METHOD 521.4

ICING/FREEZING RAIN

CONTENTS

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> **NOTE:** Tailoring is essential. Select methods, procedures, and parameter levels based on the tailoring process described in Part One, paragraph 4.2.2, and Annex C. Apply the general guidelines for laboratory test methods described in Part One, paragraph 5 of this Standard.

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. Use this Method to evaluate materiel that may be exposed to icing such as produced by freezing rain or freezing drizzle. (See paragraph 2.2.1.1 below.)

b. Use this Method to develop 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 buildup on aircraft flying through supercooled clouds. Though 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). Also not considered are the icing effects from falling, blowing or re-circulating snow and wet snow or slush. These are considered less severe than those in paragraph 2.1.1.

2. TAILORING GUIDANCE.

2.1 Selecting the Icing/Freezing Rain Method.

After examining requirements documents and applying the tailoring process in Part One of this Standard to determine where icing/freezing rain is anticipated in the life cycle of materiel, use the following to confirm the need for this Method and to place it in sequence with other methods. This Method is designed to determine if materiel can operate after ice accumulation from rain, drizzle, fog, splash or other sources. When ice removal is required before operation, use integral deicing equipment or expedients normally available to the user in the field. Evaluate deicing equipment and expedients to assess their effectiveness and the potential for damage that may degrade performance.

2.1.1 Effects of Icing/Freezing Rain.

Ice formation can impede materiel operation and survival and affect the safety of operating personnel. Consider the following typical problems to help determine if this Method is appropriate for the materiel being tested. This list is not intended to be all-inclusive.

a. Binds moving parts together.

b. Adds weight to radar antennas, aerodynamic control surfaces, helicopter rotors, etc.

c. Increases footing hazards for personnel.

d. Interferes with clearances between moving parts.

e. Induces structural failures.

f. Reduces airflow efficiency as in cooling systems or filters.

g. Impedes visibility through windshields and optical devices.

h. Affects transmission of electromagnetic radiation.

i. Provides a source of potential damage to materiel from the employment of mechanical, manual, or chemical ice removal measures.

j. Reduces efficiency of aerodynamic lifting and control surfaces.

k. Reduces (aircraft) stall margins.

2.1.2 Sequence Among Other Methods.

a. General. Use the anticipated life cycle sequence of events as a general sequence guide (see Part One, paragraph 5.5).

b. Unique to this Method.

(1) One approach is to conserve test item life by applying what are perceived to be the least damaging environments first. For this approach, generally apply the icing/freezing rain following rain tests, but prior to salt fog tests, because residual salts could impair the formation of ice. Also, apply this test prior to dynamic tests that could loosen components.

(2) Another approach is to apply environments to maximize the likelihood of disclosing synergetic effects. For this approach, subject the test item to the dynamic tests prior to conducting the icing test.

2.2 Selecting Procedure Variations.

This Method has one procedure. However, the test procedure may be varied. Before conducting this test, complete the tailoring process by selecting specific procedure variations (special test conditions/techniques for this procedure) based on requirements documents, Life Cycle Environmental Profile (LCEP), and information provided within this Method. Consider the following in light of the operational purpose and life cycle of the materiel.

2.2.1 Ice Formation.

2.2.1.1 Principal Causes.

A buildup of ice occurs in four principal ways:

a. From rain, drizzle, or fog falling on materiel whose temperature is at or below freezing.

b. From sublimation.

c. From freezing rain or freezing drizzle falling on materiel at or near freezing.

d. From sea spray and splash that coats materiel when the materiel temperature is below freezing.

2.2.1.2 Types of Ice.

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 0.5 g/cm^3 (hard rime). Factors that favor rime formation are small drop size, slow accretion, a high degree of supercooling, and rapid dissipation of latent heat of fusion. The opposite effects favor 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 vapor. Glaze is denser, harder, and more transparent than rime. Its density may range from 0.6 to 0.9 g/cm^3. Factors that favor glaze formation are large drop size, rapid accretion, slight supercooling, and slow dissipation of heat of fusion. The opposite effects favor 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.

2.2.2 Configuration and Orientation.

Consider the following factors:

a. Whether or not the test item receives icing on all sides and the top.

b. Whether or not the test item is in its deployment configuration. If required, perform tests in other configurations such as for shipping or outside storage.

2.2.3 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, do not use an initial test item temperature below 0 °C (32 °F) to allow water to penetrate (cracks, seams, etc.) prior to freezing.

2.2.4 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 (1 in/h) is suggested in the test procedure and is based on data from previous testing.

2.2.5 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. Side-spray coverage is achieved by using wind or an additional hand-held nozzle. Minimize any wind in order to maintain uniform ice accretion.

c. A single nozzle directing the spray over the appropriate surfaces of the test item.

2.2.6 Droplet Size.

The droplet size range may have to be adjusted for different size facilities. A fine spray in the range of 1.0 mm to 1.5 mm diameter nominal droplet size has produced satisfactory icing in some facilities.

2.2.7 Ice Thickness.

Unless specifically measured data for the anticipated situation are available, the following ice thicknesses are recommended (paragraph 6.1, reference b):

a. 6 mm (0.24 in) - represents general conditions, light loading.

b. 13 mm (0.5 in) - represents general conditions, medium loading.

c. 37 mm (1.5 in) - represents heavy ground loading and marine mast loading.

d. 75 mm (3 in) - represents extremely heavy ground loading and marine deck loading.

2.3 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 REQUIRED.

3.1 Pretest.

The following information is required to conduct icing/freezing rain tests adequately.

a. General. Information listed in Part One, paragraphs 5.7 and 5.9; and Part One, Annex A, Task 405 of this Standard.

b. Specific to this Method.

(1) Ice thickness to be applied.

(2) Ice removal method(s) (if employed).

(3) Any variations from recommended test temperatures and droplet sizes.

(4) Surfaces of the test item to which ice is to be applied.

(5) Velocity of any wind used.

c. Tailoring. Necessary variations in the basic test procedures to accommodate environments identified in the LCEP.

3.2 During Test.

Collect the following information during conduct of the test:

a. General. Information listed in Part One, paragraph 5.10, and in Annex A, Tasks 405 and 406 of this Standard.

b. Specific to this Method.

(1) Record of chamber temperatures versus time conditions.

(2) Record of the test item temperature-versus-time data for the duration of the test.

3.3 Post-Test.

The following post test data shall be included in the test report.

a. General. Information listed in Part One, paragraph 5.13, and in Annex A, Task 406 of this Standard.

b. Specific to this Method.

(1) Actual ice thicknesses.

(2) Results of required ice removal efforts.

(3) Initial analysis of any failures/problems.

(4) Type of ice developed, i.e., glaze or rime.

(5) Any deviations from the original test plan.

4. TEST PROCESS.

4.1 Test Facility.

The required apparatus consists of a chamber or cabinet together with auxiliary instrumentation capable of establishing and maintaining the specified test conditions. Use a facility equipped so that test conditions within the chamber can be stabilized soon after the test item is installed. Arrange water delivery equipment to minimize the collection of puddles/ice in the chamber. Make continuous recordings of chamber temperature measurements and, if required, test item temperatures.

4.2 Controls.

Before each test, verify the critical parameters. Ensure the nozzle spray pattern is wide enough to guarantee uniform impingement for all test wind velocities. Unless otherwise specified, if any action other than test item operation (such as opening the chamber door) results in a significant change in the test item or chamber temperature (more than 2°C

(4°F)), restabilize the test item at the required test temperature before continuing. If the operational check is not completed within 15 minutes, reestablish the test item temperature conditions before continuing.

4.3 Test Interruption.

Test interruptions can result from two or more situations, one being from failure or malfunction of test chambers or associated test laboratory equipment. The second type of test interruption results from failure or malfunction of the test item itself during operational checks.

4.3.1 Interruption Due To Chamber Malfunction.

a. General. See Part One, paragraph 5.11 of this Standard.

b. Specific to this Method.

(1) Undertest interruption. Interruption of an icing/freezing rain test is unlikely to generate any adverse effects. Normally, continue the test from the point of interruption once the test conditions have been re-established.

(2) Overtest interruption. Follow any interruption that results in more extreme exposure of the test item than required by the requirements document by a complete operational and physical checkout. If there are no problems, restore the test item to its pretest condition and restart the test.

4.3.2 Interruption Due To Test Item Operation Failure.

Failure of the test item(s) to operate as required during operational checks presents a situation with several possible options.

a. The preferable option is to replace the test item with a "new" one and restart from Step 1.

b. A second option is to replace / repair the failed or non-functioning component or assembly with one that operates as intended, and restart the entire test from Step 1.

NOTE: When evaluating failure interruptions, consider prior testing on the same test item and consequences of such.

4.4 Test Setup.

a. General. See Part One, paragraph 5.8.

b. Unique to this Method.

(1) 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.

(2) To facilitate measurement of ice thickness, mount depth gauges such as copper bars or tubes of an appropriate size in places where they will receive the same general water spray as the test item. Other thickness measurement techniques may be used if they can be shown to indicate the ice thickness.

NOTE: Since artificially produced freezing accretion rates tend to depend on the distance between the test item and spray device, for structures with large height variations such as antenna masts, place test bars at different heights.

(3) Using chilled water (between 0 °C and 3 °C (32 °F and 37 °F)) in the spraying system will cause a faster ice buildup rate than unchilled water.

4.5 Test Execution.

The following steps, alone or in combination, provide the basis for collecting necessary information concerning the materiel in an icing/freezing rain environment.

4.5.1 Preparation for Test.

4.5.1.1 Preliminary Steps.

Before starting the test, review pretest information in the test plan to determine test details (e.g., procedures, item configuration, cycles, durations, parameter levels for storage/operation, ice thickness, etc.).

4.5.1.2 Pretest Standard Ambient Checkout.

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

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

Step 2 Install the test item in the chamber (Part One, paragraph 5.8.1) in the required configuration and orientation, and at standard ambient conditions (Part One, paragraph 5.1).

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

Step 4 Conduct an operational checkout (Part One, paragraph 5.8.2) as described in the plan to obtain baseline data, and record the results.

Step 5 If the test item operates satisfactorily, proceed to paragraph 4.5.2. If not, resolve the problems and repeat Step 4 above.

4.5.2 Procedure - Ice Accretion.

Step 1 Stabilize the test item temperature at 0 °C (-0/+2 °C (32 °F (-0/+4 °F)).

Step 2 Deliver a uniform, pre-cooled water spray for 1 hour to allow water penetration into the test item crevices/openings (although a water temperature of 0 to 3 °C (32 to 37 °F) is ideal, a water temperature of 5 °C (41 °F) and a water delivery rate of 25 mm/h (1 in/h) has proven satisfactory).

Step 3 Adjust the chamber air temperature to -10 °C (14 °F) or as specified, and maintain the water spray 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**: If it is difficult to produce a satisfactory layer of glaze ice, vary one or more of the parameters as necessary, i.e., water or test item temperature, spray rate or duration, distance between the nozzles and the test item, etc. Generally an air temperature no warmer than -2 C (28°F) is more likely to produce glaze ice.

> **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 4 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 5 If Step 4 resulted in failure, or if the specification requires or allows ice removal, remove the ice. Limit the method of ice removal to that determined in paragraph 3.1b, 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. Examine for safety hazards and, if appropriate (and possible), attempt to operate the test item. If the test item fails to operate as intended, follow the guidance in paragraph 4.3.2 for test item failure.

Step 6 Examine for safety hazards and, if appropriate (and possible), attempt to operate the test item at the specified low operating temperature of the materiel. If the test item fails to operate as intended, follow the guidance in paragraph 4.3.2 for test item failure.

Step 7 If required, repeat Steps 3 through 6 to produce other required thicknesses of ice.

Step 8 Stabilize the test item at standard ambient conditions and perform a post-test operational check. See paragraph 5 for analysis of results.

Step 9 Document (with photographs if necessary) the results for comparison with pretest data.

5. ANALYSIS OF RESULTS.

In addition to the guidance provided in Part One, paragraphs 5.14 and 5.17, the following information is provided to assist in the evaluation of the test results. Apply any data relative to failure of a test item to the test analysis, and consider related information such as:

a. For materiel that must operate without ice removal: If 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: If the performance of the test item has been degraded below the specified limits/requirements after normal ice removal efforts have been undertaken.

c. If normal ice removal damages the materiel.

d. If a non-apparent hazardous situation has been created.

6. REFERENCE/RELATED DOCUMENTS.

6.1 Referenced Documents.

a. Glossary of Meteorology, Edited by Ralph E. Huschke, Published by the American Meteorological Society (1959); Air Force Institute of Technology Library.

b. Letter, Cold Regions Research and Engineering Laboratory, Corps of Engineers (U.S.), CECRL-RG, 22 October 1990, SUBJECT: Ice Accretion Rates (Glaze).

6.2 Related Documents.

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

b. MIL-HDBK-310, Global Climatic Data for Developing Military Products.

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

d. NATO STANAG 4370, Environmental Testing.

e. Allied Environmental Conditions and Test Publication (AECTP) 300, Climatic Environmental Tests (under STANAG 4370), Method 311.

f. Egbert, Herbert W. “The History and Rationale of MIL-STD-810 (Edition 2),” January 2010; Institute of Environmental Sciences and Technology, Arlington Place One, 2340 S. Arlington Heights Road, Suite 100, Arlington Heights, IL 60005-4516.

g. Bennett, Ivan. (1959). Glaze: Its Meteorology and Climatology, Geographic Distribution and Economic Effects (Technical Report EP-105). Natick, MA: Quartermaster Research and Engineering Center.

h. Tattelman, Paul and Gringorton, Irving. (1973). Estimate Glaze Ice and Wind Loads at the Earth’s Surface for the Contiguous United States. AFCRL, Hanscom AFB, MA.

i. Burt, Chris. Extreme Weather (2004), NY: W.W. Norton and Co.

j. Ludlam, David. The American Weather Book (1982), NY: Houghton Mifflin Co.

k. Sanderson, J. (1973). Occurrence of Ice in the Form of Glaze, Rime, and Hoarfrost with respect to the Operation and Storage of V/STOL Aircraft (ETL-DR-73-1), US Army ETL, Fort Belvoir, VA.

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