabilize the test item at standard ambient conditions and perform a post-test operational check.

Step 10 Document (with photographs if necessary) the results for comparison with pretest data.

5. EVALUATION OF THE TEST RESULTS

See Method 301, paragraph 13.

The following guidance is provided to aid in failure analysis. In most cases the test item is considered to have failed if:

a. For materiel that must operate without ice removal, the performance of the test item has been degraded beyond that specified in the requirements document.

b. For materiel that requires ice removal before operation, the performance of the item has been degraded beyond the specified limits/requirements after normal ice-removal efforts have been undertaken.
c. Normal ice removal damages the materiel.

6. REFERENCES AND RELATED DOCUMENTS

In addition to the references given in Method 301, paragraph 14, the following are provided for background information.

a. EEC Directive 78/317/EEC, Motor Vehicles Defrosting and Demisting of Systems, August 1979.

b Glossary of Meteorology, Edited by Ralph E. Huschke, Published by the American Meteorological Society (1959).

c. Letter, Cold Regions Research and Engineering Laboratory, Corps of Engineers (U.S.), CECRL-RG, 22 October 1990, SUBJECT: Ice Accretion Rates (Glaze).

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METHOD 312

LOW PRESSURE (ALTITUDE)

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METHOD 312

LOW PRESSURE (ALTITUDE)

NOTE: *METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD.*

1. SCOPE

1.1. Purpose

Low-pressure (altitude) tests are performed to determine if materiel can withstand and/or operate in a low-pressure environment and/or withstand rapid pressure changes.

1.2. Application

Specific applications are to determine if:

a. The materiel can be stored and operated at high ground elevation sites.

b. The materiel can be transported or operated in pressurized/unpressurized areas of aircraft.

c. The materiel can survive a rapid or explosive decompression and, if not, to determine if it will damage the aircraft or present a hazard to personnel.

d. The materiel can withstand external carriage on aircraft.

1.3. Limitations

This method is not intended to be used to test materiel to be installed in space vehicles, aircraft, or missiles that fly at altitudes above 30,000m.

2. TEST GUIDANCE

See General Guidance and Requirements, paragraphs 1 and 2.

2.1. Effects of the Environment

In addition to thermal effects (see Method 303), examples of problems that could occur as a result of exposure to reduced pressure are shown below. Exposure to high humidity immediately following flight can draw moisture into items, but if it is necessary to evaluate such combined effects, other test methods (such as Method 317 of this AECTP) should be used. The list below is not intended to be all-inclusive and some of the examples may overlap the categories:

2.1.1. Physical/Chemical

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

b. Deformation, rupture or explosion of sealed containers.

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

d. Overheating of materiel due to reduced heat transfer.

e. Evaporation of lubricants.

f. Erratic starting and operation of engines.

g. Failure of hermetic seals.

2.1.2. Electrical

Erratic operation or malfunction of materiel resulting from arcing or corona.

2.2. Choice of Test Procedure

(See General Guidance and Requirements, paragraphs 1 and 2.) Four test procedures are included within this Method: storage, operation, rapid decompression, and explosive decompression. Based on the test data requirements, determine which of the test procedures or combination of procedures is applicable.

2.2.1. Procedure I - Storage/Air Transport

Procedure I is appropriate if the materiel is to be stored at high ground elevations or transported in its shipping/storage configuration.

2.2.2. Procedure II - Operation/Air Carriage

Procedure II is used to determine the performance of the materiel under low pressure conditions and may be preceded by procedure I, procedure III, procedure IV, or all three. If there are no low pressure storage, rapid or explosive decompression requirements, this procedure can stand alone.

2.2.3. Procedure III - Rapid Decompression

Procedure III is used to determine if a rapid decrease in pressure of the surrounding environment will cause a materiel reaction that would endanger nearby personnel or the aircraft in which it is being transported. This procedure may be preceded by either the storage or the operational test.

2.2.4. Procedure IV - Explosive Decompression

Procedure IV is similar to Procedure III except that it involves an "instantaneous" decrease in the pressure of the surrounding environment.

2.3. Sequence

(See General Guidance and Requirements, paragraph 2.2.)

Other testing may contribute significantly to the effects of low pressure on the test item (see paragraph 2.1), and may have to be conducted before this method. For example:

a. Low-temperature and high-temperature testing may affect seals.

b. Dynamic tests may affect the structural integrity of the test item.

c. Aging of non-metallic components may reduce their strength.

2.4. Choice of Test Parameters

(See General Guidance and Requirements, paragraphs 1-4.)

After the test procedure is chosen, determine the test parameters such as test pressure and temperature, rate of change of pressure (and temperature if appropriate), duration of exposure, and test item configuration.

2.4.1. Test pressure and temperature

Base determination of the specific test pressures and temperatures on the anticipated deployment or flight profile of the test item.

a. Ground areas. If measured data are not available, temperatures may be obtained for appropriate ground elevations and geographical locations from Leaflet 2311. The highest elevation currently contemplated for NATO ground military operations (equipment operating and nonoperating) is 4,570m with an equivalent air pressure of 57 kPa.

b. Transport aircraft cargo compartment pressure conditions. Table 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 equivalent altitude will assure that the materiel shipped by air will successfully withstand the low-pressure environment. The range of temperatures associated with the various low pressure situations is such that identification of same in this document is impractical. Test temperatures should be obtained from measured data or from appropriate national sources.

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

2.4.2. 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 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.

TABLE I. - Minimum normal cargo compartment pressures.

Aircraft	Minimum Cargo Compartment Pressure (kPa)	Equivalent Altitude (m)
C-130	56.8	4,570
C-141	59.1	4,270
C-5A	60.1	4,110
DC-8/707/DC-9-80	56.8	4,570
DC-10/747/KC-10	56.8	4,570
L-1011/767	56.8	4,570
C-160 Transall	59.1	4,270
VC-10	79.2	1,980
A-300/C	74.6	2,400

2.4.3. Rapid decompression rate

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

a. Massive damage to the aircraft, but the aircraft survives and decompression is virtually instantaneous.

b. Relatively small holes caused by foreign objects through which decompression could occur at a slower rate than above.

c. Relatively gradual loss of pressure due to loosening of aircraft structure (including seals).

Explosive decompression should be accomplished in 0.1 second or less; rapid decompression should not take more than 15 seconds.

2.4.4. Test Duration

For Procedure I, the test duration should be representative of the anticipated service environment but, if this is determined to be extensive, a test duration of at least 1 hour is considered adequate for most materiel. Once the test pressure has been reached and any required functions performed, Procedures II, III and IV do not require extended periods at the test pressure.

3. INFORMATION TO BE PROVIDED IN THE TEST INSTRUCTION

See General Guidance and Requirements, paragraphs 5 and 6.

4. TEST CONDITIONS AND PROCEDURES

See General Guidance and Requirements, paragraphs 7 - 10, for test facility, test conditions and test control information.

4.1 Test Facility

See Method 301, General Guidance and Requirements, paragraph 8,

4.2 Controls

Unless otherwise specified, the altitude change rate shall not exceed 10 m/s.

4.3 Test Interruption

(See General Guidance and Requirements, paragraph 11.) To achieve the desired effects, the test item must be subjected to the full duration of the low pressure test without interruption.

4.4 Procedures

The following test procedures, alone or in combination, provide the bases for collecting the necessary information concerning the test item in a low-pressure environment. Unless otherwise specified, the chamber temperature shall be maintained at the anticipated service environment temperature.

4.4.1 Preparation for Test

Before starting any of the test procedures, determine the information specified in General Guidance and Requirements, paragraphs 5 and 6.1 as well as altitude change rates, and perform the test preparation procedure specified in General Guidance and Requirements, paragraph 12.

4.4.2 Procedure I - Storage/Air Transportation

Step 1. Place the test item in its storage/transit configuration and position it in the test chamber.

Step 2. If appropriate, stabilize the test item to the required test temperature.

Step 3. Adjust the chamber air pressure to the required test altitude, at an altitude change rate as specified in the test plan.

Step 4. Maintain the conditions for a minimum of 1 hour unless otherwise specified in the test plan.

Step 5. Adjust the chamber air to standard ambient conditions at the rate specified in the test plan.

Step 6. Visually examine the test item to the extent possible and conduct an operational check. Document the results.

4.4.3 Procedure II - Operation/Air Carriage

Step 1. With the test item in its operational configuration, adjust the chamber air pressure (and temperature if appropriate) to the required equivalent operational altitude at a rate not to exceed that specified in the test plan.

Step 2. Conduct an operational check of the test item in accordance with the requirements documents, and document the results.

Step 3. Adjust the chamber air to standard ambient conditions at the rate specified in the test plan.

Step 4. Visually examine the test item to the extent possible and conduct an operational check. Document the results.

4.4.4 Procedure III - Rapid Decompression

Step 1. With the test item in the storage or transit configuration, adjust the chamber air pressure (and temperature if appropriate) at the rate specified in the test plan to the maximum equivalent altitude of the anticipated aircraft (cabin pressure) (from Table 1).

Step 2. Reduce the chamber air pressure to an equivalent altitude of 12,200m (18.8 kPa), or as otherwise specified in the test plan, in 10 ± 5 seconds. Maintain this stabilized reduced pressure for at least 10 minutes.

Step 3. Adjust the chamber air to standard ambient conditions at the rate specified in the test plan.

Step 4. Visually examine the test item to the extent possible and conduct an operational check. Document the results.

4.4.5 Procedure IV - Explosive Decompression

Step 1. With the test item in the storage or transit configuration, adjust the chamber air pressure (and temperature if appropriate) at the rate specified in the test plan to the maximum equivalent altitude of the anticipated aircraft (cabin pressure).

Step 2. Reduce the chamber air pressure to an equivalent altitude of 12,200m (18.8 kPa), or as otherwise specified in the test program, in not more than 0.1 seconds. Maintain this stabilized reduced pressure for at least 10 minutes.

Step 3. Adjust the chamber air to standard ambient conditions at the rate specified in the test plan.

Step 4. Visually examine the test item to the extent possible and conduct an operational check. Document the results.

5. EVALUATION OF THE TEST RESULTS

(See General Guidance and Requirements, paragraph 13.) For Procedure IV, the test item fails only if explosive decompression causes a hazard to the aircraft or to the personnel; the test item need not show satisfactory post-test performance unless otherwise specified.

6. REFERENCES AND RELATED DOCUMENTS

See General Guidance and Requirements, paragraph 14.

STANAG 4044, Adoption of a Standard Atmosphere, 10 April 1969, (ICAO Standard Atmosphere).

METHOD 313

SAND AND DUST

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METHOD 313

SAND AND DUST

NOTE: *METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD.*

1. SCOPE

1.1 Purpose

a. Perform the small-particle dust ($\leq$149 µm) procedures to ascertain the ability of materiel to resist the effects of dust (including abrasion) that may obstruct openings, penetrate into cracks, crevices, bearings and joints, and to evaluate the effectiveness of filters.

b. Perform the blowing sand test to determine if materiel can be stored and/or operated under blowing sand (150 to 850 µm particle size) conditions without degradation of performance, effectiveness, reliability, and maintainability due to the abrasion (erosion) or clogging effect of large, sharp-edged particles.

1.2 Application

This method is applicable to all mechanical, optical, electrical, electronic, electrochemical, and electromechanical devices for which exposure to a dry, blowing sand, blowing dust-laden atmosphere, or settling dust is anticipated.

1.3 Limitations

This method is not suitable for determining erosion of airborne (in flight) materiel because of the particle impact velocities involved, or for determining the effects of a buildup of electrostatic charge. Because of the difficulty of controlling test conditions, this Method does not address sand or dust testing out-of-doors. This method does not address aerosols other than dust.

2. TEST GUIDANCE

See Method 301, paragraphs 1 and 2.

2.1 Effects of the Environment.

Although the blowing sand and dust environment is usually associated with hot-dry regions, it exists seasonally in most other regions. Naturally - occurring sand and dust storms are an important factor in the deployment of materiel, but with the increased mechanisation of military operations, they can cause fewer problems than does sand and dust associated with man's or battlefield activities. Examples of problems that could occur as a result of exposure to blowing sand, blowing dust and settling dust are as follows; the list is not intended to be all-inclusive.

a. Abrasion and erosion of surfaces.

b. Penetration of seals.

c. Degraded performance of electrical circuits.

d. Obstruction/clogging of openings and filters.

e. Physical/interference with mating parts.

f. Fouling/interference of moving parts.

g. Reduction of thermal conductivity.

h. Interference with optical characteristics.

i. Overheating and fire hazard due to reduced/restricted ventilation or cooling.

2.2 Choice of Test Procedure.

(See Method 301, paragraphs 1 and 2.)

This Method includes three laboratory (chamber) test procedures: Blowing Dust, Blowing Sand and Settling Dust. Select the applicable procedure based on the materiel's intended deployment exposure and function.

2.2.1 Procedure I: Blowing dust.

Use this procedure to assess the susceptibility of materiel to concentrations of blowing dust (particle size less than 150 µm).

2.2.2 Procedure II: Blowing sand.

Use this procedure to assess the susceptibility of the materiel to the effects of blowing, large particle sand (150 µm and larger).

2.2.3 Procedure III: Settling dust.

Use this procedure to determine the effect of settling dust (<100 µm) on materiel (usually electrical) in sheltered or enclosed areas with negligible airflow (e.g., offices, laboratories, store rooms, tents) where dust may accumulate over long periods. The settling dust test can also be used to verify the effectiveness of air filters.

2.3 Choice of Test Severities.

(See Method 301, paragraphs 1-4.)

After choosing the test procedure, determine the values of the test parameters and whether the test item is to operate during the test. In the absence of field data, use the following guidance.

2.3.1 Temperature.

Unless otherwise specified, conduct the blowing sand and blowing dust tests with the test item at the high operating or storage temperature obtained from the temperature response of the test item in the high temperature test (Method 302). In the absence of this information, perform the tests at 49°C, i.e., the maximum ambient air temperature for the A1 climatic category (Leaflet 2311). Unless otherwise specified, perform the settling dust test at the standard ambient temperature.

2.3.2 Air velocity.

a. Blowing Dust. In the absence of specified values, the air velocities used in the blowing dust test procedure include a minimum air velocity of 1.5 m/s to maintain test conditions, and a higher air velocity of 9 m/s typical of desert winds. Use other air velocities if representative of natural conditions and if the capabilities of the test chamber allow.

b. Blowing sand. Winds of 18 m/s capable of blowing the large particle sand are common, while gusts up to 30 m/s are not unusual. If the air velocity around the materiel in its field application is known to be outside of this range, use the known velocity, otherwise select an air velocity in the range of 18 to 30 m/s for most blowing sand applications.

***NOTE**: In order for particles to attain impact velocities ranging from 18-30 m/s, normally use a minimum distance of 3 m from the sand injection point to the test item.*

c. Settling dust. Use the minimum air velocity required to disperse dust in the air above the test item, but ensure it does not exceed 0.2 m/s at the test item.

2.3.3 Sand and dust composition

a. Blowing Dust

(1) Composition: Conduct the small particle (blowing dust) procedure with any of the following (by weight):

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

$CaC0_3$, $MgC0_3$, $Mg0$, $Ti0_2$, etc.	5%
Ferric oxide (Fe_20_3)	10 ± 5%
Aluminium oxide (Al_20_3)	20 ± 10%
Silicon dioxide ($Si0_2$)	remaining percentage

(b) Silica flour (ground silica) has been widely used in dust testing and contains 97 to 99 per cent (by weight) silicon dioxide ($Si0_2$).

(c) If other materials are used for dust testing, their particle size distribution may fall below that in paragraph 2.3.3a(2) below. Ensure material to be used is appropriate for the intended purpose and regions of the world being simulated. These materials for dust testing include:

- Talc (talcum power) (hydrated magnesium silicate).
- F.E. (fire extinguisher powder composed mainly of sodium or potassium hydrogen carbonate with a small amount of magnesium stearate bonded to the surface of the particles in order to assist free-running and prevent clogging - must be used in dry conditions to prevent corrosive reaction and formation of new chemicals (ref. C)).
- Quartz (the main constituent of many dusts occurring in nature).
- Undecomposed feldspar and olivine (that have similar properties to quartz).
- Portland cement - must be kept dry to prevent solidification or corrosion.

WARNING: Refer to the supplier's Material Safety Data Sheet (MSDS) or equivalent for health hazard data. Exposure to silica flour (ground silica) can cause silicosis; other materials may cause adverse health effects.

(2) Particle Size. Unless otherwise specified, use a particle size distribution of 100% of the material by weight less than 150 µm, with a median diameter (50% by weight) of 20 ± 5 µm. This dust is commonly referred to as a "140 mesh silica flour (ground silica)" (about 2% retained on a 140 mesh (106 µm) sieve), and should provide comparable results to prior test requirements. National documentation may contain other more specific distributions. If particle size measurements are carried out using techniques other than sieve analysis, it must be demonstrated that the same results are produced.

b. Blowing Sand. Unless otherwise specified, for the large particle sand test, use silica sand (at least 95% by weight $Si0_2$). Use sand with a sub-angular structure, a mean Krumbein (roundness and sphericity) number range 0.5 to 0.7, and a hardness factor of 7 mhos. If possible, determine the particle size distribution from the geographical region in which the materiel will be deployed. There are 90 deserts in the world, each with different particle size distributions. The recommended particle size distribution for the large particle sand test is between 150 µm and 850 µm, with a mean of 90% ± 5 % by weight smaller than 600 µm and larger than 149 µm, and as least 5% by weight 600 µm and larger. When materiel is designed for use in a region that is known to have an unusual or special sand requirement, analyse a sample of the local sand to determine the distribution of the material used in the test. Specify the details of its composition in the requirements documents.

WARNING: The same health hazard considerations as noted for the dust apply. Refer to the supplier's Material Safety Data Sheet (MSDS) or equivalent for health hazard data; exposure to crystaline silica can cause silicosis.

c. Settling Dust. Although settling dust can be of various composition(s) to reflect real world conditions (to include quartz, silica, salts, fertilizers, organic fibres, etc.), the small particle dusts described above should be adequate to evaluate the potential effects of most settling dust. Use dust with particle sizes less than 100 µm.

2.3.4 Sand and dust concentrations

a. Blowing Dust. Maintain the average dust concentration for the blowing dust test at 10 ± 7 g/m^3 unless otherwise specified. This figure is not unrealistic and is used because of the limitations of most chambers, i.e., control.

b. Blowing Sand. Unless otherwise specified, maintain the average sand concentrations as follows (ref. a):

(1) For materiel likely to be used close to helicopters operating over unpaved surfaces: 2.2 ± 0.5 g/m^3.

(2) For materiel never used or exposed in the vicinity of operating aircraft, but that may be used or stored unprotected near operating surface vehicles: 1.1 ± 0.3 g/m^3.

(3) For materiel that will be subjected only to natural conditions: 0.18 g/m^3, -0.0/+0.2 g/m^3. (This large tolerance is due to the difficulties of measuring concentrations at low levels.)

c. Settling Dust. For the settling dust test, the relationship between severity (duration and concentration) is difficult to determine. Real conditions vary considerably, and this test is intended to standardise a procedure to demonstrate survival of the materiel, and not necessarily to duplicate real conditions. Consequently, only guidelines are given for the relationship between the severity levels of the test and some values measured under real conditions. Unless otherwise specified, use a dust settlement rate of 6 g/m^2/day. Table 1 (ref. c) provides average dust deposits for various areas, along with a rough guide to acceleration factors for the specified rates. For example, a 3-day test equates to between 51 days and 1800 days (5 years) for rural and suburban environments, and between 9 days and 18 days for an industrial environment.

Table 1 - Settling Dust Quantities and Acceleration Factors.

AREA	DUST SETTLEMENT PER DAY (g/m^2)	ACCELERATION FACTOR
Rural and suburban	0.01 - 0.36	600 - 17
Urban	0.36 - 1.00	17 - 6
Industrial	1.00 - 2.00	6 - 3

2.3.5 Orientation

a. Blowing Dust Tests. Orient the test item such that the most vulnerable surfaces face the blowing dust. Rotate the test item as required to expose all vulnerable surfaces to equal portions of the total test time.

b. Blowing Sand Tests. Orient the test item with respect to the direction of the blowing sand such that the test item will experience maximum erosion effects. The test item may be re-oriented at 90-minute intervals.

c. Settling Dust Tests. Install the test item in the test chamber in a manner representative of its anticipated deployment in service.

2.3.6 Duration

a. Blowing Dust. Unless otherwise specified, recommend blowing dust tests be conducted for 6 hours at standard ambient temperatures and 6 hours at the high storage or operating temperature. It is permissible to stop between the two 6-hour periods provided the humidity level is kept below 30% and all test conditions are restabilized prior to continuing.

b. Blowing Sand. For blowing sand tests, 90 minutes per face is considered to be a minimum.

c. Settling Dust. For settling dust tests using a basic deposition rate of 6 g/m^2/day, combined with the values shown in Table 1 should provide a rough guide to acceleration factors for the areas shown. If no specific area is identified, use a test duration of 3 days (for standardisation purposes) to provide a reasonable severity.

2.3.7 Operation During Test.

a. Blowing Dust or Sand. Determine the need to operate the test item during exposure to sand or dust from the anticipated in-service operational requirements. For example, operate heating/cooling materiel while exposed to extreme ambient environments, but certain materiel, although exposed to severe environments, may be operated only in an environmentally controlled shelter. Specify the time and periods of operation in the test plan. This schedule should normally contain at least one 10-minute period of continuous functioning of the test item during the last hour of the test, with the test item’s most vulnerable surface facing the blowing sand or dust.

b. Settling Dust. Condition materiel that employs forced air cooling with the air cooling system operating to determine the effect of dust trapped in filters; during the test, operate heat-generating materiel with ventilation openings for convection cooling; preferably, intermittently operate heat-generating materiel of closed construction in order to induce a breathing effect by thermal cycling.

2.4 Sequence

(See Method 301, paragraph 2.3.)

This method can produce a dust coating on, or severe abrasion of a test item, that could influence the results of other environmental test methods such as Solar Radiation (Method 305), Humidity (Method 306), Mould Growth (Method 308), and Salt Fog (Method 309). Therefore, use judgement to determine the sequence of tests. Preferably, apply this method following the High Temperature test (Method 302), since the temperature derived from that test is used in this method (see paragraph 2.3.1). The presence of dust in combination with other environmental parameters can induce corrosion or mould growth. A warm, humid environment can cause corrosion in the presence of chemically aggressive dust.

3. INFORMATION TO BE PROVIDED IN THE TEST INSTRUCTION

In addition to the information derived from Method 301, paragraphs 5 and 6, the following are required for these tests:

a. Sand or dust composition.

b. Sand or dust concentration.

c. Test item orientation and time of exposure per orientation.

d. Methods of sand and dust removal as used in service.

e. Test temperatures.

f. Whether and when the test item is to be operated.

g. Procedures for determining the test item’s degradation due to abrasion.

4. TEST CONDITIONS AND PROCEDURES

See Method 301, paragraphs 7 - 10, for test facility, test conditions and test control information.

4.1 Test Facility

In addition to the information provided in Method 301, paragraph 8, ensure the test item and facility are properly grounded to avoid buildup of an electrostatic charge and possible dust explosions. The following information is also appropriate.

4.1.1 Blowing dust.

a. Use a test facility that consists of a chamber and accessories to control dust concentration, velocity, temperature, and relative humidity of dust-laden air. In order to provide adequate circulation of the dust-laden air, do not occupy more than 50% of the test section's cross-sectional area (normal to airflow) and 30% of the volume of the test chamber by the test item(s). Ensure the chamber has a means of maintaining and verifying the concentration of dust in circulation. A minimum acceptable means for doing this is by use of a properly calibrated smoke meter and standard light source. Introduce the dust-laden air into the test space in such a manner as to allow the air to become as close to laminar as possible, but at least in a manner that prevents excessive turbulence as the flow of dust-laden air strikes the test item.

b. Use dust in this test as outlined in paragraph 2.3.3.

4.1.2 Blowing sand.

a. Control the sand feeder to emit the sand at the specified concentrations. To simulate the effects produce in the field, locate the feeder in such a manner as to ensure the sand is approximately uniformly suspended in the air stream when it strikes the test item.

NOTE: *Uniform sand distribution is usually easier to obtain when the sand-air mixture is directed downward.*

b. Because of the extremely abrasive characteristics of blowing sand, 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 item.

NOTE: *The sand collected in the separator may be reused for subsequent tests if, after analysis, it still conforms to the requirements of paragraph 2.3.3 of this Method.*

4.1.3 Settling dust.

Use a facility such as shown in Figure 1 or equivalent. Ensure the following:

a. RH: $\leq$ 30%.

b. Temperature: Use the temperature anticipated for materiel in service. If unknown, use standard ambient conditions (Method 301, paragraph 7.1).

c. Dust density: 6 g/m^2/day - settles under own weight.

d. Air movement: Minimum around the test item.

e. Dust not injected directly into the test item.

f. Chamber sufficiently high to allow the settling of dust.

g. Collection receptacles for dust density verification. (Not near fan intakes.)

h. The settled dust is not disturbed during injection.

i. Test item centrally located on horizontal plane, at least 150 mm from any wall or other test item (unless more is required for test item intake fans).

j. Injection period: constant or hourly so as to achieve 0.25 g/m^2 each hour (6 g/m^2/day).

4.2 Controls

a. In addition to the controls specified in Method 301, paragraph 10, control the test chamber relative humidity (RH) so that it does not exceed 30% because higher levels may cause caking of dust particles.

b. For the blowing sand test, continuously measure the humidity and temperature during the test. Verify the air velocity and sand concentration prior to testing by determining the sand flow rate using the following formula:

$$Rate = Concentration \times Area \times Velocity$$

where: Rate = mass of sand introduced into the test chamber per set time interval
Concentration = sand concentration required by the test plan
Area = cross-sectional area of the discharge duct
Velocity = velocity of air at the sand injection point

c. For the settling dust test, maintain the air velocity in the vicinity of the test item near zero (essentially stagnant) to allow settling of the finer dust particles.

d. The settling dust test requires collection plates in the vicinity of the test item to verify the quantity of deposited dust.

4.3 Test Interruptions

(See Method 301, paragraph 11.)

Assuming test parameters are within test tolerances, the abrasion, penetration and collection of dust are cumulative effects that are not affected by premature test stoppage. Reestablish appropriate test conditions and continue from the point of interruption.

4.4 Procedures

See Method 301, paragraph 6.

WARNING: ***The relatively dry test environment combined with the moving air, dust and sand particles may cause a buildup of electrostatic energy that could effect operation of the test item. Use caution when making contact with the test item during or following testing. (See paragraph 4.1*****)**

4.4.1 Preparation for Test.

a. Before starting any of the test procedures, determine the information specified in Method 301, paragraphs 5 and 6.1, and perform the test preparation procedure specified in Method 301, paragraph 12. Additional pretest information required includes:

    (1) Sand and dust composition.

    (2) Sand and dust concentration.

b. For the blowing sand test, calibrate the sand dispensing system for the sand concentration specified in the test plan, and adjust the air supply or test item position to obtain the specified air velocity at the test item when it is located a minimum of 3m from the sand injection point.

c. See Method 301, paragraph 8b(1). Considering the requirements of paragraph 4.4.1b, position the test item in the test chamber as near the centre of the test section as practical. For the blowing sand and blowing dust tests, initially orient the test item so as to expose the most critical or vulnerable parts to the sand or dust stream, then re-orient the test item(s) as required. For the settling dust test, position the test item in its normal orientation for operation or storage.

d. For the settling dust test, verify the fallout rate over a two-hour period. Use a one-minute injection period followed by a 59-minute settling period each hour.

4.4.2 Procedure I - Blowing dust

***WARNING**: Silica flour (ground silica) (or other dusts of similar particle size) may present a health hazard. When using silica flour (ground silica), ensure the chamber is functioning properly and not leaking; if a failure of containment is noted and personnel might have been exposed, air samples should be obtained and compared to the current threshold limit values of the national safety and health regulations. 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 personnel to the silica dust is possible.*

Step 1. With the test item in the chamber, adjust the test section temperature to standard ambient conditions and the air velocity to the required value, determined from the test plan. Adjust the relative humidity to less than 30% and maintain it throughout the test.

Step 2. Adjust the dust feed control for a dust concentration of 10 ± 7 g/m^3.

Step 3. Unless otherwise specified, maintain the conditions of Steps 1 and 2 for 6 hours. If required, periodically reorient the test item to expose other vulnerable faces to the dust stream. ***SEE ABOVE WARNING NOTES IN 4.4 AND 4.4.2.***

Step 4. Stop the dust feed. Reduce the test section air velocity to approximately 1.5 m/s and adjust the temperature (see para 2.3.1) to that determined from the test plan.

Step 5. Maintain the Step 4 conditions for 1 hour following test item temperature stabilisation.

Step 6. Adjust the air velocity to that used in Step 1 and restart the dust feed to maintain the dust concentration as in Step 2.

Step 7. Continue the exposure for a total of 6 hours or as otherwise specified. If required, operate the test item in accordance with the test plan.

Step 8. Turn off all chamber controls and allow the test item to return to standard ambient conditions and the dust to settle. ***SEE THE WARNING AT THE BEGINNING OF THIS PROCEDURE AND IN 4.4.***

Step 9. Remove accumulated dust from the test item by brushing, wiping or shaking, taking care to avoid introduction of additional dust or disturbing any that may have already entered the test item. Do not remove dust by either air blast or vacuum cleaning unless these methods are likely to be used in service.

Step 10. Perform a functional check in accordance with the approved test plan, and document the results for comparison with pretest data.

Step 11. Inspect the test item for dust penetration and abrasion, giving special attention to bearings, grease seals, lubricants, filters, ventilation points, etc.

4.4.3 Procedure II - Blowing sand.

Step 1. Position the test item a minimum of 3m from the sand injection point. Adjust the air velocity to that required by the test plan and stabilise the test item at its high operating temperature.

Step 2. Adjust the sand feeder to obtain the sand mass flow rate determined from the pretest calibration.

Step 3. Maintain the conditions of Steps 1 and 2 for the duration specified in test plan. If required, reorient the test item at 90-minute intervals to expose all vulnerable faces to the blowing sand and repeat Steps 1-2.

Step 4. If functioning of the test item during the test is required, perform a functional test of the item during the last hour of the test and document the results. If not, proceed to Step 5.
SEE THE WARNING NOTE IN PARAGRAPH 4.4.2

Step 5. Turn off all chamber controls and allow the test item to return to standard ambient conditions. Remove accumulated sand from the test item by using the methods anticipated to be used in service such as brushing, wiping, shaking, etc., taking care to avoid introduction of additional sand into the test item.

Step 6. Conduct a functional check of the test item in accordance with the approved test plan and record results for comparison with pretest data.

Step 7. Visually inspect the test item for abrasion and clogging effects, and any evidence of sand penetration.

4.4.4 Procedure III - Settling dust.

SEE THE WARNING NOTE IN PARAGRAPH 4.4.2

Step 1. With the test item and collection plates in the test chamber, adjust the test section temperature to standard ambient conditions or as otherwise specified, and the relative humidity to less than 30%. (Maintain less than 30% relative humidity throughout the test.)

Step 2. If the materiel will be in operation during exposure to settling dust, turn on the test item. Following stabilisation of the test item temperature, inject the required quantity of dust into the test section for 60 ± 5 seconds.

Step 3. Allow the dust to settle for 59 minutes.

Step 4. Verify the dust fallout rate and, if required, repeat steps 2 and 3 above for the required number of cycles as determined in paragraph 2.3.4c.

Step 5. Without unnecessarily disturbing the dust deposits, perform a functional check in accordance with the approved test plan, and document results for comparison with pretest data.

Step 6. Inspect the test item for dust penetration, giving special attention to bearings, grease seals, lubricants, filters, ventilation points, etc.

5. EVALUATION OF THE TEST RESULTS

In addition to the guidance provided in Method 301, paragraph 13, the following are provided to assist in the evaluation of the test results.

a. Sand or dust has penetrated the test item in sufficient quantity to cause binding, clogging, seizure or blocking of moving parts, non-operation of contacts or relays, or the formation of electrically conductive paths with resulting short circuits.

b. Functional performance is within the specified requirements/tolerances.

c. Protective coatings were compromised.

d. Abrasion of the test item exceeds the specified requirements.

e. The test item operates as required.

6. REFERENCES AND RELATED DOCUMENTS

See Method 301, paragraph 14.

a. 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.

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

c. International Electrotechnical Commission Publication 68, Test L, Dust and Sand.

d. International Electrotechnical Commission Publication 721-2-5, Test L: Dust and Sand.

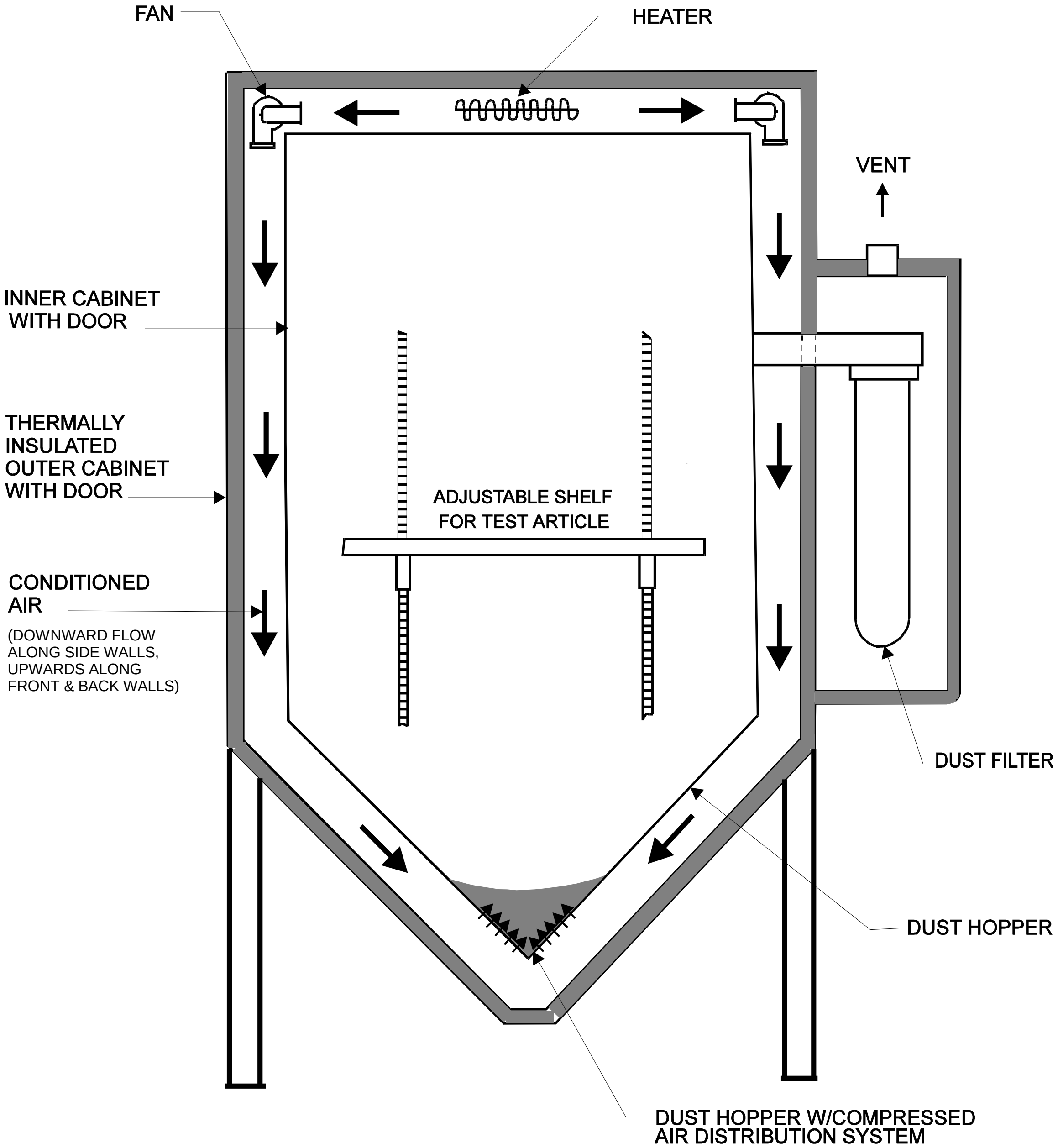

Figure 1. Example of a settling dust test facility

METHOD 314

CONTAMINATION BY FLUIDS

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METHOD 314

CONTAMINATION BY FLUIDS

NOTE: *METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD.*

1. SCOPE

1.1 Purpose.

To determine if materiel is unacceptably affected by temporary exposure to contaminating fluids (liquids) such as may be encountered during its life cycle, either occasionally,[6] intermittently,[7] or over extended periods.[8]

1.2 Application.

Select the tests described in this Method when there is a high probability of fluid contamination during the materiel's life cycle. Contamination may arise from exposure to fuels, hydraulic fluids, lubricating oils, solvents and cleaning fluids, de-icing and anti-freeze fluids, runway de-icers, insecticides, disinfectants, coolant dielectric fluid, and fire extinguishants.

WARNING: *THIS METHOD REQUIRES THE USE OF SUBSTANCES AND/OR TEST PROCEDURES THAT MAY HAVE AN ENVIRONMENTAL IMPACT OR BE INJURIOUS TO HEALTH IF ADEQUATE PRECAUTIONS ARE NOT TAKEN. ADDITIONAL INFORMATION IS PROVIDED IN ANNEX A. REFER TO THE SUPPLIER'S MATERIAL SAFETY DATA SHEET (MSDS) OR EQUIVALENT FOR HEALTH HAZARD DATA ON THE VARIOUS CHEMICALS USED, AND COORDINATE WITH LOCAL ENVIRONMENTAL AUTHORITIES.*

1.3 Limitations.

This test is not intended to demonstrate the suitability of materiel to perform during continuous contact with a fluid, e.g., an immersed fuel pump, nor should it be used to demonstrate resistance to electrolytic corrosion.

2. TEST GUIDANCE

See General Guidance and Requirements, paragraphs 1 and 2.

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[6] *Extraordinary/unusual circumstances occurring once or twice in a year.*
[7] *Regular basis under normal operation, possibly seasonally, over the life of the materiel.*
[8] *Long periods such that materiel is thoroughly exposed.*

2.1 Effects of the Environment.

Examples of problems that could occur as a result of exposure to contaminating fluids follow, but the list is not intended to be all-inclusive and some of the examples may overlap.

a. Packaging failure.

b. Crazing or swelling of plastics and rubbers.

c. Leeching of antioxidants and other soluble materials.

d. Seal or gasket failures.

e. Adhesion failures.

f. Paint/legend removal.

g. Corrosion.

2.2 Contaminant Fluid Groups. (See para 2.5.1 below.)

The following groups of fluids are listed in Table I. In addition to the guidance provided below, consider that personnel and/or their clothing may introduce the contaminant in areas not normally considered for direct contamination.

2.2.1 Fuels.

Fuels will, for the most part, be of the gasoline or kerosene type, and whereas the former may be expected to evaporate rapidly - possibly with few permanently harmful effects, the latter - being more persistent - can be damaging to many elastomers, particularly at elevated temperatures. Fuels do not normally affect paints and most plastics, but silicone resin bonded boards may tend to de-laminate after prolonged exposure. Some fuels may have additives to inhibit icing or to dissipate static charges. Where there is reason to believe that these additives may increase the severity of the test, include them in the test fluids.

2.2.2 Hydraulic Fluids.

Commonly-used hydraulic fluids may be of the mineral oil or ester-based synthetic type, and may be at elevated temperatures in their working states. The latter are damaging to most elastomers and to plastics; phosphate esters are especially damaging to these materials and to paint finishes.

2.2.3 Lubricating Oils.

Mineral or synthetic-based lubricating oils may be at elevated temperatures in their working states. Mineral oil is damaging to natural rubber but less so to synthetics such as polychloroprene, chloro-sulphonated polyethylene and silicone rubber. Synthetic lubricants are extremely damaging to plastics such as PVC as well as to many elastomers.

2.2.4 Solvents and cleaning fluids.

Many areas of aircraft or vehicles may require dirt or grease removal before servicing can begin. The fluids given in Table 1 are representative of those presently in use.

2.2.5 De-icing and anti-freeze fluids.

These fluids may be applied, often at elevated temperatures, to the leading edges, intakes, etc., of aircraft and may penetrate areas where they can contaminate components and equipment. These fluids are based, typically, on inhibited ethylene glycols.

2.2.6 Runway De-icers.

These fluids are used on runways and other areas to lower the freezing point of water. They may penetrate undercarriage and equipment bays of aircraft as a fine mist.

2.2.7 Insecticides.

Aircraft flying in and through the tropics may be treated with insecticide sprays as a routine precaution. To ensure that these will not have an adverse effect on materiel, it may be necessary to make exploratory tests using proprietary insecticides.

2.2.8 Disinfectants.

The primary contaminating agent is likely to be the disinfectant used, that will be a formaldehyde/phenol preparation, and its use on waste liquid from galleys and toilet compartments, where a leak may permit contamination of materiel below the leak.

2.2.9 Coolant Dielectric Fluids.

These are used as thermal transfer liquids to assist cooling of certain equipment. They are usually based on silicate ester materials, and their effects on materials may be considered to be similar to the phosphate ester hydraulic fluids, although not quite as severe.

2.2.10 Fire Extinguishants.

Halon (chloro bromo fluoro hydrocarbon) or similar compounds are likely to be used on aircraft, and will be relatively short-lived. Ground-based extinguishants are aqueous foams derived from fluoro chemicals or fluoroproteins. Their effects will be mainly due to water or buildup of trapped residues. The necessity for testing with these products is based on the need to maintain equipment functioning after release of the extinguishant.

2.3 Choice of Procedural Options. (See Method 301, paragraphs 1 and 2.)

There are three exposure options provided in the test procedure: occasional contamination, intermittent contamination, and extended contamination. The requirements document should specify the option to be used based on the anticipated life cycle scenario, along with the order of application of the test fluids if more than one is required.

2.4 Sequence.

Do not perform these tests prior to other climatic environmental tests because of potential effect of the contaminants or their removal by decontaminants.

2.5 Choice of Test Parameters. (See Method 301, paragraphs 1, 2 and 4.)

The most significant parameters used in this test method are the fluid to be used, the temperature and duration of exposure. It is also important in this test procedure to specify the operational configuration of the test item, as well as whether or not the test item is heat dissipating during operation.

2.5.1 Test Fluid(s).

Select a test fluid(s) from those listed in Table 1, that is representative of that commonly encountered during the life cycle. Each specified test fluid is the worst case representative of a group of fluids and is the most likely to affect the performance of the materiel. In the requirements document list other fluids identified during the tailoring process as possible contaminants. Service grades of fluids may be changed or modified with development formulations and equipment demands. Some may subsequently be found undesirable because of environmental or health and safety problems. Table 1 may be updated as necessary in the future.

2.5.2 Combination of Test Fluids.[9]

When more than one test fluid is to be applied, consider the following:

a. The need to assess the effect of the fluids individually, combined or in succession.

b. If the order of exposure to fluids in service is known, or if the order of exposure to fluids recognized as having synergistic effects is known and is realistic in service, specify this order.

c. If the test item should be cleaned between or after tests, or if a new test item should be used for each test fluid. Choice of cleaning fluid should not result in further contamination. Some of the specified test fluids may be used as cleaning fluids (e.g., aviation fuel, solvents, or cleaning fluids), otherwise, a fluid known to be used in normal cleaning procedures should be used.

2.5.3 Test Temperature.

Use temperatures representative of the actual conditions under which fluid contamination can occur either intentionally or accidentally. The application of contaminating fluids could result in thermal shock as well as contamination effects.

2.5.3.1 Test Item Temperature.

Use a test item temperature representative of the materiel temperature when exposed to the contaminating fluid. For example, materiel to be de-iced will most likely be at or below freezing; materiel exposed to hydraulic leaks while on tarmac may have surface temperatures above 50^{o}C.

2.5.3.2 Test Fluid Temperature.

In most cases, use the temperature of the test fluid equal to its temperature during its most extreme operating condition. Design assessment may prove that other temperatures provide a more severe environment, e.g., longer exposure at lower temperatures because of slower evaporation. Table I includes worst-case test fluid temperatures.

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[9] *When mixing two or more fluids, ensure they are compatible and will not produce hazardous reactions.*

2.5.3.3Soak Temperature.

In order for contamination effects to mature, a soak of the test item following contamination is necessary. The temperature of both the contaminating fluid and the materiel will, most likely, change during actual contamination situations. The post-contamination soak will not necessarily reflect the exposure scenario, but rather the worst-case effect(s) on the materiel. Accordingly, for the soak temperature, use the materiel's maximum life cycle temperature for the anticipated exposure situation.

2.5.4 Method of Application.

The method of application of contaminating fluids should, if known, be the same as would occur during the life cycle of the materiel. If not known, consider an application no more severe than would be reasonably expected.

2.5.5 Soak Duration.

Unless otherwise justified, expose the contaminated test item to the required soak temperature (para 2.5.3.3) for a minimum of 96 hours.

3. INFORMATION TO BE PROVIDED IN THE TEST INSTRUCTION

In addition to that provided in Method 301, paragraphs 5 and 6, following information shall be provided:

a. The test fluid(s) to be used and its temperature.

b. The method of test fluid application.

c. The soak (post-wetting) temperature and duration.

d. The cleaning/decontaminating fluids.

e. The sequence of test fluid applications and post-test cleaning instructions.

f. The type of exposure, i.e., occasional, intermittent or extended.

g. Any requirement for long term surveillance and inspections.

4. TEST CONDITIONS AND PROCEDURES

See Method 301, paragraph 7 - 10, for test facility, test conditions and test control information.

4.1 Test Facility

In addition to the information provided in Method 301, para 8, use a test facility that includes an enclosure and a temperature control mechanism designed to maintain the test item at a specified temperature. The contamination facility is a tank within the test enclosure (non-reactive with the contaminant) in which the test item is exposed to the selected contaminant by immersion, spraying, splashing or brushing. Design the temperature control mechanism to maintain the test item at the specified temperature. When the flash point of the test fluid is lower than the test temperature, design the test facility to fire and explosion standards.

4.2 Controls

In addition to the controls provided in Method 301, para 10, ensure the test and cleaning (decontaminating) fluids are handled and disposed as required by local environmental and safety requirements. Some test fluid specifications are referenced in Table I.

4.3 Test Interruptions

See Method 301, paragraph 11.

4.4 Procedure

The following test procedure may be used to determine the resistance of the material to contaminating fluids. Conduct the operational checks after each exposure to each of the specified fluids.

4.4.1 Preparation for Test.

Before starting the test procedure, determine the information specified in Method 301, paragraphs 5 and 6.1, and perform the test preparation procedure specified in Method 301, paragraph 12. Unless otherwise specified, clean the test item to remove unrepresentative coatings or deposits of grease. If more than one fluid has been identified, determine if each is to be evaluated simultaneously or sequentially. If sequential testing is specified, specify in the requirements document any necessary cleaning method between tests for different contaminants.

4.4.2 Contamination Test Procedure.

Step 1. Place the test item in its specified configuration (operational, storage, etc.) and place it in the test facility. If appropriate, the configuration may include appropriate electrical or mechanical connections.

Step 2. Stabilize the test item at the appropriate temperature for the identified contamination scenario (see paragraph 2.5.3.1).

Step 3. Stabilize the temperature of the specified fluid(s) to that determined from paragraph 2.5.3.2. If simultaneous application of more than one fluid is required, apply the fluid with the highest application temperature first, the next highest next, and so on until all required fluids have been applied[10].

Step 4.

a For occasional contamination, apply the specified fluid(s) (e.g., dip, spray, etc.) to the entire surface of the test item that is likely to be exposed.

b. For intermittent contamination, apply the specified fluid(s) (e.g., dip, spray, etc.) to the entire surface of the test item that is likely to be exposed. Repeat this procedure one or more times as necessary to maintain all the test item surfaces in a wetted condition for the period specified in the requirements document. If not specified, subject the test item to 3 24-hour cycles, each cycle consisting of 8 hours in the wetted condition, followed by a drain period of 16 hours at the temperature specified in Step 2.

c. For extended contamination, immerse the test item in the specified fluid and maintain for the period specified in the requirements document. If not specified, the fluid temperature shall be as given in Table 1, and the duration of immersion shall be a minimum of 24 hours.

Step 5. Allow the test item to drain naturally. Shaking or wiping is not permitted but, if representative of service conditions, it may be rotated about any axis to allow for drainage from different positions.

Step 6. Maintain the test item at the temperature determined in paragraph 2.5.3.1 for 8 hours (see step 2).

Step 7. Stabilize the test item at standard ambient conditions.

Step 8. Visually examine the test item for degradation of materials, protective finishes and dimensional changes. Record results.

Step 9. If appropriate, conduct an operational check of the test item similar to that in Method 301, paragraph 12, and document the results for comparison with the pretest data.

Step 10. If testing sequentially, repeat steps 2-9 for each specified fluid.

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[10] *Before mixing two or more fluids, ensure they are compatible and will not produce hazardous reactions.*

Step 11. If specified, store the test item at standard ambient conditions to permit evaluation of any long-term effects.

5. EVALUATION OF TEST RESULTS

In addition Method 301, paragraph 13, any contamination effects must be analyzed for its immediate or potential (long term) effects on the proper functioning of the test item. Satisfactory operation immediately following this test is not the sole criterion for pass/fail.

6. REFERENCES AND RELATED DOCUMENTS

See Method 301, paragraph 14.

a. Defence Standard 42-40/Issue 1, Foam Liquids, Fire Extinguishing (Concentrates, Foam, Fire Extinguishing), UK Ministry of Defence

b. Defence Standard 68-161/Issue 1, Dispensers, Insecticide Aerosol Flying Insect Killer, UK Ministry of Defence

c. BS 6580:1992, Specification for Corrosion Inhibiting, Engine Coolant Concentrate ('Antifreeze'), British Standards Institute

d. Defence Standard 79-17/Issue 2, Compound, Cleaning, Foaming, for Aircraft Surfaces, UK Ministry of Defence

e. MIL-C-47220, Coolant Fluid, Dielectric Reviewer: 68 GS, 14 May 1985 (U.S.)

f. Test Operations Procedure (TOP) 3-2-609, Chemical Compatibility of Nonmetallic Materials Used in Small Arms Systems, 3 February 1987; USATECOM, AMSTE-TM-T, APG, MD 21005-5055

Table I - Major Contaminant Fluid Groups and Test Fluids.

Contaminant Fluid Group		Test Fluid	Test Fluid Temperature (±2°C) ***
Fuels	**Kerosene**	Aviation turbine fuel (JP-4 (NATO F-40), JP-5 (NATO F-44), JP-8 (NATO F-34), etc.)	**70**
	Diesel	DL-A, DL-1, DL-2 (ASTM D975)	**23**
	Gasoline (Piston engine)	ISO 1817, Test liquid B; ASTM 4814, Automotive spark ignition engine	**40**[*]
Hydraulic oils	**Mineral oil based**	NATO H-520/NATO H-515; U.S. MIL-H-5606	**70**
	Phosphate ester based (synthetic)	ISO 1817, test liquid 103; U.S. MIL-H-46170 (FRH); NATO H-544	**70**
	Silicone based	Dimethyl silicone (ZX42; NATO S1714)	**70**
Lubricating oils	**Mineral based**	NATO 0-1176 (OMD 80); NATO Stock #4210 99 224 8369	**70**
	Internal combustion engines	MIL-PRF-2104, 15W40; NATO D-1236	**70**
	Ester based (synthetic)	ISO 1817, test liquid 101	**150**
Solvents & cleaning fluids		Propan-2-ol (isopropyl alcohol)	**50**[*]
		1.1.1 - Trichloroethane/NATO H-515	**50**
		Denatured alcohol	**23**[*]
		Cleaning compound for aircraft surfaces	**23**
Deicing & antifreeze fluids		Inhibited ethylene glycol (BS 6580) 80% and 50% solution in water (v/v); U.S. antifreeze MIL-A-46153 (NATO S-750)	**23**
Runway de-icers		25% urea/25% ethylene glycol in water (v/v)[**]	**23**
Insecticides		Insecticides	**23**
Disinfectant (heavy duty phenolics)		Clear, soluble phenolics, e.g., phenol or its derivatives dissolved in a surfactant and diluted with water to give a clear solution	**23**
		Black fluids, e.g., refined tar products dissolved in a carrier oil and emulsified with detergent	**23**
		White fluids, e.g., colloidal emulsions of refined coal tar products in water, usually containing a small amount of surfactant	**23**
Coolant dielectric fluid		Coolanol 25R (DTD 900/4931)	**70**
Fire extinguishants		Protein: NATO Stock #4210 99 224 6855	**23**
		Fluoroprotein: NATO Stock #4210 99 224 6854	**23**

[*] *Exceeds the critical flash point temperature; obtain expert advice.*

[**] *Subject to change; identified as environmental hazard.*

[***] *See paragraph 2.5.3.2 . Use these temperatures if no other information exists.*

ANNEX A

Environmental and Toxicological Considerations

1. GASOLINE FUELS AND MINERAL/SYNTHETIC OILS.

a. Open burning will produce environmental pollution.

b. Contact with the skin will promote de-fatting.

c. Ignition under certain circumstances will cause explosion.

d. Low flash point of gasoline (piston engine): $-18^{o}C$.

e. Spillage can cause contamination of waterways and underground water supplies. Three hundred liters of gasoline has the capacity to produce a surface film over one square kilometer of still water.

f. Carcinogenic chemicals such as benzene are present in fuels; oils often contain other toxic ingredients.

g. Tri alkyl phosphate is a typical synthetic hydraulic oil. Spillage can cause toxic pollution of waterways and underground water supplies.

2. SOLVENTS AND CLEANING FLUIDS.

a. Propan-2-ol is flammable.

b 1.1.1 Trichloroethane is currently being withdrawn from use because of its environmental impact when reacting with ozone. It is also believed to have mutagenic properties.

c. Denatured alcohol is both toxic and flammable. It is a mixture containing approximately 95% ethyl alcohol, 5% methyl alcohol and minor ingredients such as pyridine.

d. Detergent made from biodegradable phosphates sodium sulphate and sodium carboxy methyl cellulose is a conventional laundry substance. Untreated discharge into waterways must be avoided.

3. DE-ICING AND ANTI FREEZE FLUIDS.

a. All aqueous solutions of ethylene glycol are toxic and the inclusion of 25% urea will promote the growth of algae.

b. 50% inhibited aqueous potassium acetate solution is commercially marketed and reputed to be a completely safe new alternative to the ethylene glycols. However, its interaction with aluminum alloys is less than satisfactory.

4. DISINFECTANT. FORMULATIONS CONTAINING FORMALDEHYDE AND O-CRESOL (AS USED IN CHEMICAL TOILETS) WILL ATTACK AND BLISTER SKIN.

5. COOLANT DIELECTRIC FLUID.

a. Coolanol 25R is a silicate ester that can be hydrolyzed to produce flammable products. The U.S. has withdrawn it from use.

b. The most recent coolants are based on polymerized alpha olefins that are both non-toxic and generally inert.

6. FIRE EXTINGUISHANTS.

The propellant gases currently used to produce foaming are chloro fluoro hydrocarbons (CFC's). These react with ozone and are therefore environmentally destructive.

7. INSECTICIDES.

Most insecticides may be regarded as toxic to man. If the delivery vehicle for the insecticide is a kerosene-type (fuel/oil) spray or mist, many of the features identified under paragraph 1 above will also apply.

METHOD 315

FREEZE / THAW

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METHOD 315

FREEZE/THAW

NOTE *: METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD.*

1. SCOPE

1.1 Purpose

The purpose of this test is to determine the ability of materiel to withstand:

a. The effects of moisture phase changes between liquid and solid, in or on the materiel as the ambient temperature cycles through the freeze point;

b. The effects of moisture induced by transfer from a cold-to-warm or warm-to-cold environment.

1.2 Application

This test is applicable to materiel that will experience one or more excursions through freeze point while wet or in the presence of moisture (free water or vapour). See paragraph 2.2 for specific examples.

1.3 Limitations

This test is not intended to evaluate the effects of low temperature, thermal shock, rain or icing. These may be determined by Methods 303, 304, 310 and 311 respectively.

2 TEST GUIDANCE

2.1 Effects of the Environment

This test induces physical changes in or on the materiel of a transitory kind. Examples of problems that could occur during this test are as follows:

a. Distortion or binding of moving parts.

b. Failure of bonding materials.

c. Failure of seals.

d. Failure of materials due to freezing/re-freezing of absorbed, adjacent or free water.

e. Changes in characteristics of electrical components.

f. Electrical flashover/reduced insulation resistance.

g. Fogging of optical systems during freeze-thaw transitions.

h. Inability to function correctly due to ice adhesion and interference or blockage of moving parts.

2.2 Test Procedure

See Method 301, paragraphs 1 and 2.

When a freeze/thaw test is deemed necessary, the procedures included in this method are considered suitable for most materiel. Three procedures are included:

a. Procedure I - To simulate the effects of diurnal cycling on materiel exposed to temperatures varying slightly above and below the freeze point that is typical of daytime warming and freezing at night when deposits of ice or condensation, or high relative humidity exist. For Procedure I to be effective, frost must form on the test item surfaces during the temperature increase through the freeze point, and then melt just prior to re-freezing.

b. Procedure II - For materiel transported directly from a cold to a warm environment such as from an unheated aircraft, missile or rocket, to a warm ground area, or from a cold environment to a warm enclosure, and resulting in free water or fogging.

***NOTE** : Tests for fogging are only appropriate for materiel designed to not fog or that has built-in de-fogging capabilities).*

c. Procedure III - For materiel that is to be moved from a warm environment to a cold environment (freeze) and then back to the warm environment, inducing condensation (free water).

2.3 Choice of Test Severities

See Method 301, paragraphs 1-4.

The most significant parameters to be specified for this test method are temperature, moisture level/form, test item configuration (operational or storage) and the number of freeze/thaw cycles.

2.3.1 Temperature range

The temperatures used shall be within the storage or operational range of the test item. Normally, the temperature cycle ranges between + 5° C and -l0° C for diurnal cycling effects, and -l0° C to standard ambient (Method 301, para 7.1), but these can be varied as required to achieve the desired effects.

2.3.2 Moisture

Water used to create the test moisture may be drawn from local (clean) water sources. The moisture may be applied as a water vapour or free water (spray).

2.3.3 Test item configuration

See Method 301, paragraph 5.

2.3.4 Number of cycles

A cycle is defined as a change from one thermal-moisture condition to another and back to the original condition. Unless otherwise specified in the test procedure, hold the test item at each condition for a minimum of one hour following temperature stabilization of the test item (Method 301, para 9). Unless otherwise justified by the materiel's life cycle profile, apply the following minimum number of cycles:

a. Diurnal cycling effects (daily freeze-thaw): Five.

b. Cold-to-warm transfer (for free water or possible fogging): Three.

c. Warm-cold-warm (for freezing and melting): One.

3. INFORMATION TO BE PROVIDED IN THE TEST INSTRUCTION

In addition to the information derived from Method 301, paragraphs 5 and 6, a brief scenario of service conditions should be provided to explain the intended simulation. Also state:

a. The type of moisture required (vapor or spray).
b. The initial test conditions and the temperatures to be used.
c. Whether the test is a demonstration of survival or functional performance.
d. The number of cycles to be used.

4. TEST CONDITIONS AND PROCEDURES

See Method 301, paragraphs 7 to 10, for test facility, test conditions and test control information.

4.1 Test Facility

In addition to the requirements specified in Method 301, paragraph 8, the use of two chambers is recommended for Procedures II and III in order to simulate the sudden temperature changes often associated with movement between outside ambient and indoor conditions. For procedures II and III, either a single chamber or combination of chambers is acceptable as long as the test procedure requirements are satisfied.

4.2 Controls

See Method 301, paragraph 10.

4.3 Test Interruptions

See Method 301, paragraph 11.

4.4 Procedures

4.4.1 Preparation for Test.

a. Before starting the test procedure, determine the information specified in Method 301, paragraphs 5 and 6.1, and perform the test preparation procedure specified in Method 301, paragraph 12.

b. Ensure any fluids contained in the test item are compatible with the temperatures used in the test.

c. Install thermocouples in/on the test item to measure temperature stabilization and surface temperatures.

4.4.2 Procedure I - Diurnal cycling effects

Step 1. Remove unrepresentative coatings/deposits and contaminants such as oils, grease and dirt that could affect the adhesion of ice to the specimen surface.

Step 2. Place the test item in the test chamber at standard ambient conditions and in the required configuration. Spray the test item sufficient to fill any horizontal pockets to simulate water collected during a rainstorm.

Step 3. Reduce the temperature inside the chamber to 10°C below the freeze point or as otherwise specified for the initial conditions at a rate not exceeding 3°C per minute. Maintain the condition for a minimum of one hour after the test item temperature has stabilized.

Step 4. Increase the chamber temperature linearly over a period of three hours. When the chamber air temperature reaches 0°C, introduce moisture using water vapor, steam, vapor generator or other means to raise and maintain the humidity at or close to saturation.

Step 5. When the test item surface temperature reaches 0°C, ensure frost has formed on the test item surfaces. If so, go to Step 6; if not, repeat Steps 3 and 4 using a faster heating rate.

Step 6. Continue raising the test chamber towards a test item surface temperature of 4° C (water at maximum density) until the frost just melts, then reduce the temperature linearly to l0°C below the freeze point over a period of three hours. Maintain the conditions for a minimum of one hour following test item temperature stabilization.

Step 7. Repeat steps 4-6 as required to complete the number of cycles identified in paragraph 2.3.4.

Step 8. Maintain the chamber and test item at the low temperature conditions until a visual examination and/or performance checks have been completed.

Step 9. Return the test item to standard ambient conditions. Perform a complete visual and operational check, and document the results.

4.4.3 Procedure II - Cold-to-warm transfer

Step 1. Remove unrepresentative coatings and contaminants such as oils, grease and dirt that could affect the formation of condensation.

Step 2. Place the test item in the test chamber at standard ambient conditions and in the required configuration.

Step 3. Adjust the chamber temperature to l0°C below the freezing point or as otherwise specified for the initial conditions at a rate not exceeding 3°C per minute. Maintain the condition until the test item temperature has stabilized plus one hour.

Step 4. Transfer the test item to another chamber (previously adjusted to the upper specified temperature) as quickly as possible such that condensation/fogging occurs. The use of insulated transport containers is recommended. This second chamber should be maintained at the specified upper temperature (usually room ambient) with a relative humidity of 95 ± 5 %.

Step 5. Start operation and any performance tests of the test item 60 ± 15 seconds after completion of the transfer, and document results.

Step 6. Return the test item to the low temperature chamber and repeat Steps 3-5 as required to complete the number of cycles identified in para 2.3.5.

Step 7. Return the test item to standard ambient conditions. Perform a complete visual and operational check, and document the results.

4.4.4 Procedure III - Rapid temperature change

Step 1. Remove unrepresentative coatings and contaminants such as oils, grease and dirt that could affect the adhesion of ice to the specimen surface.

Step 2. Place the test item in the test chamber at standard ambient conditions and in the required configuration.

Step 3. Adjust the chamber temperature to the specified upper temperature (usually room ambient) at a rate of approximately 3°C per minute, and a relative humidity of 95 ± 5 %. Maintain these conditions until the test item temperature has stabilized plus one hour.

Step 4. Transfer the test item as quickly as possible and in not more than 5 minutes to another chamber stabilized at 10°C below the freeze point. The use of insulated transport containers is recommended. Stabilize the test item temperature and hold for one additional hour.

Step 5. Unless otherwise specified, perform an operational check.

Step 6. If more than one cycle is required, stabilize the test item at room ambient temperature and at a RH of 95% as in Step 3, note the presence of any free water, and repeat Step 4.

Step 7. Return the test item to above-freezing conditions as soon as possible.

Step 8. As any ice melts, note location(s) of free water.

Step 9. Perform an operational check and physical inspection, and document results.

Step 10. Adjust the test item to standard ambient conditions and repeat Steps 3-9 as necessary to verify prior results.

5 EVALUATION OF THE TEST RESULTS

See Method 301, paragraph 13.

6. REFERENCES AND related DOCUMENTS

See Method 301, paragraph 14.

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EXPLOSIVE ATMOSPHERE

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METHOD 316

EXPLOSIVE ATMOSPHERE

NOTE: *METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD.*

1. SCOPE

1.1 Purpose

The explosive atmosphere test is performed to:

a demonstrate the ability of materiel to operate in fuel-air explosive atmospheres without causing ignition, or

b. demonstrate that an explosive or burning reaction occurring within encased equipment will be contained, and will not propagate outside the test item..

1.2 Application

This method applies to all materiel designed for use in the vicinity of fuel-air explosive atmospheres associated with aircraft, automotive and marine fuels at or above sea level. Procedure II specifically relates to atmospheres in a space in which flammable fluids or vapors exist, or can exist, either continuously or intermittently (e.g., in fuel tanks or within fuel systems). NOTE: Materiel tested to Procedure II is designed such that ignition of an explosive mixture is contained within the materiel without igniting the surrounding explosive atmosphere; and, during normal operation, or as a result of any fault, the temperature of any external surface will not rise to a level capable of causing ignition (including hermetically-sealed materiel). Use other explosive atmosphere safety tests (e.g., electrical or mine safety) if more appropriate.

1.3 Limitations

a. This test utilizes an explosive mixture that has a relatively low flash point that may not be representative of some actual fuel-air or aerosol (such as suspended dust) mixtures.

b. The explosive atmosphere test is a conservative test in that if the test item does not ignite the test fuel-air mixture, there is a low probability that the materiel will ignite prevailing fuel vapour mixtures in service. Conversely, the ignition of the test fuel-air mixture by the test item does not mean the materiel will always ignite fuel vapours that occur in actual use.

c. This test is not appropriate for altitudes above approximately 16km where the lack of oxygen inhibits ignition.

d. Because this test is designed for electrical spark ignition, this method is not intended to demonstrate ignition due to high surface temperatures.

2. TEST GUIDANCE

2.1 Effects of the Environment

Low levels of electrical energy discharge or electrical arcing by devices as simple as pocket transistor radios can ignite mixtures of fuel vapour and air. A "hot spot" on the surface of the case of a hermetically sealed, apparently inert materiel case can ignite fuel-air mixtures. Fuel vapours in confined spaces can be ignited by a low energy discharge such as a spark from a short circuited flashlight cell, switch contacts, electrostatic discharge, etc.

2.2 Choice of Test Procedure

(See Method 301, paragraphs 1 and 2.)

2.2.1 Procedure I (Explosive Atmosphere) may be used to determine the ability of all sealed and unsealed materiel to operate safely in a fuel-vapour laden environment.

2.2.2 Procedure II (Explosion Containment) 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 materiel malfunction.

2.3 Sequence

(See Method 301, paragraph 2.3.)

Considering the approach to conserve test item life by applying what are perceived to be the least damaging environments first, generally apply explosive atmosphere tests late in the test sequence. Vibration, shock, and temperature stresses may distort seals and reduce their effectiveness, thus making ignition of flammable atmospheres more likely. It is recommended that the test items first undergo vibration, shock, and/or temperature testing.

2.4 Choice of Test Parameters

(See Method 301, paragraphs 1-4.)

2.4.1 Fuel

Unless otherwise specified, use n-hexane as the test fuel, either reagent grade or 95% n-hexane with 5% other hexane isomers. This fuel is used because its ignition properties in flammable atmospheres are equal to or more sensitive than the similar properties of both 100/130 octane aviation gasoline, JP-4 and JP-8 jet engine fuel. Optimum mixtures of n-hexane and air will ignite from hot-spot temperatures as low as 223^{o}C, while optimum JP-4 fuel-air mixtures require a minimum temperature of 230^{o}C for auto-ignition, and 100/130 octane aviation gasoline and air requires 441^{o}C for hot-spot ignition. Minimum spark energy inputs for ignition of optimum fuel vapour and air mixtures are essentially the same for n-hexane and for 100/130-octane aviation gasoline. Much higher spark energy input is required to ignite JP-4 or JP-8 fuel and air mixtures. Use of fuels other than hexane is not recommended.

Warning : *Due to the hazardous nature of the fuels used in this test, the Test Facility Operators must ensure that they comply with Local and National Regulations, especially with respect to the personal exposure levels, pollution, and hazardous material disposal.*

2.4.2 Fuel-vapour mixture

Use a homogeneous fuel-air mixture in the correct fuel-air ratios for the explosive atmosphere test. 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. This yields an air/vapour ratio (AVR) of 8,33 by weight.

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 1).

  (4) Test altitude: maximum operating altitude and ambient ground (nominal).

  (5) Net volume of the test chamber: free volume less test item displacement expressed in liters.

b. Calculation of the volume of liquid n-hexane fuel for each test altitude:

Volume of 95 percent n-hexane (ml) =

$$(4.27x\,10^{-4})\left[\frac{(\text{net chamber vol (liters)})\ x\ (\text{chamber pressure (pascals)})}{(\text{chamber temp (K)})\ x\ (\text{specific gravity of n-hexane})}\right]$$

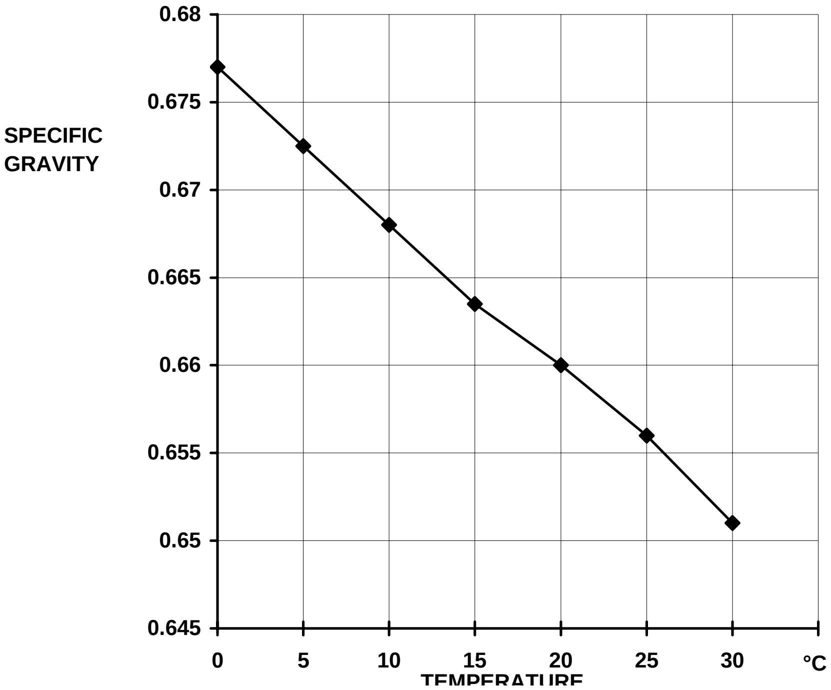

Figure 1 - Specific gravity of n-hexane.

2.4.3 Temperature

Heat the fuel-air mixture to the highest ambient air temperature at which the materiel is required to function during deployment and provide the greatest probability of ignition. Perform all testing at this maximum air temperature. For forced-air-cooled materiel, use the highest temperature at which the materiel can be operated and performance evaluated in the absence of cooling air as the test temperature.

2.4.4 Effect of Humidity on Flammable Atmosphere

The effect of humidity upon the fuel-air composition need not be considered in the test if the ambient air dewpoint temperature is 10°C or less because this concentration of water vapour 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 an equivalent of 1525 meters above the test level to site pressure (a 17 percent change in pressure), the volume of n-hexane will decrease from 4.61 percent to 3.85 percent. This decrease will compensate for the fuel enrichment effect that results from water vapour dilution of the test air supply.

2.4.5 Altitude simulation

The energy required to ignite a fuel mixture increases as pressure decreases. All test conditions will be met with two steps in a single explosive atmosphere test performed at the highest anticipated operating altitude of the materiel (not exceed 12,200 m where the possibility of an explosion begins to dissipate), and between 78 and 107 kPa (most ground ambient pressures).

2.5 Definitions

For the purpose of this Method, the following definitions apply:

a. Simulated altitude. Any height that is produced in the test chamber by reducing air pressure.

b. 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 2.4.5.

3. INFORMATION TO BE PROVIDED IN THE TEST INSTRUCTION

In addition to the information specified in Method 301, paragraphs 5 and 6, the following are required:

a. The fuel volume and/or weight.

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

c. The off/on cycling rate for the test item.

d. Any information relative to the location of spark-emitting devices or high temperature components.

4. TEST CONDITIONS AND PROCEDURES

See Method 301, paragraphs 7 through 10, for test facility, test conditions and test control information.

4.1 Test Facility

(See Method 301, paragraph 8.)

Use a chamber with a means of igniting the fuel-air mixture such as a spark-gap device, as well as a means of determining the explosiveness of a sample of the mixture such as a spark-gap or glow plug ignition source with sufficient energy to ignite a 3.82-percent hexane mixture. An alternative method of determining the explosive characteristics of the vapour is by using a calibrated explosive gas meter that verifies the degree of explosiveness and the concentration of the fuel-air mixture.

4.2 Controls

See General Guidance and Requirements, paragraph 10 and consider the following:

4.3 Test Interruptions

(See Method 301, paragraph 11.)

If there is an unscheduled undertest interruption, restore the chamber air pressure to ground ambient pressure and purge the chamber to remove the flammable atmosphere. Inject the required volume of n-hexane and reinitiate the test using the same test item.

4.4 Procedure

4.4.1 Preparation for test

Before starting the test procedure, determine the information specified in Method 301, paragraphs 5 and 6.1. Perform the test preparation procedure specified in Method 301, paragraph 12, and include the following:

a. For test item thermal stabilization measurements for both procedures, install thermocouples on the most massive functional part of the test item, and two thermocouples attached to the inside of the test chamber to detect any temperature increase due to burning of the mixture.

b. Procedure I

(1) Install the test item in the test chamber in such a manner that it may be functioned and controlled from the exterior of the chamber via sealed cable ports. Remove or loosen the external covers of the test item to facilitate the penetration of the explosive mixture. Test items requiring connection between two or more units may, because of size limitations, have to be tested independently. In this case, extend any interconnections through the cable ports.

(2) Function the test item to determine correct operation. If possible, identify the location of any sparking or high temperature components that could cause an explosion.

(3) When necessary, simulate in-service mechanical loads on drive assemblies and servo-mechanical systems, and electrical loads on switches and relays; duplicate torque, voltage, current, inductive reactance, etc. In all instances, operate the test item in a manner representative of service use.

c. Procedure II

(1) Make provision to circulate the fuel-air mixture into the case being tested. In the case of forced-air-cooled materiel, the cooling air must contain the proper fuel-air mixture. For materiel not using forced-air cooling, drill and tap the case for insertion of a hose from a blower (to insert the fuel-air mixture), as well as for an outlet hose connection. Take adequate precautions to prevent ignition of the ambient mixture by backfire or release of pressure through the supply or vent hose. Do not alter the case internal volume by more than ±5% with any modification to facilitate the introduction of ignitable vapor.

(2) Provide a positive means of igniting the explosive mixture within the case. Drill or tap the case as necessary for a spark gap, or mount a spark gap internally. Ensure points of ignition are not be more that 12.5 mm from any vent holes or flame arresting devices; and, unless the design of the materiel makes this impractical, use as many points of ignition as are practical.

(3) To detect explosions within the case, insert a thermocouple into the case and attach it to a sensitive galvanometer outside the test chamber.

(4) Ensure the air within the test chamber has a water vapor dew point lower than 10°C (see paragraph 2.4.4).

4.4.2 Operation in Explosive Atmosphere

Step 1. With the test item installed, seal the chamber and stabilize the test item and chamber inner walls to within 10°C below the high operating temperature of the test item.

Step 2. Adjust the chamber air pressure to simulate the highest operating altitude of the materiel (not to exceed 12,200 m) plus 2000 meters to allow for introducing, vapourising and mixing the fuel with the air as described in Paragraph 2.4.2.

Step 3. Slowly introduce the required volume of n-hexane into the test chamber.

Step 4. Circulate the test atmosphere and continue to reduce the simulated chamber altitude for at least three minutes to allow for complete vapourisation of fuel and the development of a homogeneous mixture.

Step 5. At a pressure equivalent to 1000m above the test altitude, verify the potential explosiveness of the air-vapour mixture by attempting to ignite a sample of the mixture taken from the test chamber using a spark plug ignition source with sufficient energy to ignite a 3.82 percent hexane mixture. If ignition does not occur, purge the chamber of the fuel vapour, and repeat Steps 1-4. An alternative method of determining the explosive characteristics of the vapour is by using a calibrated explosive gas meter that verifies the degree of explosiveness and the concentration of the fuel-air mixture.

Step 6. Function the test item and continue operation from this step until completion of step 8. Ensure electrical contacts are actuated as frequently as reasonably possible.

Step 7. To ensure adequate mixing of the fuel and air, slowly decrease the simulated chamber altitude at a rate no faster than 100 meters per minute by bleeding air into the chamber.

Step 8. Stop decreasing the altitude at 1000 m below the test altitude, perform one last functional check and switch off power to the test item.

Step 9. Verify the potential explosiveness of the air-vapour mixture as in Step 5 above. If ignition does not occur, purge the chamber of the fuel vapour, and repeat the test from Step 1.

Step 10. Adjust the chamber air pressure to simulate the altitude at the ground level where the test is being performed plus 2000 meters to allow for introducing, vapourising and mixing the fuel with the air as described in 2.4.2.

Step 11. Slowly introduce the required volume of n-hexane into the test chamber for testing at ground level. If desired, introduction of the required volume of fuel can commence at any point following completion of Step 9.

Step 12. Circulate the test atmosphere and continue to reduce the simulated chamber altitude for at least three minutes to allow for complete vapourisation of fuel and the development of a homogeneous mixture.

Step 13. At a pressure equivalent to 1000 m above the ground altitude, verify the potential explosiveness of the air-vapour mixture as in Step 5 above, and repeat the necessary steps if ignition does not occur.

Step 14. Function the test item and continue operation from this step until completion of Step 16. Ensure electrical contacts are actuated as frequently as reasonably possible.

Step 15. To ensure adequate mixing of the fuel and air, slowly decrease the simulated chamber altitude at a rate no faster than 100 meters per minute by bleeding air into the chamber.

Step 16. Stop decreasing the altitude at ground pressure, perform one last functional check and switch off power to the test item.

Step 17. Verify the potential explosiveness of the air-vapour mixture as in Step 5 above. If ignition does not occur, purge the chamber and repeat Steps 10-17.

Step 18. Document test results as per paragraph 4.

4.4.3 Explosion Containment

Step 1. Place the test item or a model of the test item of the same volume and configuration within the case, and install the case in the explosion chamber.

Step 2. Ensure that the air within the test chamber has a water vapor dew point lower than 10°C per paragraph 2.4.4.

Step 3. Seal the chamber with the test item inside, and raise the ambient air temperature inside the chamber to high operating temperature of the test item.

Step 4. When the temperature of the both the test item and the test chamber inner walls come to within 11°C of the chamber ambient air temperature, reduce the chamber air pressure to 2000m of simulated altitude above the site ambient pressure (i.e., ground level).

Step 5. Slowly introduce the required quantity of n-hexane into the test chamber to obtain an optimum fuel-vapor/air mixture, and then introduce it into the interior of the test item.

Step 6. Slowly decrease the simulated chamber altitude (no faster than 100 meters per minute) to return the pressure altitude to site ambient pressure (i.e., ground level).

Step 7. 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 3.

Step 8. If the explosion inside the test item's case did not propagate to the fuel/air mixture outside the test item, repeat Steps 4-10 four times if the test item's case is not in excess of 0.02 times the chamber volume. 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 3-10 four times.

Step 9. 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 the chamber sample does not ignite, purge the chamber of all air/fuel vapor mixture, and repeat the entire test from Step 3.

Step 10. Document the test results.

5. EVALUATION OF THE TEST RESULTS

In addition to that specified in Method 301, paragraph 13, for Procedure I, ignition of test fuel vapour constitutes failure of the test item. For 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. Apply any data relative to failure of a test item to meet the requirements of the materiel specifications to the test analysis.

6. REFERENCES AND RELATED DOCUMENTS

See Method 301, paragraph 14.

a. Haskin, W.L. Explosion-Proof Testing Techniques. 1963.
ASD-TDR-62-1081. DTIC number AD-400-483.

b. Zabetakis, M.G., A.L. Furno, and G.W. Jones. "Minimum Spontaneous Ignition Temperatures of Combustibles in Air," Industrial and Engineering Chemistry 46 (1954), 2173-2178.

c. Washburn, E.W., ed. International Critical Tables of Numerical Data. Chemistry. and Technology. Vol. III. New York: National Research Council/ McGraw-Hill, 1928. pp 27-29.

d. Kuchta, J.M. Summary of Ignition Properties of Jet Fuels and Other 1975. AFAPL-TR-75-70, pp 9-14. DTIC number AD-A021-320.

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

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METHOD 317

TEMPERATURE, HUMIDITY, ALTITUDE

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METHOD 317

TEMPERATURE, HUMIDITY, ALTITUDE

***NOTE**: METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD.*

1 SCOPE

1.1 Purpose

The main objectives of these tests are to determine if:

a. Materiel is safe to handle and/or operate during and following exposure to combined environments involving variations in temperature, humidity and air pressure, or

b. Materiel can be stored and operated as specified in the requirements documents during and following exposure to combined environments involving temperature, humidity and air pressure variations that it is expected to encounter during its service life, or

c. Materiel experiences physical damage during and/or after experiencing exposure to combined environments involving temperature, humidity and ambient pressure variations .

1.2 Application

Most of the simulated conditions included in this test method relate to unconditioned cargo-bay air transport or external air carriage of materiel, but some others such as high altitude air drop from aircraft may be relevant.

This test method is used when the requirements documents state that the materiel is likely to be transported or operated in situations where combination of temperature, humidity and pressure variations may occur.

These variations may be caused by displacements of materiel at altitude such as those occurring during aircraft missions (tactical or logistic transport, dropping of materiel, etc.).

Some of these situations, such as those encountered with specific jet fighter missions, may produce cyclic variations of those environments due to rapid variations of altitude. The application of this Method relies on the knowledge of these variations.

1.3 Limitations

This method is not intended to be used to test materiel to be installed in space vehicles, aircraft, or missiles that fly at altitudes above 30,000m. Method 312 should be used when only the low pressure effects on materiel are to be investigated.

2 TEST GUIDANCE

2.1 Effects of the Environment

In addition to the effects of the individual environments (temperature, humidity, low pressure) listed in Methods 302, 303, 306 and 312, the combination of these environments may produce the following effects on materiel (the list is not intended to be all-inclusive):

Acceleration of corrosion due to humidity condensation in/on materiel and differential pressure cycling,

Acceleration of humidity ingress when passing from high altitude (low pressure-low temperature-low humidity) to ground or near-ground level conditions (standard ambient pressure and warm, moist atmospheres), particularly at an airfield in hot, wet tropical regions.

Therefore where possible it is preferable to conduct the combined test as this allows simultaneous control of the individual environments allowing greater reproducibility of test conditions, particularly between test sites.

2.2 Choice of Test Procedure

(See General Guidance and Requirements, paragraphs 1 and 3.3.)

Two types of test procedures are included in this Method.

Procedure I is used to assess the possible effects of air-transport climatic conditions on materiel in unconditioned cargo-bay on its performance and safety in use.

Procedure II is used to assess the possible effects of external tactical air-carriage climatic conditions on materiel, when temperature-humidity-pressure changes follow the flight profile with sequential altitude changes.

2.3 Choice of Test Parameters

(See General Guidance and Requirements, paragraphs 1 through 4.)

The essential parameters for defining the combined environment tests (procedures I and II) include air temperature, associated humidity and pressure, exposure time (duration), and test item configuration. Such data can be tailored from ground temperature/humidity data extracted from AECTP 200, Category 230, from reference tables of standard atmospheres (e.g., ISO 5878) and from temperature/humidity/pressure conditions measured in aircraft cargo-bays during operational use. Test parameters for procedure II are highly dependent on the tactical mission profile, which include air speed, rate of climb or descent, atmospheric temperature and air humidity at low altitude.

2.3.1 Ground (initial) conditions

The severities of the ground conditions are directly related to the climatic categories of the geographical locations. They are based upon actual measurements or taken from climatic data documents such as AECTP 200, Category 230. Altitude conditions may be obtained from:

Real data measurements

MIL-HDBK-310

Standard Atmosphere tables such as those referenced in STANAG 4044

Table 1, where statistical values of air temperature at various altitudes in the northern hemisphere are given.

2.3.2 Induced conditions

For the logistic air transport conditions, the induced air conditions are those encountered in the cargo-bay. The main characteristics of this environment are described in AECTP 200, category 230 (for consideration if specific measured data are not available).

During tactical flights, the induced temperature experienced by materiel externally stored must be determined either from specific measurements, or computed from information on flight conditions (speed, altitude) and external atmospheric temperature versus time.

3 INFORMATION TO BE PROVIDED IN THE TEST INSTRUCTION

See Method 301 General Guidance and Requirements, paragraphs 5 and 6.

4 TEST CONDITIONS AND PROCEDURES

See Method 301 General Guidance and Requirements, paragraphs 7 - 10, for test conditions, test facility, and test control information.

4.1 Test Facility

(See Method 301 General Guidance and Requirements, paragraph 8.)

The inside of the enclosure must be designed in such a way as to prevent condensation from falling on the test item from the ceiling or walls.

4.2 Controls

(See Method 301 General Guidance and Requirements, paragraphs 7, 8 and 10.)

4.2.1 Humidity measurement

Monitoring and control of the humidity inside the test enclosure may be accomplished by using psychrometric systems, but when lowering air pressure inside the chamber it may induce inaccurate monitoring of the humidity. New types of capacitive sensors allow control of humidity in the chamber at lower pressure levels than psychrometric systems.

4.2.2 Temperature measurement

The temperature of the air surrounding the test item must be measured at a distance equal to half that separating the test item from the walls of the enclosure, without exceeding 1 metre from the test item. Care must be taken when taking these measurements due to low air density.

4.2.3 Pressure measurement

Unless otherwise specified, the rate of change of altitude shall not exceed 10 m/s.

4.3 Test Interruptions

(See Method 301 General Guidance and Requirements, paragraph 11.)

4.4 Procedures

The following test procedures provide the basis for assessing the suitability of the test item in a combination of temperature, pressure and humidity environment.

4.4.1 Preparation for test

Before starting any of the test procedures, determine the information specified in General Guidance and Requirements, paragraphs 5 and 6.1, and perform the test preparation procedure specified in General Guidance and Requirements, paragraph 12.

4.4.2 Procedure I - Logistic air transport (stabilized conditions)

Step 1. Place the test item in its air-transport configuration and install it in the test chamber. (If appropriate, the configuration may include loading due to normal stacking configurations.)

Step 2. Adjust the chamber air conditions (temperature, pressure and humidity) to the required initial ground level conditions specified in the test plan and maintain for the specified time following temperature stabilization of the test item.

Step 3. Adjust simultaneously the air temperature and pressure to simulate the conditions specified in the test program. During this phase, humidity and temperature may become difficult to control due to the low pressure conditions and the humidity generation shall be stopped.

***NOTE:** When it is not possible to adjust simultaneously the temperature, humidity and pressure to simulate the real conditions, adjustments of the three parameters may be done in the following order: temperature, humidity, and pressure.*

Step 4. Maintain the stabilized conditions (temperature, pressure, humidity) for the time specified in the test program.

Step 5. Adjust simultaneously the air temperature, pressure and humidity at the specified rate to the final conditions specified in the test plan.

***NOTE**: When it is not possible to adjust simultaneously the temperature, humidity and pressure to simulate the real conditions, adjustments of the three parameters may be done in the following order: temperature, humidity, and pressure.*

Step 6. Place the test item in an operational configuration and conduct an operational check of the test item when appropriate.

Step 7. Repeat Step 3 to 6 to produce the required number of cycles as specified in the test plan.

Step 8. If appropriate adjust the temperature, humidity, and pressure to the final ground conditions.

4.4.3 Procedure II - Tactical air carriage (cycling conditions)

Step 1. With the test item configured for operation, adjust the chamber air conditions to either the standard or controlled ambient conditions (paragraph 7 of General Guidance and Requirements), and conduct a pretest checkout.

Step 2. Adjust the chamber air conditions to the ground (initial) temperature, humidity, and pressure levels specified in the test plan.

Step 3. Adjust simultaneously the air temperature and pressure to simulate the high level flight conditions specified in the test requirements. During this phase, humidity and temperature may become difficult to control due to the low pressure conditions and the humidity generation shall be stopped.

NOTE: *when it is not possible to adjust simultaneously the temperature, humidity and pressure to simulate the real conditions, adjustments of the three parameters may be done in the following order: temperature, humidity, and pressure.*

Step 4. Maintain the stabilized conditions (temperature, humidity, pressure) for the time specified in the test program. If required, conduct an operational check of the test item in accordance with the approved test plan, and document the results.

Step 5. Adjust simultaneously the air temperature, pressure, and humidity at the specified rate to the final conditions specified in the test plan.

NOTE: *when it is not possible to adjust simultaneously the temperature, humidity and pressure to simulate the real conditions, adjustments of the three parameters may be done in the following order: temperature, humidity and pressure.*

Step 6. Maintain these conditions for the time specified in the test plan. If required in the test plan, conduct an operational check of the test item in accordance with the approved test plan, and document the results.

Step 7. Repeat Step 3 to 6 to produce the required number of cycles as specified in the test plan.

Step 8. If appropriate, adjust the temperature, humidity, and pressure to the final ground conditions.

Step 9. Visually examine the test item to the extent practical.

Step 10. With the test item not operating, stabilize the test item at standard or controlled ambient conditions.

Step 11. Conduct an operational check of the test item in accordance with the approved test plan, and document the results for comparison with pretest data. Visually examine the test item to the extent practical, to determine the extent of any physical damage.

5 EVALUATION OF THE TEST RESULTS

See Method 301 General Guidance and Requirements, paragraph 13.

6 REFERENCES AND RELATED DOCUMENTS

See Method 301 General Guidance and Requirements, paragraph 14.

STANAG 4044, Adoption of a Standard Atmosphere, 10 April 1969, (ICAO Standard Atmosphere).

MIL-HDBK-310: Global Climatic Data for Developing Military Products, 23 June 1997.

LATITUDE		15°N				30°N				45°N				60°N				80°N			
Altitude km (kft)	**Pressure mbar(hpa)**	**M**	**1%**	**10%**	**20%**	**M**	**1%**	**10%**	**20%**	**M**	**1%**	**10%**	**20%**	**M**	**1%**	**10%**	**20%**	**M**	**1%**	**10%**	**20%**
3 (10)	700	10.5	+6	+8	+9	4.8	-8	-4	-2	-5	-24	-19	-17	-13	-37	-31	-28	-17	-37	-32	-30
4.5 (15)	533	-3	-8	-6	-5	-12	-21	-17	-15	-25	-40	-34	-31	-34	-50	-43	-40	-39	-51	-46	-43
7.7 (25)	366	-20	-26	-23	-22	-28	-37	-33	-31	-40	-53	-47	-45	-45	-60	-53	-51	-49	-61	-56	-53
9.25 (30)	300	-36	-43	-40	-38	-44	-54	-50	-48	-54	-67	-61	-59	-56	-70	-64	-62	-60	-71	-66	-64
10.8 (35)	250	-43	-50	-47	-45	-48	-58	-54	-53	-55	-68	-62	-60	-56	-70	-64	-62	-61	-72	-67	-65
12.3 (40)	200	-53	-60	-56	-55	-54	-64	-60	-59	-56	-69	-63	-61	-56	-70	-64	-62	-63	-75	-69	-67
13 (42)	185	-56	-63	-60	-58	-56	-66	-62	-60	-56	-69	-63	-61	-56	-70	64	-62	-63	-75	-69	-67
15.5 (50)	125	-69	-77	-73	-72	-63	-74	-70	-70	-57	-71	-65	-62	-56	-70	-64	-61	-66	-78	-72	-70
18.5 (60)	70	-68	-76	-73	-71	-63	-73	-69	-68	-57	-71	-65	-62	-57	-71	-65	-62	-67	-87	-78	-76
21.5 (70)	44	-61	-69	-66	-64	-58	-72	-69	-66	-57	-71	-65	-62	-57	-83	-67	-64	-65	-86	-77	-75
26.2 (85)	20	-51	-58	-55	-52	-50	-60	-55	-54	-57	-73	-70	-62	-60	-85	-75	-69	-65	-89	-79	-74

For each altitude and latitude north, the mean value of temperature (M) is given together with those temperatures that are equal or lower than 1%, 10%, or 20% of the period of the two coldest winter month.

METHOD 319

ACIDIC ATMOSPHERE

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METHOD 319

ACIDIC ATMOSPHERE

NOTE: *METHOD 301, GENERAL GUIDANCE AND REQUIREMENTS, CONTAINS INFORMATION NECESSARY TO CONDUCT THE TEST PROCEDURES OF THIS METHOD, AND MUST BE USED IN COMBINATION WITH THIS TEST METHOD.*

1. SCOPE

1.1 Purpose

To determine the resistance of materials and protective coatings to acidic atmospheres.

1.2 Application

Use this test method when the requirements documents state that the materiel is likely to be stored or operated in areas where acidic atmospheres exist such as industrial areas or near the exhausts of any fuel-burning device.

1.3 Limitations

This method is not a replacement for the salt fog method, nor is it suitable for evaluating the effects of hydrogen sulphide.

2. GUIDANCE/REQUIREMENTS

2.1 Effects of the Environment

Acidic atmospheres are of increasing concern, especially for materiel in the vicinity of industrial areas or near the exhausts of fuel burning devices. Examples of problems that could occur as a result of acidic atmosphere exposure are as follows. The list is not intended to be all-inclusive, and some of the examples may overlap the categories. Reference a. provides further information

a. Chemical attack of surface finishes and non-metallic materials.

b. Corrosion of metals.

c. Pitting of cement and optics.

2.2 Test Procedure

(See Method 301, para 1 and 2.)

When an acidic atmosphere test is deemed necessary, the procedure included in this method is considered suitable for most applications. The tailoring options are limited.

2.3. Sequence

(See Method 301, paragraph 2.2.)

Perform acidic atmosphere testing after any humidity or fungus testing, and before any sand and dust testing or other tests that damage protective coatings.

a. Sand and dust testing deposits may inhibit acid effects as well as abrade protective coatings;

b. Acid deposits may inhibit mould growth.

c. Residual deposits may accelerate chemical reactions during humidity testing.

Because this test is similar in severity to the salt fog test, recommend separate test items be used for each.

2.4 Choice of Test Severities

(See Method 301, paragraphs 1 through 4.)

The essential parameters for defining the acidic atmosphere test include exposure temperature, exposure time (duration), test item configuration, chemical composition of the test atmosphere, and concentration of the test solution.

2.4.1 Temperature

The test method and exposure temperature used in this procedure are similar to those used in the salt fog test.

2.4.2 Test Duration

Two severity levels are defined (reference b). In view of the complexity of naturally occurring corrosion processes, no strict equivalencies with real exposure can be quoted. Use severity "A" below for simulating infrequent periods of exposure, or for exposure in areas of low acidity. Use severity "B" below to represent approximately 10 years natural exposure in a moist, highly industrial area, or a shorter period in close proximity to vehicle exhaust systems, particularly ship funnel exhausts where the potential acidity is significantly higher.

a. Three 2-hour spraying periods with 22 hours storage after each.

b. Four 2-hour spraying periods with 7 days storage after each.

2.4.3 Test item configuration

(See Method 301, para 5.)

2.4.4 Chemical composition and concentration

Use a test solution to be sprayed containing 0.88 g sulphuric acid/liter of solution (0.009M H_2S0_4), and 0.45 g nitric acid/liter of solution (0.007M $HN0_3$) in distilled or deionized water. This will produce a solution with a pH of 1.67 that is representative of the worst case conditions in the vicinity of smokestacks as measured in the UK. Reference c. provides information regarding the more common chemical environmental contaminants, together with some consequent likely forms of corrosion which materiel could encounter.

WARNING: Strong acids are hazardous. The solution to be sprayed is harmful to people and clothing. Operators carrying out the test must take suitable precautions.

WARNING: Refer to the supplier's Material Safety Data Sheet (MSDS) or equivalent for health hazard data.

(a) Do not enter the chamber during spraying and, before entry after spraying, purge the chamber with clean air to a level that will satisfy local safety requirements. Continue purging at intervals if necessary to ensure the concentration of noxious fumes remains at a suitably low level.

(b) Wear a suitable respirator and/or eye protection. Use rubber gloves to handle test items.

2.4.5 Operational considerations

The test item will not normally be required to function during the test, but may be required to do so on completion, or on completion of a representative sequence of environmental tests.

3. Information to be provided in the test instruction

In addition to the information required in Method 301, paragraph 6, provide the following information:

a. Whether the test is a demonstration of performance or survival.

b. Whether the requirement is to demonstrate safety, safety and performance, or resistance to chemical attack after the test.

c. The test cycle, severities and durations to be used.

d. If functional performance is to be assessed, the phases of the test when the test item is to operate and be assessed, and the levels of performance required.

e. Whether the test item is to be tested in its normal packaging or unpackaged.

f. The method of mounting the test item.

4. TEST CONDITIONS AND PROCEDURES

See Method 301, paragraphs 7 - 10, for test conditions, test facility, and test control information.

4.1 Test Facility

See Method 301, paragraph 8. Additionally:

a For construction of the chamber, supporting racks and spraying equipment, use materials inert to the acid solution being sprayed, and that will not cause electrolytic corrosion of material with which it comes in contact.

b. Do not respray acidic test solution drippings from the walls and ceilings of the chamber and from the test item. Vent the exposure chamber to prevent pressure buildup.

c. Use a chamber capable of maintaining temperatures in the exposure zone at 35 ±2°C. Continuously control this temperature during the test. Do not use immersion heaters within the chamber exposure area for the purpose of maintaining the temperature within the exposure zone.

d. Use an acid solution reservoir and dispenser made of material that is non-reactive with the acid solution, e.g., glass, hard rubber, or plastic. The reservoir provides a continuous supply to a tank normally (but not necessarily) situated inside the test section in which the acid solution level is held reasonably constant. The atomizers are connected to this tank.

e. Use a chamber with a means for injecting the acid solution into the test chamber, and with an input air humidifier to minimize clogging of the nozzles. Use atomizers of such design and construction as to produce a finely divided, wet, dense fog. Use atomizing nozzles and a piping system made of material that is non-reactive to the acid solution. Use a facility designed to provide the required atomization distribution and fallout.

f. Use a test setup that includes a minimum of 2 fallout 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. Place the receptacles so that they are not shielded by the test item and will not collect drops of solution from the test item or other sources.

g. Maintain constant air pressure for the continuous, uniform atomization of the acid solution using a compressed air supply, and produce a fallout such that each receptacle collects from 1 to 3 ml of solution per hour for each 80 cm^2 of horizontal collecting area (10 cm diameter).

4.2 Controls

In addition to that specified in Method 301, paragraph 10, the following controls apply to this test:

a. Compressed air: Preheat the oil and dirt-free compressed air used to produce the atomized solution (to offset the cooling effects of expansion to atmospheric pressure) and pre-humidify it such that the temperature is 35 ± 2°C and the relative humidity is in excess of 85% at the nozzle (see Table 1).

Table 1. 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

b. Heat the acid solution to within ±6 degrees C of the test section temperature before injection into the test section.

c. Test section air circulation: Use an air velocity in the test chambers that is minimal (essentially zero).

4.3 Test interruptions

See Method 301, paragraph 11.

4.4 Procedure

The following test procedure provides the basis for assessing the suitability of the test item in an acidic atmosphere environment, and has limited tailorability.

4.4.1 Pretest information.

See General Guidance and Information, paragraphs 5 and 6.1.

4.4.2 Preparation for test

a. Prepare a test solution as specified in paragraph 2.4.4.

WARNING: **MAKE THE SOLUTION BY ADDING ACID TO WATER, NOT VICE VERSA. FAILURE TO DO SO COULD CAUSE A VIOLENT REACTION.**

WARNING: **Strong acids are hazardous. The solution to be sprayed is harmful to people and clothing. Operators carrying out the test must take suitable precautions.**

WARNING: **Refer to the supplier's Material Safety Data Sheet (MSDS) or equivalent for health hazard data.**

(1) Do not enter the chamber during spraying and, before entry after spraying, purge the chamber with clean air to a level that will satisfy local safety requirements. Continue purging at intervals if necessary to ensure the concentration of noxious fumes remains at a suitably low level.

(2) Wear a suitable respirator and/or eye protection. Use rubber gloves to handle materiel.

b. Chamber operation verification: Immediately before the test and with the exposure chamber empty, adjust all test parameters to those levels required for the test. Maintain these conditions for at least one 24-hour period (or until proper operation and fallout collection can be verified). With the exception of fallout rate, continuously monitor all test parameters to verify that the test chamber is operating properly.

c. Perform the pretest standard ambient check as specified in Method 301, paragraph 12. Handle the test item as little as possible, particularly on the significant surfaces, and prepare it for test immediately before exposure. Unless otherwise specified, use test items free of surface contamination such as oil, grease, or dirt, which could cause de-wetting. Do not include the use of corrosive solvents, solvents that deposit either corrosive or protective films, or abrasives other than pure magnesium oxide in the cleaning methods.

4.4.3 Acidic atmosphere test procedure

Step 1. With the test item installed in the test chamber in its storage configuration (or as otherwise specified in the requirements documents), adjust the test chamber temperature to 35°C and temperature condition the test item for at least 2 hours before introducing the acid solution.

Step 2. Expose the test item to one of the two following severities as specified in the test plan. (See paragraph 2.4.2.)

a. Four 2-hour spraying periods with 7 days storage after each.

b. Three 2-hour spraying periods with 22 hours storage after each.

Step 3. At the completion of Step 2, stabilize the test item at standard ambient conditions.

Step 4. Visually examine the test item to the extent practical.

Step 5. If required, place the test item in an operational configuration and conduct an operational check of the test item.

Step 6. If required, test items may be cleaned by rinsing in distilled/deionized water and dried by the application of heat (up to 55°C), where this is acceptable, or by other means.

Step 7. At the end of this test, and in conformity with the requirements documents, examine the test item for corrosion and deterioration of parts, finishes, materials and components.

5. EVALUATION OF THE TEST RESULTS

In addition to the failure criteria in Method 301, paragraph 13, 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.

6. REFERENCEs and RELATED DOCUMENTS

See Method 301 paragraph 14.

a. IEC 68-2-52, 1966, Test Kb, Salt Mist, Cyclic, NaCl solution.

b. Acid Deposition in the United Kingdom, Warren Spring Laboratory
SBN 085624 323X.