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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 1428

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Submitted for recognition as an American National Standard

FLUID, AIRCRAFT DEICING/ANTI-ICING, NON-NEWTONIAN, PSEUDO-PLASTIC, SAE TYPE II

1. SCOPE:

1.1 Form:

This specification covers a deicing/anti-icing material in the form of a non-Newtonian fluid.

1.1.1 Fluids defined as non-Newtonian shall exhibit different apparent viscosity values when tested at the same temperature, using the same viscometer and spindle in a predetermined volume, when the only variant is the rotational speed of the spindle. Such a fluid, shall exhibit reduced apparent viscosity values as the spindle speed is increased, this shall be demonstrable at the temperatures listed in 3.2.3.1.

1.1.2 Fluids described as pseudoplastic shall have the capability to change their rate of flow with a change in shear stress, and revert to original flow behavior when the shear stress is removed.

1.2 Application:

These fluids may be used as follows:

a. Cold and undiluted for anti-icing
b. Heated and undiluted for deicing/anti-icing as a one step process
c. Diluted with water and heated for deicing/anti-icing, as a one step process
d. Diluted with water and heated as the deicing stage in a two-step process, usually when (a.) above is step two

Consult relevant aircraft manufacturers' data relating to application techniques, dilution rates, temperature limitations, and, if applicable, aircraft rotation speed limitations.

1.3 Precautions:

1.3.1 The lowest operational use temperature for SAE Type II fluids shall be the lowest temperature at which the fluid has been tested and certified as acceptable in accordance with the aerodynamic acceptance test (3.2.5).

1.3.2 The deicing/anti-icing formulations may be mildly toxic and contact with human skin and eyes should be avoided. Prolonged exposure to concentrations of vapor or windborne droplets should be avoided.

1.3.3 Caution should be exercised in the use of glycol-water deicing/anti-icing solutions in and around aircraft electrical/electronic circuitry with noble metal coated wiring or terminals which could come into contact with the fluid. Exothermic reactions which may result in fire have been reported. This may occur where defectively insulated wires, switches, or circuit breakers carrying direct current are encountered. Type II fluids which are based on glycols, should contain an inhibitor to minimize this potential fire hazard.

1.3.4 The fluids meeting this specification are unique to each manufacturer and may be adversely affected by mixing with other aircraft deicing/anti-icing fluids.

1.3.5 Airport authorities should ascertain the friction coefficient of the runway following contamination with deicing/anti-icing fluid.

1.4 Safety - Hazardous Materials:

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and processes and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2470 Anodic Treatment of Aluminum Alloys, Chromic Acid Process
AMS 2475 Protective Treatments, Magnesium Alloys
AMS 2825 Material Safety Data Sheets
AMS 4037 Aluminum Alloy Sheet and Plate, 4.4Cu - 1.5Mg - 0.60Mn (2024-T3 Flat Sheet, T351 Plate), Solution Heat Treated

2.1 SAE Publications: (Continued)

AMS 4041 Aluminum Alloy Sheet and Plate, Alclad, 4.4Cu - 1.5Mg - 0.60Mn (Alclad 2024 and 1-1/2% Alclad 2024-T3 Flat Sheet: 1-1/2% Alclad 2024-T351 Plate)
AMS 4049 Aluminum Alloy Sheet and Plate, Alclad, 5.6Zn - 2.5Mg - 1.6Cu - 0.23Cr, (Alclad 7075-T6 Sheet, 7075-T651 Plate), Solution and Precipitation Heat Treated
AMS 4376 Magnesium Alloy Plate, 3.0Al - 1.0Zn, (AZ318-H26), Cold Rolled and Partially Annealed
AMS 4911 Titanium Alloy Sheet, Strip, and Plate, 6Al - 4V, Annealed
MAM 4911 Titanium Alloy Sheet, Strip, and Plate, 6Al - 4V, Annealed, Metric
AMS 5045 Steel Sheet and Strip, 0.25 Carbon, maximum, Hard Temper

2.2 ASTM Publications:

Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM C 672 Scaling Resistance of Concrete Surfaces Exposed to De-icing Chemicals
ASTM D 93 Flash Point by Pensky-Martens Closed Tester
ASTM D 891 Specific Gravity of Liquid Industrial Chemicals
ASTM D 1177 Freezing Point of Aqueous Engine Coolant Solution
ASTM D 1193 Reagent Water
ASTM D 1331 Surface and Interfacial Tension of Solutions of Surface-Active Agents
ASTM D 1568 Sampling and Chemical Analysis of Alkylbenzene Sulfonates
ASTM D 1747 Refractive Index of Viscous Materials
ASTM D 2196 Viscosity Measurements and Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscometer
ASTM D 3278 Flash Point of Liquids by Setaflash Closed Cup Apparatus
ASTM D 4177 Automatic Sampling of Petroleum and Petroleum Products
ASTM E 70 pH of Aqueous Solution with the Glass Electrode
ASTM F 483 Total Immersion Corrosion Test for Aircraft Maintenance Chemicals
ASTM F 484 Stress Crazing of Acrylic Plastics in Contact with Liquid or Semi-Liquid Compounds
ASTM F 485 Effects of Cleaners on Unpainted Aircraft Surfaces.
ASTM F 502 Effects of Cleaning and Chemical Maintenance Materials on Painted Aircraft Surfaces
ASTM F 519 Mechanical Hydrogen Embrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals
ASTM F 945 Stress Corrosion of Titanium Alloys by Aircraft Engine Cleaning Materials
ASTM F 1105 Preparing Aircraft Cleaning Compounds, Liquid Type, Solvent Based for Storage Stability Testing
ASTM F 1110 Sandwich Corrosion Test
ASTM F 1111 Corrosion of Low Embrittling Cadmium Plate by Aircraft Maintenance Chemicals

2.3 U.S.Government Publications:

Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-P-25690 Plastic, Sheets and Parts, Modified Acrylic Base, Monolithic, Crack Propagation Resistant
MIL-P-83310 Plastic Sheet, Polycarbonate Transparent
MIL-STD-290 Packaging of Petroleum and Related Products

2.4 APHA Publications:

Available from American Public Health Association, 1015 Eighteenth Street, NW, Washington, DC 20036.

Standard Methods for the Examination of Water and Waste Water.

3. TECHNICAL REQUIREMENTS:

3.1 Material:

The composition of the fluid shall be optional with the manufacturer and shall be based on freeze point depressants with additives such that the finished product shall meet requirements of this specification.

3.1.1 Toxicity: Fluid shall meet all local, state, and/or federal regulations.

3.1.2 Appearance: Fluid, as received by purchaser, shall be homogeneous, uniform in color, and free from skins, lumps, and from foreign materials detrimental to usage of the product. If fluid is colored, it shall not be orange or blue-green.

3.1.3 Biodegradability: Fluid shall be tested in accordance with "Standard Methods for the Examination of Water and Waste Water." The manufacturer shall provide results of bioassays which shall contain not less than the following information.

3.1.3.1 A statement of the ecological behavior of the fluid.

3.1.3.2 The theoretical total oxygen demand (TOD) of the fluid, expressed in kilograms-oxygen to kilograms-fluid.

3.1.3.3 Percent of fluid degraded in 5 days, 15 days, and 28 days, at 20 °C (68 °F).

3.1.4 Trace Contaminants

Report the presence, in percentages by weight, of sulfur, halogens, phosphate, nitrate, and heavy metals (lead, chromium, cadmium, and mercury).

3.2 Properties:

The fluid shall conform to the following requirements; tests shall be performed in accordance with specified test methods.

3.2.1 Fluid As Received in Undiluted Form: Shall be as follows.

3.2.1.1 Flash Point: Shall be not lower than 100 °C (212 °F) determined in accordance with ASTM D 93 or ASTM D 3278. In case of dispute, flash point determined in accordance with ASTM D 93 shall apply.

3.2.1.2 Specific Gravity: Shall be within ±0.015 units of the preproduction value, determined in accordance with ASTM D 891.

3.2.1.3 pH: Shall be within ±0.5 units of the preproduction value, determined in accordance with ASTM E 70.

3.2.1.4 Refractive Index: Shall be within ±0.0015 units of the preproduction value, determined in accordance with ASTM D 1747.

3.2.1.5 Surface Tension: Shall be within ±10% of the preproduction value at 20 °C (68 °F), determined in accordance with ASTM D 1331.

3.2.2 Fluid Stability:

3.2.2.1 Thermal Stability - Accelerated Aging: Prior to aging, the sample shall be visually examined to determine degree of turbidity and freedom from insoluble deposits. Determine the pH in accordance with ASTM E 70. Determine the viscosity at 20 °C (68 °F) in accordance with ASTM D 2196.

3.2.2.1.1 Take two samples, each 500 mL, and transfer each sample to a 600 mL glass jar fitted with a well closed screw cap with polyethylene seal. Transfer the closed jars containing the samples of fluid to a circulating air oven or heated water bath and elevate the temperature to 70 °C ± 2 (158 °F ± 4) and maintain the samples in this environment for 30 days.

3.2.2.1.2 After 30 days, remove the jars containing the fluid samples from the heated environment and examine the contents for evidence of separation, insoluble deposit, or turbidity greater than a fresh sample. Report any evidence of these factors. Allow the sample to cool to 20 °C ± 2 (68 °F ± 4) and re-test for viscosity as in 3.2.2.1 and record the result. Compare these results to those recorded before aging and the viscosity shall neither be reduced by more than 20% nor be increased by more than 10% from those readings. pH of the aged fluid, determined as in 3.2.1.3, shall be within ±0.5 units of the unaged sample.

3.2.2.2 Exposure to Dry Air - Stability: The fluid, after exposure to an environment of 30 to 40% relative humidity (RH) at 75 °C ± 3 (167 °F ± 5) during a time which results in a weight reduction of 20% ± 1, shall have a viscosity not exceeding 500 mPa.s, measured using the Brookfield viscometer, with the No. 1 spindle at 3.0 RPM, with sample at 20 °C (68 °F).

3.2.2.3 Thin Film, Thermal Stability: The fluid shall be applied to an unpainted aluminum or aluminum alloy test panel, approximately 152 x 51 mm (6 x 2 inches), with a film thickness of 0.25 mm ± 0.025 (0.010 inch ± 0.001). The panel shall be placed, inclined at an angle of 20 degrees, in an oven maintained at 100 °C ± 2 (212 °F ± 4). After 30 minutes ± 1, remove the panel, allow it to cool to ambient temperature, and inspect. The fluid remaining on the panel shall not form a film insoluble in water. Confirm by rinsing for 60 seconds ± 10 with running tap water at ambient temperature, followed by a rinse in ASTM D 1193, Type IV, water from a squeeze bottle for 15 seconds ± 5. Allow to air dry and report any evidence of visible residue.

3.2.2.4 Storage Stability: Prior to the start of this test, determine the viscosity at 20 °C (68 °F) in accordance with ASTM D 2196. The fluid shall be tested in accordance with ASTM F 1105. On completion of the test, the fluid shall be retested for viscosity as before and the result compared to the original values. These results shall not vary by more than +10% or -20%.

3.2.2.5 Shear Stability: The anti-icing performance shall be confirmed after the product has been sheared using the laboratory method as in 3.2.2.5.1.

3.2.2.5.1 Pour 500 mL ± 5 at 20 °C ± 1 (68 °F ± 2) into a straight-sided glass vessel, 85 mm ± 5 diameter, and position a Brookfield counter rotating mixer so the bottom of the blade is 25 mm ± 2 from the bottom of the vessel and mix for 5 minutes ± 10 seconds at 3500 RPM ± 100 (calibrated in water prior to each test). After allowing the sample to de-aerate for at least 24 hours, test for anti-icing performance in accordance with.3.2.4

3.2.2.6 Hard Water Stability: The fluid, diluted 1:1 with standard hard water made up as in 3.2.2.6.1 and aged as in 3.2.2.6.2, shall show no evidence of insoluble deposit and the pH shall not vary by more than ±0.5 units from a fresh unaged sample. A sample of the fluid, after hard water stability testing, shall be tested for anti-icing performance in accordance with 3.2.4.2 and anti-icing performance reported.

3.2.2.6.1 Composition of Hard Water: Dissolve 400 mg ± 5 calcium acetate dihydrate ($Ca[C_2H_3O_2]_2.2H_2O$), and 280 mg ± 5 magnesium sulfate heptahydrate ($MgSO_4.7H_2O$), both of analytical reagent quality, in one liter of ASTM D 1193, Type IV, water.

3.2.2.6.2 Place 350 mL of the diluted fluid in a 500 mL glass jar fitted with a polyethylene lined screw cap. Place the jar in an oven or waterbath and raise the temperature to 95 °C ± 1 (203 °F ± 2). Allow the sample to remain in this elevated temperature environment for 30 days, remove, allow to cool to 20 °C ± 1 (68 °F ± 2), and inspect as in 3.2.2.6.

3.2.3 Rheological Properties: The special rheological properties defined in 3.2.3.1 and 3.2.3.1.1 relate to thickened fluids which are classed as non-Newtonian, pseudoplastic as defined in 1.1.1 and 1.1.2 and are specified to ensure the flow of the film when a minimum of shear stress is induced. The exposure of a film of the applied fluid to different environmental factors shall not impair this performance, either by buildup of film thickness due to consecutive applications or by forming a gel. Fluids of all types shall be tested as in 3.2.3.1.1, 3.2.4, and 3.2.5.

3.2.3.1 Viscosity: The fluid shall exhibit non-Newtonian flow behavior over the temperature range at which the fluid has been tested and certified as acceptable in accordance with the aerodynamic acceptance test (3.2.5). The viscosity of the fluid at the lowest operational use temperature obtained from 3.2.5 shall be reported.

3.2.3.1.1 The viscosity of any fluid as supplied, undiluted, shall be within 10% of the preproduction value at +20, 0, -10, -20 °C (68, 32, 14, -4 °F), determined using the Brookfield viscometer fitted with the No. 1 or No. 2 spindle in a sample of 500 mL contained in a 600 mL beaker described in 3.2.2.5.1. If the small sample adaptor is used, the spindle, container size, and the results of both determinations shall be reported. Results using spindle speeds of 0.3, 6, and 30 RPM shall be reported. For quality control purposes, the manufacturer shall specify the typical preproduction values, measured in accordance with ASTM D 2196, for the qualified product.

3.2.4 Anti-icing performance: When applied to a surface having a slope of 10 degrees from horizontal, the fluid shall form a film which will protect against the formation of frozen deposits beyond the 25 mm line for not less than four hours in the high humidity endurance test (HHET) (3.2.4.1), and for not less than 30 minutes in the water spray endurance test (WSET) (3.2.4.2). Confirmation shall be obtained from six panels, three panels from each of two successive runs, determined in accordance with Appendix I.

3.2.4.1 Procedure HHET: The fluid shall be sheared in accordance with 3.2.2.5.1 and applied to the surface of the test panel at 20 °C ± 0.5 (68 °F ± 1) by pouring from the top edge. Ensure three panels are evenly and completely wetted. Any excess fluid shall be collected in a suitable tray. At least two panels shall be left blank for monitoring the accumulation of ice formed during the testing period. The air temperature shall be maintained at 0 °C ± 0.5 (32 °F ± 1) with the relative humidity being held at 96% ± 2. The horizontal air velocity shall be 0.2 m/s ± 0.05. The test cell face temperature shall be maintained at -5 °C ± 0.5(+23 °F ± 1). After four hours, the panels coated with the candidate fluid shall show no evidence of any freezing beyond 25 mm from the upper edge. After four hours, the uncoated panels shall have the accumulated ice removed and weighed, or in the case of removable panels which have been weighed prior to the start of the test, re-weighed, and the accumulation of ice shall be the difference between the before and after weights. Each panel shall have accumulated an average of 1.2 grams ± 0.2 per dm^2 during the four hour test.

3.2.4.2 Procedure - WSET: The fluid shall be sheared in accordance with 3.2.2.5.1 and applied to three of the test cell panels at 20 °C ± 0.5 (68 °F ± 1) by pouring from the top edge, ensuring these panels are evenly and completely wetted. Any excess fluid shall be collected in a suitable tray. At least two panels shall be left blank for monitoring the accumulation of ice formed during the testing period. The air temperature shall be maintained at -5 °C ± 0.5 (+23 °F ± 1), the panel temperature shall be maintained at -5 °C ± 0.5 (+23 °F ± 1),and average water spray of 5 g/dm^2 ± 0.2 per hour. The test shall continue until the ice formation on the coated panels reaches the 25 mm point from the upper edge of those panels. The time to reach this point shall be reported. The ice which forms on the untreated panels shall be collected after 30 minutes or at the time the treated panels reach the 25 mm point, whichever is the longest, and the ice shall be weighed to confirm the water spray intensity. In the case of removable panels which have been weighed prior to the start of the test, these shall be re-weighed and the difference in weight shall be considered the ice catch. Report the weight of ice collected on each blank panel.

3.2.5 Aerodynamic Acceptance: The fluid shall demonstrate acceptable aerodynamic performance, tested in accordance with Appendix II. A fluid is acceptable if no more than 10% of the independent boundary layer displacement thickness measurements exceed (is greater than) the acceptance criterion boundary layer displacement thickness envelope as shown in Figure 7. None of the allowable test points shall exceed the acceptance criterion boundary layer displacement thickness by more than 10%, determined in accordance with Appendix II.

3.3 Fluid Tested Both as a Concentrate and Diluted Solution:

Shall be as follows, determined on the fluid as received and on a solution made up of concentrated fluid diluted 1:1 with ASTM D 1193, Type IV, water.

3.3.1 Freezing Point: Shall be not higher than -32 °C (-26 °F) for the fluid in the as supplied, concentrated form, determined in accordance with ASTM D 1177. When diluted at a ratio of 1:1 by weight with ASTM D 1193, Type IV, water, the freeze point shall be not higher than -10 °C (+14 °F), determined in accordance with ASTM D 1177.

3.3.2 Effect on Aircraft Materials:

3.3.2.1 Sandwich Corrosion: Specimens, after testing in accordance with ASTM F 1110, shall not show corrosion worse than control panels run using ASTM D 1193, Type IV, water.

3.3.2.2 Total Immersion Corrosion: The fluid, tested in accordance with ASTM F 483, shall neither show evidence of corrosion of panels nor cause a weight change of any test panel greater than shown in Table 1.

TABLE 1 - Total Immersion Corrosion

Test Panel	Weight change mg/cm^2 per 24 hours
AMS 4037 Aluminum Alloy, anodized as in AMS 2470	0.3
AMS 4041 Aluminum Alloy	0.3
AMS 4049 Aluminum Alloy	0.3
AMS 4376 Magnesium Alloy, dichromate treated as in AMS 2475	0.2
AMS 4911 or MAM 4911 Titanium Alloy	0.1
AMS 5045 Carbon Steel	0.8

3.3.2.3 Low-Embrittling Cadmium Plate: Test panels, coated with low embrittling cadmium plate, shall not show a weight change greater than 0.3 mg/cm^2 per 24 hours, determined in accordance with ASTM F 1111.

3.3.2.4 Stress-Corrosion Resistance: The fluid shall not cause cracks in AMS 4911 or MAM 4911 titanium specimens, determined in accordance with ASTM F 945, Method A.

3.3.2.5 Hydrogen Embrittlement: The fluid shall be non-embrittling determined in accordance with ASTM F 519, Types 1a, 1c, or 2a.

3.3.2.6 Effect on Transparent Plastics:

3.3.2.6.1 Fluid, heated to 65 °C ± 2 (149 °F ± 5) shall not craze, stain, or discolor MIL-P-25690, Type A, acrylic plastic, determined in accordance with ASTM F 484.

3.3.2.6.2 Similarly fluid shall not craze, stain, nor discolor MIL-P-83310 polycarbonate plastic, determined in accordance with procedures in ASTM F 484 except the specimens shall be stressed for 30 minutes ± 1 to an outer fiber stress level of 13.8 MPa (2000 psi).

3.3.3 Effect on Painted Surfaces: Fluid, heated to 65 °C ± 2 (149 °F ± 4) and applied to a painted surface having an initial surface temperature of 22 °C ± 2 (72 °F ± 4), shall not produce any streaking, discoloration, or blistering of the paint film, and shall not decrease paint film hardness by more than two pencil hardness numbers, determined in accordance with ASTM F 502.

3.3.4 Effect on Unpainted Surfaces: Fluid, tested in accordance with ASTM F 485, shall neither produce streaking nor leave any stains which require polishing to remove.

3.3.5 Pavement Compatibility:

3.3.5.1 Pavement Scaling Resistance: The surface shall show a rating not greater than 2 after 50 freeze thaw cycles, determined in accordance with ASTM C 672 except that a 25% by volume solution of the fluid in tap water shall be substituted for the calcium chloride specified.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

The vendor of the fluid shall supply all samples for vendor's tests and shall be responsible for obtaining independent laboratory confirmation of conformance to the requirements of this AMS. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the fluid conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Lot Acceptance Tests: Tests for pH (3.2.1.3), refractive index (3.2.1.4), and viscosity at +20 and -20 °C (+68 and -4 °F) (3.2.3.1) are acceptance tests and shall be performed on each lot.

4.2.2 Periodic Tests: Tests for anti-icing performance (3.2.4) and aerodynamic performance (3.2.5) are periodic tests, and shall be performed at least every two years; 3.2.5 shall be performed by an approved and autonomous test facility and 3.2.4 shall be performed by an approved and, where possible, an autonomous facility.

4.2.3 Preproduction Tests: Tests for all technical requirements, except for storage stability (3.2.2.4) which may be waived by purchaser to permit entry of a new product, are preproduction tests and shall be performed prior to or on the initial shipment of the fluid to a purchaser, , when a change in any ingredient or production method requires reapproval as in 4.4.2, and when purchaser deems confirmatory testing to be required.

4.2.3.1 For direct U.S.Military procurement, substantiating test data and, when requested, preproduction fluid shall be submitted to the cognizant agency as directed by the procuring activity, contracting officer, or request for procurement.

4.3 Sampling and Testing:

Shall be in accordance with 4.3.1 or 4.3.2 (as applicable). A lot shall be all fluid produced in one continuous manufacturing process using materials from the same batches of raw materials and presented for vendors inspection at one time. Sufficient fluid from a single production lot shall be taken to perform all required tests.

4.3.1 Bulk Shipments: ASTM D 4177

4.3.2 Drum Shipments: ASTM D 1568

4.3.3 When a statistical sampling plan has been agreed upon by purchaser and vendor, sampling shall be in accordance with such plan in lieu of sampling as in 4.3.1 or 4.3.2 and the report of 4.5 shall state such plan was used.

4.4 Approval:

4.4.1 Sample fluid shall be approved by purchaser before fluid for production use is supplied, unless such approval be waived by purchaser. Results of tests on production fluid shall be essentially equivalent to those on the approved sample.

4.4.2 Vendor shall use ingredients, manufacturing processes, and methods of inspection for production fluid which are essentially the same as those used to produce the fluid which is presented for qualification to this specification. If necessary to make any change in ingredient or manufacturing process, vendor shall submit such fluid for reapproval. Production fluid made by the revised procedure shall not be shipped to user until full testing and approval has been received.

4.4.3 Whenever a fluid is to be produced by a licensee or subcontractor, all testing shall be required on fluid produced at the new site, prior to initial shipment, as if the fluid were being initially qualified unless the production method, materials, and handling are the same as the originally qualified vendor's production materials and methods. In any case, the fluid so produced shall initially be confirmed by the aerodynamic acceptance test (3.2.5).

4.5 Reports:

The vendor of fluid shall furnish before the initial shipment a report showing the results of tests to determine conformance to all technical requirements. These tests shall be carried out by approved and independent testing facilities. The aerodynamic acceptance test facility shall determine and report the results of tests for viscosity (3.2.3.1), refractive index (3.2.1.4), and pH (3.2.1.3) from the sample of fluid submitted for testing. This report shall include the purchase order number, lot number, AMS 1428, quantity, and manufacturer's product identification.

4.5.1 Subsequent reports covering tests carried out at two year intervals shall compare the results obtained to those referred to in manufacturer's data.

4.5.2 A material safety data sheet conforming to AMS 2825, or equivalent, shall be supplied to each purchaser prior to or concurrent with the report of preproduction test results or, if the preproduction test be waived by purchaser, concurrent with the first shipment of fluid for production use. Each request for modification of the fluid formulation or change in the reportable status of any of the raw materials used shall be accompanied by a revised material safety data sheet for the proposed formulation.

4.6 Resampling and Retesting:

If any sample used in the above tests fails to meet the specified requirements, disposition of the fluid may be based on the results of testing three additional samples for each original nonconforming sample. Failure of any retest sample to meet the specified requirements shall be cause for rejection of the fluid represented, and no additional testing shall be permitted. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY:

5.1 Packaging and Identification:

5.1.1 The fluid shall be packaged in containers of a size and type agreed between purchaser and vendor, or shall be delivered in bulk.

5.1.2 Except for bulk shipments, each container shall be legibly marked with not less than the manufacturers identification, lot number, quantity, AMS 1428, and, if requested, purchase order number.

5.1.2.1 Labelling requirements shall meet all federal, state, and local laws. In the U.S.A., there are several states whose Right to Know Regulations relate to labelling. Fluid manufactured, stored, or used in those states is subject to those regulations.

5.1.3 Containers of fluid shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, labelling, and safe transportation of the fluid to ensure carrier acceptance and safe delivery.

5.1.4 For direct U.S. Military procurement, packaging shall be in accordance with MIL-STD-290, Commercial Level, unless Level A is specified in the request for procurement.

6. ACKNOWLEDGMENT:

A vendor shall mention this specification number in all quotations and when acknowledging purchase orders.

7. REJECTIONS:

Fluid not conforming to this specification, or to modifications approved by purchaser, shall be subject to rejection.

8. NOTES:

8.1 For direct U.S. Military procurement, purchase documents should specify not less than the following:

Title, number, and date of this specification
Size and type of containers desired
Quantity of fluid desired
Level A packaging, if required (See 5.1.4).

8.2 Similar Specifications:

ISO 11 078 - 1992 Aerospace-Aircraft Deicing/Anti-icing non-Newtonian fluids, ISO Type II

8.3 Fluid meeting the requirements of this specification has been classified under Federal Supply Classification (FSC) 6850.

8.4 Key Words:

Aircraft deicing/anti-icing fluid, non-Newtonian, pseudo-plastic, SAE Type II

PREPARED UNDER THE JURISDICTION OF AMS COMMITTEE J (AMCM).

APPENDIX A

ENVIRONMENTAL CHAMBER FOR ANTI-ICING PERFORMANCE TESTS UNDER CONTROLLED CONDITIONS ON AIRCRAFT DEICING/ANTI-ICING FLUID

1. SCOPE:

1.1 This document establishes the minimum requirements for an environmental test chamber, and test procedures to carry out anti-icing performance tests according to the current materials specification for aircraft deicing/anti-icing fluids. The primary purpose for such a test method is to determine the anti-icing endurance under controlled laboratory conditions of SAE Type I and Type II fluids.

1.2 This test may involve the use of hazardous materials, operations and equipment. This Appendix does not purport to address all of the safety problems associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.3 The values stated in SI units are to be regarded as the standard.

2. REFERENCED DOCUMENTS:

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 4037 Aluminum Alloy Sheet and Plate, 4.4Cu - 1.5Mg - 0.6Mn (2024-T3 Flat Sheet, T351 Plate) Solution Heat Treated

2.2 ASTM Publications:

Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM D 1193 Reagent Water

2.3 ISO Publication:

Available from International Organization for Standardization, Case Postal 56, Rue de Varembe, CH-1211, Switzerland.

ISO 9002-1987 Quality Systems Model for Quality Assurance in Production and Installation

3. SUMMARY OF TEST:

3.1 This test describes how to determine the laboratory anti-icing performance of SAE Type I and Type II fluids. The test fluids to be evaluated are applied to a test plate exposed to two types of freezing conditions, and their anti-icing performance is evaluated by measuring the minimum exposure time before a specified degree of freezing occurs. A general description of the two types of anti-icing test referred to in this appendix is as follows.

3.2 Water Spray Endurance Test:

This test involves pouring the unchilled fluid onto an inclined test plate at -5 °C ± 1 and applying a cooled water spray in air at -5 °C ± 0.5 and the relative humidity is 96% ± 2. The water spray endurance is recorded as the time for ice formation to reach the first 25 mm mark at the top of the test plate under these conditions, when water spray intensity corresponds to 5 g/dm^2 per hour. This is equivalent to an average precipitation rate of 0.5 mm per hour. It is a fundamental requirement of this test that the spray impinges onto the surface of the test plate as water droplets which freeze on impact.

3.3 High Humidity Endurance Test:

This test involves pouring the unchilled fluid onto an inclined test plate at -5 °C ± 05, when the air temperature is 0 °C ± 0.5 and the relative humidity is 96% ± 2. The high humidity endurance is recorded as the time for ice formation to reach the first 25 mm mark at the top of the test plate under these conditions, when the ice formation after four hours corresponds to 1.2 g/dm^2, this is equivalent to a water accumulation rate (in the form of frost) of 0.03 mm per hour. It is a fundamental requirement of this test that the RH value is maintained to an accuracy of ±2% RH in the absence of any visible precipitation (such as mist, fog, or drizzle).

4. EQUIPMENT AND TEST PARAMETERS:

4.1 General:

A description of the minimum requirements for the environmental test chamber and associated test equipment, including test plate chilling unit, test plate, spray equipment, humidity generator, and data acquisition is given below. A summary of the performance requirements for the test equipment is given in Table 1. Other spray and humidity control equipment which meet the requirements of this Appendix are acceptable.

4.2 Test Chamber:

The test chamber used to perform both water spray endurance and high humidity endurance anti-icing tests shall have a minimum volume of 1 m^3 for each 2.25 dm^2 of test panel area (or 8 m^3 for the minimum test plate dimensions described in 4.3). A window, shall be installed and shall be double glazed or heated to prevent condensation to provide a clear view of the test plate. It is recommended to videotape the tests using superimposed real time as a record of the test procedure and duration of the tests. The chamber shall be fitted with a door or equivalent entry port to allow for fluid application, ice catch measurement and inspection of the test chamber equipment.

The test chamber shall be capable of air temperature control in the range 0 to -5 °C with an accuracy of ±0.5 °C, the temperature sensing device shall be mounted at the exit side of the air recirculating system and shall be within 0.5 m of the side of the test plate, but outside the direct line of the spray nozzle when in use. The air exchange rate in the chamber shall correspond to an average air velocity of 0.2 m/s ± 0.05 when measured 5 cm above the surface of the test plate. Humidity control shall be capable of 96% RH ± 2 RH when the air temperature is at 0 °C in the absence of any visible precipitation such as mist, fog, or drizzle. There shall be no water droplets having a diameter greater than 4 µm, determined in accordance with one of the test methods described in 5.4. Under these conditions of RH and air temperature, and in the presence of horizontal air velocity of 0.2 m/s ± 0.05, the frost accumulation rate on the test plate (cooled to -5 °C ± 0.5) shall be 1.2 g/dm^2 ± 0.2 after four hours.

The humidity can be produced using a saturated water vapor generator housed in the exit side of the air recirculating system and controlled using a suitably calibrated humidity sensor linked to a control system. When a high humidity condition is required, the humidity sensor shall be placed 5 cm above the surface of the test plate at the center line of the upper edge of the test plate. Both the air temperature and humidity sensing devices shall be linked to a continuous pen recorder of electronic data acquisition system as a means of checking the environmental control characteristics of the test chamber throughout the course of a test run.

4.3 Test Plate:

The test plate is either the upper surface of the test plate chiller unit or removable panels sited on the face of the chiller unit. Both the test plate and chiller unit are housed within the test chamber.

The test plate shall be AMS 4037 aluminum alloy with the test face polished to an average surface roughness of 0.1 to 0.2 µm Ra. The chiller unit face shall be inclined at 10 degrees ± 0.2 from the horizontal. The upper surface of the test plate shall comprise of at least six panels, each separated by a divider which will protrude 5 mm above the surface of the test plates to obviate the possibility of cross contamination between fluid applied to adjacent panels. Each test plate shall measure 30 x 10 cm (area = 3 dm^2) and shall be clearly marked as follows:

4.3 (Continued):

(a) With a horizontal line running across and 25 mm from the upper edge of the test plate; this marking (permanent marking pen) will be used to estimate the degree of ice formation on fluid treated panels during the course of a test run (See 6.4).

(b) With an additional two horizontal lines one at 10 cm from the upper edge and the other at 20 cm from the upper edge; these markings to be used during calibration of test equipment (See 5.4.3).

The lower surface of the test plate shall be coupled to a fluid cell capable of accepting a recirculating supply of heat transfer fluid such that the upper surface of the test plate can be controlled to a temperature of -5 °C ± 0.5. The temperature sensing device shall be mounted in the recirculating fluid cell or in the return pipe taking the heat transfer fluid from the fluid cell to the heat exchanger. This temperature sensor shall be linked to a continuous pen recorder or electronic data acquisition system to check and record the test plate temperature throughout the course of a test run.

4.4 Spray Equipment:

4.4.1 General Requirements:

The spray equipment is used in the water spray endurance test to provide the water spray from a nozzle supplied with low flow water and atomized by compressed air or by spinning disc, this equipment is housed in the upper region of the test chamber above the test plate. The water shall conform to ASTM D 1193, Type IV, and when used, the compressed air shall be clean and oil free. The spray equipment shall be adjusted in order to meet the following criteria:

(a) Average droplet diameter of the water spray shall be 20 μm, with 50% of the droplets in the range 15 to 35 μm.

(b) The average intensity of the water spray produced during a test shall correspond to 5 g/dm^2 ± 0.2 per hour.

(c) The water spray shall be evenly distributed over the entire area of the test plate.

(d) The water spray shall impinge on the surface of the test plate in the form of water droplets which freeze on impact when both the air and test plate temperatures are at -5 °C.

The exact type and geometry of the spray system used to generate the water spray for the test is left to the discretion of the user, provided the foregoing parameters are met.

As a means of providing some background information, an example of a suitable spray system is outlined below.

4.4.2 Example of Spray Equipment:

The nozzle comprises two sections, outer and inner units for the respective passage of water and compressed air. The critical dimensions are given in Figure 1. Typical input water and air pressures to achieve the required intensity are: water flow rate of 24 cm^3 per minute, air pressure 25 psi. In this example the nozzle is mounted 65 cm above the test plate and is capable of traversing along a 1 m path parallel to the test plate face and some 60 cm behind the upper edge of the plate. The nozzle reciprocates at 18 passes per minute, and in this configuration provides even and reproducible coverage of the test plate at the specified rate. See Figure 2 for a schematic layout of this system.

4.5 Temperature Control Equipment:

Both the air and test plate temperatures shall be maintained at the required level using heat exchangers connected to on/off temperature control equipment comprising solid state temperature sensor such as a platinum resistance probe (100 ohms at 0 °C), coupled to a proportional temperature controller having a minimum resolution of 0.5 °C.

4.6 Humidity Control Equipment:

Relative humidity shall be maintained at the specified level using a saturated water vapor generator, or equivalent, connected to on/off humidity control equipment comprising humidity sensor of the capacitance, resistance or conductivity type capable of covering the range 90 to 100% RH at 0 °C; this in turn is coupled to a controller capable of regulating the saturated water vapor generator heater supply (and therefore the amount of water vapor introduced into the air stream).

4.7 Air Distribution System:

Shall comprise of a fan to provide air recirculation through the main body of the test chamber and to the heat exchanger. Ducting for the passage of air to and from the heat exchanger shall have entry and exit ports positioned to provide good air recirculation throughout the test chamber. The heat exchanger shall be capable of cooling the air and maintaining it at the specified level. The air movement within the test chamber, measured during high humidity endurance testing, shall be as specified. Air flow shall be measured using a suitable anemometer or velometer.

5. CALIBRATION OF TEST EQUIPMENT:

5.1 Standard Measuring Devices:

All temperature sensors, humidity sensors, electronic balance, anemometer, and timing device shall be maintained in a known state of calibration in accordance with recognized international standards such as ISO 9002-1987.

5.2 Surface Roughness of Test Plate:

The average surface roughness of the aluminum alloy test plate shall be 0.1 to 0.2 µm Ra. This measurement shall be made width-wise across the upper section of each test plate using a surface measuring instrument.

5.3 Average Air Velocity:

It is a requirement of the high humidity test that the average air velocity in the test chamber, when measured 5 cm above the centerline at the upper edge of the test plate be 0.2 m/s ± 0.05.

5.4 Water Droplet Size:

5.4.1 Water spray droplet size shall have an average diameter of 20 µm ± 2, with 50% of the droplets in the range 15 to 35 µm.

5.4.2 During the high humidity test the water vapor must not contain any droplet greater in diameter than 4 µm.

5.4.3 The following methods can be used to determine the droplet sizes referred to in 5.4.1 and 5.4.2.

a. Slide Impact Method: A sample of the water droplets from the precipitation is collected on an oil coated microscope slide. An oil having a viscosity of 5000 mPas at 20 °C, spread to a thickness of about 500 µm will be suitable. The oil can be either a mineral oil or a silicone oil. The droplet size is determined by direct observation under a microscope using an eye piece with the appropriate graticle, or from enlarged photographs of the slide.

b. Laser Diffraction Method: Using a laser diffraction particle analyzer, incorporating a low power laser transmitter and photo detector, the size of the droplets can be measured as they fall towards the surface of the test plate. This is done by analyzing the diffraction patterns which will give the size and the distribution of the droplets. Some equipment is capable of achieving this in real time.

5.4.4 Ice Catch Calibration: For both types of anti-icing tests, it is important to establish that even and reproducible ice formation occurs over the surface of the test plates. To carry out this evaluation, ice catch measurements must be performed under the appropriate test conditions for water spray endurance and high humidity endurance. A summary of the test conditions follows:

a. Water Spray Endurance

air temperature	-5 °C ± 0.5
test plate temperature	-5 °C ± 0.5
test plate slope	10 degrees ± 0.2 from horizontal
water spray intensity	5 g/dm² ± 0.2 per hour

5.4.4 (Continued):

b. High Humidity Endurance

air temperature	0 °C ± 0.5
test plate temperature	-5 °C ± 0.5
test plate slope	10 degrees ± 0.2 from horizontal
relative humidity	96% ± 2
horizontal air velocity	0.2 m/s ± 0.05
frost accumulation	1.2 gm/dm^2 ± 0.2 after four hours

There are two ways to assess the ice catch.

(i) Use three panels, each 10 x 10 cm in place of each 10 x 30 cm test plate, this is the preferred method, since the preweighed panels can be weighed on completion of test and the difference in the recorded weights is the ice catch.

(ii) Mark the 10 x 30 cm test panels with lines at the 10 cm and 20 cm points, on completion of test, scrape the ice from each third in turn and weigh it. The disadvantage with this method is the possibility of damaging the polished surface of the test panel.

In either case the ice catch on each 10 x 10 cm section shall correspond to 5.0 gm ± 0.2 for each hour of the water spray test and 1.2 gm ± 0.2 for each four hours in the high humidity test. The degree of repeatability shall be checked by performing not less than two successive test runs. The same performance limits must be achieved in each run. This calibration shall be run at least once every six months or whenever a piece of equipment is repaired or replaced.

6. TEST PROCEDURE:

6.1 Test Plate Cleanliness:

The test plates shall be free of all visible contamination, smears, or stains, except for the horizontal lines marked at the 25 mm point from the upper edge of the test plate. Any contamination shall be removed by washing in hot (80 °C ± 5) ethanol and in hot water, then thoroughly dried. Between test runs using the same candidate fluid, a hot water wash and dry will suffice. Particular care should be taken to ensure the test plate to divider interface is clean and dry in order to obviate the formation of ice seed crystals, which could lead to premature failure indications.

6.2 Ensure the test chamber and test plate support are at the required temperature.

6.3 If the candidate test fluid is an SAE Type II fluid, it shall have been sheared in accordance with the specification some 24 hours before the test is to commence. If the candidate fluid is an SAE Type I fluid, shearing is not necessary. The diluent shall be ASTM D 1193, Type IV, water. The candidate test fluid shall be at ambient temperature, in the range 15 to 25 °C. For each test panel to be coated with the fluid prepare 100 ml for each test run.

6.4 Pour the fluid onto each test plate in turn in the order shown in Figure 3. Start the timing device, after five minutes, turn on the water spray or humidity generator, observe the panels and, when the ice front touches the 25 mm line, record the time of this event. Immediately turn off the water spray or humidity generator and weigh the ice catch on each 10 x 10 cm section of the uncoated panels. If the ice catch is within the specified limits for the test being conducted, the time for the ice front to reach the 25 mm line is valid for that test. Repeat the test using the alternate layout for the test panels to be coated with the candidate test fluid. If the two successive runs indicate conformance to the ice catch criteria, the times for the ice fronts to reach the 25 mm mark shall be recorded on the report.

6.5 Reproducibility/Precision:

The water spray endurance and high humidity endurance tests are dynamic by nature, and small variations can be expected. The acceptable variance between successive runs of the same candidate test fluid for the water spray endurance test is ± 1.5 minutes.

Similarly, the high humidity endurance test is considered valid if the time variation between successive test runs of the same candidate test fluid is within ± 15 minutes.

6.6 Report:

The report shall state the name and address of the facility conducting the tests, together with a statement confirming the test facility is autonomous of the manufacturer or vendor of the fluid. The following information will also appear on the test document:

Date tests conducted
Manufacturer or vendor's name and address
Name or reference number of fluid tested
Type of fluid (SAE Type I or SAE Type II)

Condition of fluid - Concentrate as supplied to test facility, and subsequently sheared in accordance with specification if SAE Type II, or unsheared and concentrate as supplied if SAE Type I, or unsheared and diluted with ASTM D 1193, Type IV, water, giving the dilution as a ratio - example: SAE Type II diluted 75:25 with water.

6.6 (Continued):

Print out showing the temperature of the test chamber, and test plate and for the high humidity test a print out showing the RH for the duration of the tests.

Summary of test results and ice catch results for each test performed. Statement that the fluid tested either conforms to, or does not conform to the requirements of the specification against which the candidate fluid was tested.

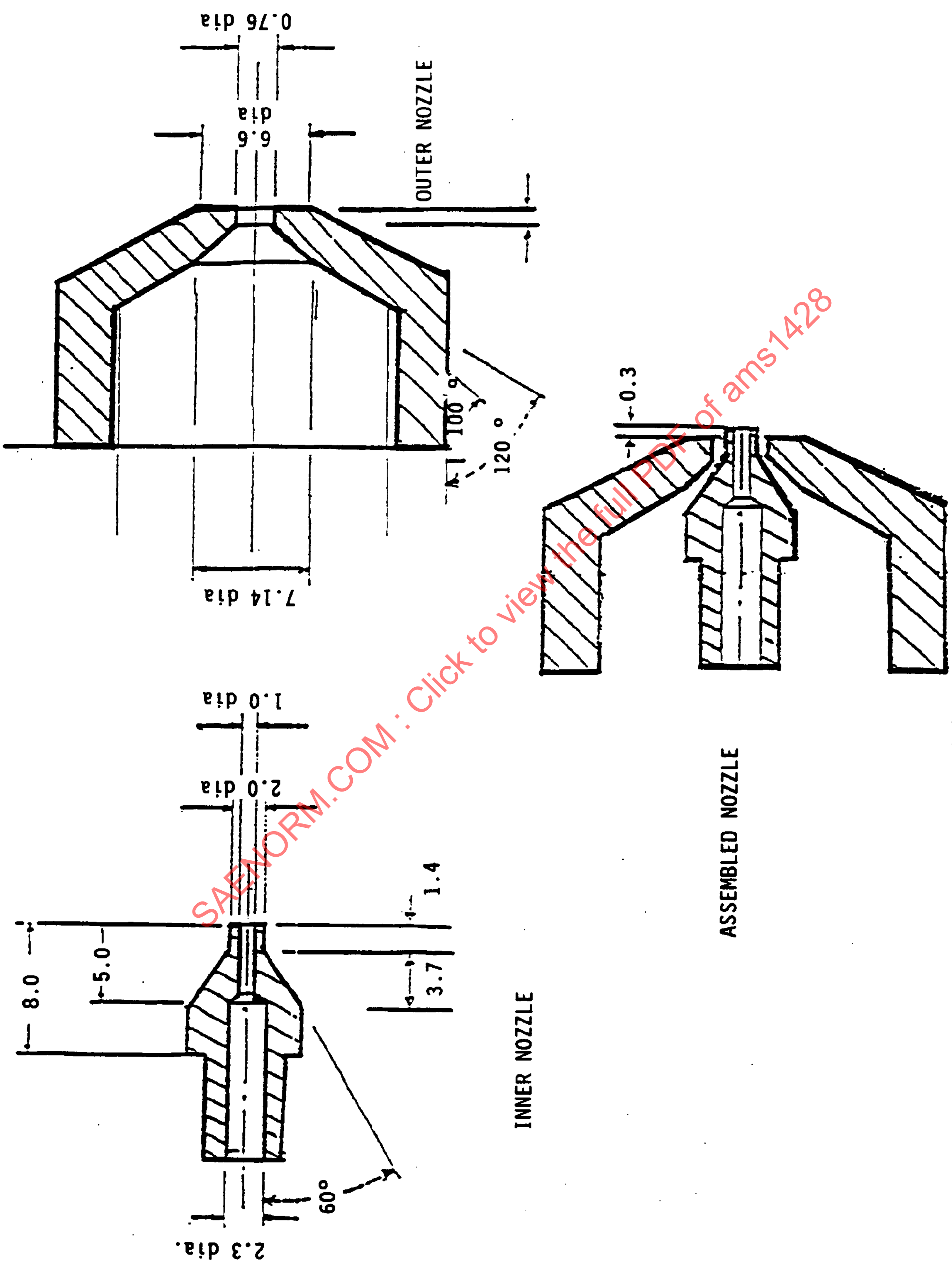

FIGURE 1 - Spray Nozzle
(All dimensions mm)

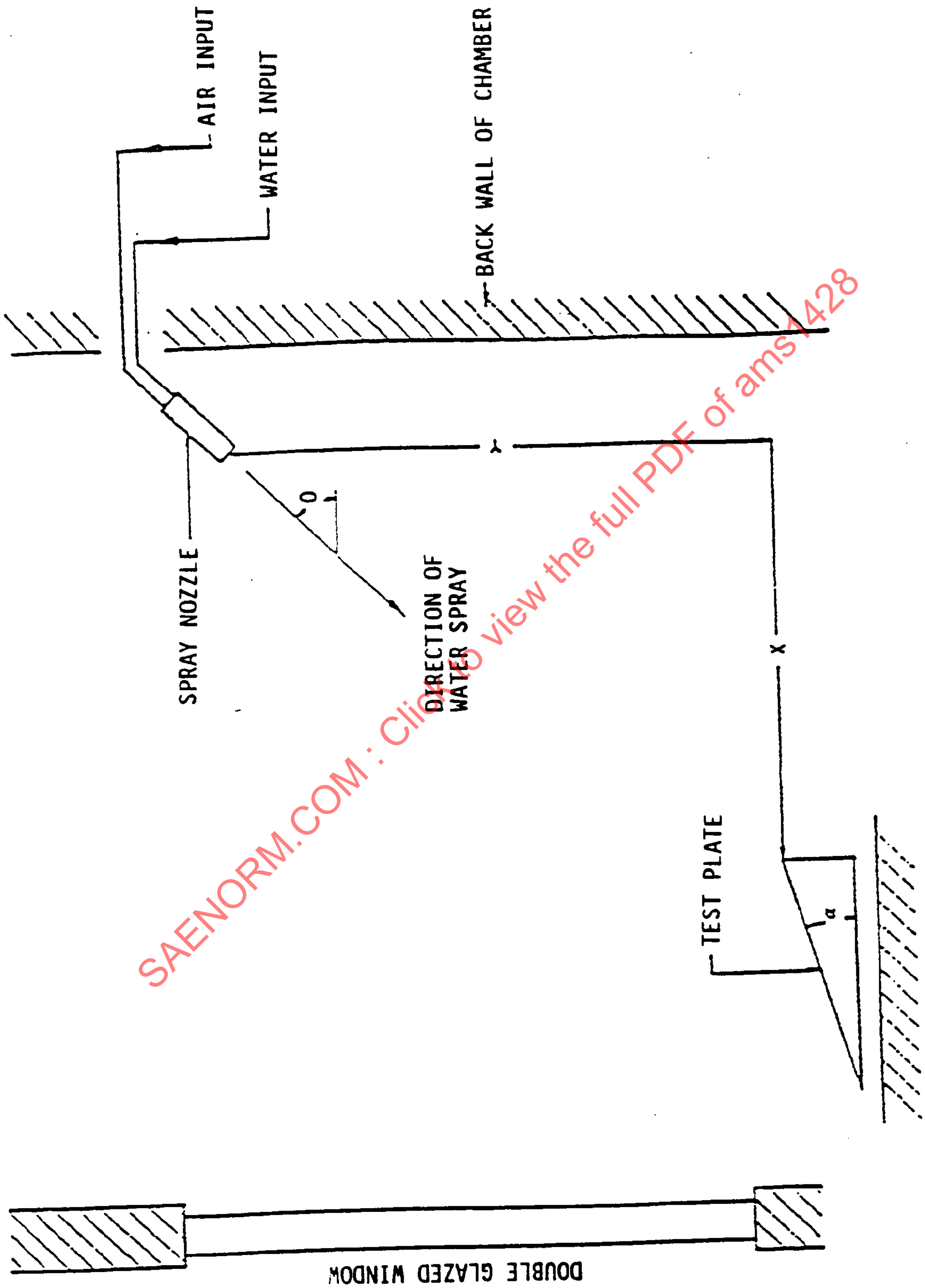

FIGURE 2 - Schematic Cross-Section of Spray Equipment

TABLE 1 - Anti-Icing Calibration Tests - Proposed Order Of Fluid Application To A Frosticator Having 6 Test Panels

RUN NO.	PANEL NO.					
	1	2	3	4	5	6
1	BLANK (A)	FLUID	BLANK	FLUID	BLANK	FLUID
2	FLUID	BLANK	FLUID	BLANK	FLUID	BLANK

FOOT NOTE:

(A) Blank panels act as controls to measure the ice catch after each run.

APPENDIX B

STANDARD TEST METHOD FOR AERODYNAMIC ACCEPTANCE OF AIRCRAFT GROUND DEICING/ANTI-ICING FLUIDS

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1. SCOPE

1.1 Objective

This standard establishes the aerodynamic flow-off requirements for fluids used to deice and/or anti-ice large transport type jet aircraft while on the ground. The take-off rotation speeds generally exceed approximately 100 to 110 knots. The objective of this standard is to ensure acceptable aerodynamic characteristics of the deicing/anti-icing fluids as they flow off aircraft lifting and control surfaces during the takeoff ground acceleration and climb.

1.2 Fluid Acceptance and Facility/Site Qualification

An aircraft ground deicing/anti-icing fluid has acceptable aerodynamic flow-off characteristics if the fluid is tested in accordance with this standard and complies with the acceptance criteria described in Section 8. If results from testing in accordance with this test method are to be used to certify that an aircraft ground deicing/anti-icing fluid complies with the acceptance criteria described in Section 8, substantiation that the facility and associated staff and resources satisfy the requirements of this test method shall be documented and submitted to the Transport Committee Project 218-4, Aerospace Industries Association of America, Inc., 1250 Eye Street, N.W., Washington D.C. 20005, United States of America to qualify the technical suitability and competency of the test site/facility. Such test sites/facilities shall be qualified at five year intervals by submitting current data which demonstrate that the facility, procedures, supporting resources, and staff continue to produce acceptable data. To maintain compliance with this standard, the fluid shall be tested when initially certified and thereafter biannually in its undiluted and diluted forms per this standard and shall continually demonstrate acceptable aerodynamic flow characteristics.

1.3 Safety Hazards

This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address any, or all, of the safety problems associated with its use. It is the responsibility of the standard user to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. SIGNIFICANCE IN USE

Aerodynamic acceptance of an aircraft ground deicing/anti-icing fluid is based on the air and fluid BLDT (boundary layer displacement thickness) on a flat plate measured after experiencing the free stream velocity time history of a representative aircraft take-off. Acceptability of the fluid is determined by comparing BLDT measurements of the candidate fluid with a datum established from the values of a reference fluid BLDT and the BLDT over the dry (clean) plate. Testing is carried out in the temperature range at which the fluid, undiluted and diluted, is to be used in airline service.

3. REFERENCED DOCUMENTS

3.1 ASTM Publications

Available from the ASTM, 1916 Race Street Philadelphia, PA 19103-1187.

ASTM D 1193 Reagent Water
ASTM D 1331 Surface and Interfacial Tension of Solutions of Surface-Active Agents
ASTM D 1747 Refractive Index of Viscous Materials
ASTM D 2196 Viscosity Measurements and Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscometer
ASTM E 70 pH of Aqueous Solutions with the Glass Electrode

3.2 U. S. Government Publications

Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-A-8243, Anti-icing and Deicing-Defrosting Fluid

4. GLOSSARY

4.1 Abbreviations

BLDT boundary layer displacement thickness
cm centimeter
Hz hertz
m meter
mm millimeter
Pa pascal
pH potential of hydrogen
RH relative humidity
RPM revolutions per minute
s second

4.2 Parameters

- b cross section width at Station 3
- c cross section perimeter at Station 3
- t time
- S_1 settling chamber cross section area (Station 1)
- S_2 test duct cross-section area at Station 2
- S_3 test duct cross-section area at Station 3
- P_1 settling chamber static pressure (Station 1)
- P_2 static pressure at Station 2
- P_3 static pressure at Station 3
- T_g gas temperature (wind)
- T_f fluid temperature (deicing/anti-icing fluid)
- T_t target temperature
- V average wind velocity in flow core (at Station 2)
- Vi idle wind velocity
- Vm maximum wind velocity
- Vs start-up wind velocity
- δ^*_d BLDT over dry surface (at Station 3)
- δ^*_f BLDT over fluid-coated surface (at Station 3)
- δ^*_{ave} BLDT perimeter average between δ^*_f and δ^*_d
- δ^*_r δ^*_f value for reference fluid
- δ^*_0 maximum acceptable value for δ^*_f at 0° C
- δ^*_{-20} maximum acceptable value for δ^*_f at -20 C°
- ρ gas density mass per unit volume

5. TEST FACILITY REQUIREMENTS

Testing shall be performed in a horizontal duct having the following geometry, flow characteristics, and instrumentation. If results produced by a test facility are to be used to certify that a deicing/anti-icing fluid has been tested in accordance with this standard and complies with Section 8, substantiation that the facility is autonomous of fluid manufacturers and complies with the following requirements shall be documented and submitted to the Transport Committee Project 218-4, Aerospace Industries Association of America, Inc., 1250 Eye Street, N.W., Washington, D.C., 20005, United States of America to qualify the technical suitability and competency of the test facility. The test facility shall be qualified at five year intervals by submitting current data which demonstrate that the facility, instrumentation, and procedures continue to produce acceptable data. The following describes the facility used to measure the aerodynamic flow-off acceptability of deicing/anti-icing fluids. In addition, the technical capability of the site/facility also includes the ability to provide or procure the data required by 6.2, adequate transducer calibration facilities to ensure accuracy and precision requirements, and trained personnel to effect the test method.

5.1 Test Duct Description

5.1.1 Dimensions: Figure 1

5.1.2 Tolerances:

Lineal dimensions	$\leq \pm 2\%$
S_2/S_3	$0.927 \pm 1\%$

5.1.3 Design features: The test duct floor shall be horizontal, while the ceiling shall slope upward linearly 8 mm from Station 2 to Station 3. Test duct surfaces shall be hydraulically smooth, resulting in a dry BLDT $\leq$ 3.0 mm at Station 3. Provisions shall be made to uniformly apply a 2 mm film of test fluid only on the test duct floor and to remove residual test fluid at the end of a test run.

5.2 Test Duct Gas Flow Core Characteristics

5.2.1 Test gas: Air, Nitrogen, or suitable gas proven to have no adverse effect on the overall testing method.

5.2.2 Temperature range	0 °C to approximately -25 °C, or the test fluid minimum usable temperature
5.2.3 Temperature stability	≤ ± 2 °C of the target temperature with a continuous flow ≥ 60s, except ≤ ± 1°C between the 27th and 33rd seconds of a test run
5.2.4 Temperature spatial uniformity	≤ ± 1 °C
5.2.5 Velocity range	0 = V ≤ 0.5 m/s to 65 m/s ± 5 within t = 25s ± 2, following a constant acceleration of 2.6 m/s^2 (measured at Station 2) with a minimum flow velocity of 65 m/s ± 5 30s after start, and maintained for 30 additional seconds. (See Figure 2.) Prior to the flow acceleration, the duct flow shall be capable of a five minute settling period with a velocity ≤ 5 m/s
5.2.6 Turbulence	≤ 0.005 ($\Delta U/U_\infty$)
5.2.7 Velocity spatial uniformity	
Vertical and lateral	$\Delta U/U_\infty \le \pm 0.005$
Longitudinal	$\Delta U \le -1$ m/s/m ± 0.008 U_∞/m
5.2.8 Relative humidity	70% ± 30%
5.3 Test Facility Thermal Stability	
5.3.1 Test duct	The test duct shall be thermally insulated or within the test facility circuit flow and capable of being pre-cooled to ensure thermal equilibrium of the test duct structure during a test run.
5.3.2 Test facility circuit	Circuit thermal insulation shall ensure the test duct temperature characteristics of Sections 5.2.
5.4 Test Facility Drainage	Drainage shall be provided downstream of the test duct, in a region of low velocity, to remove test fluid and to ensure no fluid returns upstream to the test duct.

5.5 Instrumentation

5.5.1 Temperature and relative humidity

5.5.1.1 Test duct gas temperature	Measured at Station 2 approximately 5 mm below the ceiling.
5.5.1.2 Test fluid temperature	Measured at Station 3 within the test fluid, approximately 1 mm above the floor.
5.5.1.3 Temperature sensor	Copper constantan thermocouples of a 0.2 mm diameter wire with a measuring function of about 0.5 mm^3. (Thermocouples T: range -180 to 400 °C, sensitivity ± 0.1 °C, accuracy ± 0.5 °C). Thermocouple calibrations should be performed at the beginning and end of a sequence of test runs.
5.5.1.4 Relative humidity	Wet bulb-dry bulb thermometers or equivalent which are regularly calibrated against wet bulb-dry bulb thermometers.

5.5.2 Test duct gas pressures

5.5.2.1 Total pressure, P_1	May be measured as of the static pressure in the settling chamber immediately upstream of the test duct, Station 1, using a 4 mm diameter flush orifice tapped into the chamber sidewall if the velocities are low, in accordance with standard wind tunnel practice.
5.5.2.2 Inlet static pressure, P_2	Measured using a 4 mm diameter flush orifice tapped into the middle of the ceiling at Station 2, free of flow disturbances from the Station 2 temperature probe.
5.5.2.3 Outlet static pressure, P_3	Measured using a 4 mm diameter flush orifice tapped into the middle of the ceiling at Station 3.

5.5.2.4 Pressure sensor

Two pressure transducers are used to measure (P_1 - P_2) and (P_2 - P_3) pressure differentials. The pressure transducer used for $P_2 - P_3$ shall have a range of at least 300 Pa with a ± 0.5% accuracy. The pressure transducer used for (P_1 - P_2) shall have a 3000 Pa range and a ± 1 % accuracy. Data stability (time variations less than 0.5%) and time response (less than 0.1 s delay) shall be achieved by appropriate data filtering and smoothing techniques. Low pass filtering between 1 and 5 Hz and data sampling at least twice the cut-off frequency of the filter are recommended. Calibration of the measurement system shall be performed over the entire range using a reference apparatus (with accuracy of ± 0.25% for (P_2 - P_3) and ± 0.5% for (P_1 - P_2)) before and after each complete test session.

5.5.3 Test duct gas velocity and turbulence

5.5.3.1 Velocity

Test duct velocity is that at Station 2. Velocity shall be computed from the measurements of (P_1 - P_2) and (S_2/S_1) using Equation 1.

$$V=\sqrt{\frac{2}{\rho}(P_1-P_2)\bigg/\left[1-\left(\frac{S_2}{S_1}\right)^2\right]} \qquad \text{(Eq. 1)}$$

Because of possible pressure leaks and losses, a calibrated pitot-static probe shall be periodically used to verify use of Equation 1.

5.5.3.2 Turbulence

Turbulence may be measured using hot wire or film sensors or other means in accordance with commonly accepted wind tunnel practices.

5.6 Example Facility

An example facility consists of a closed circuit, refrigerated wind tunnel with a 0.5 m x 0.5 m test section. The test duct is inserted in the test section of the wind tunnel. The test duct may be fitted with a short inlet convergent to achieve required maximum speed, and a long diffuser to avoid large power losses due to wake effects. The facility has a settling chamber fitted with honeycomb and/or grids and a 9: 1 contraction ratio separates this chamber and the wind tunnel test section entrance in order to provide good airflow quality. A 50 hp fan drive motor with variable RPM is controlled, by computer, via the time signal of the difference between actual wind velocity and required value. Refrigeration is obtained via a heat exchanger placed upstream of the settling chamber; a two stage freon-glycol refrigeration circuit powered by a 75 hp compressor provides adequate temperature setting (-30 °C). A schematic of the suggested facility is shown in Figure 3.

6. TEST FLUID REQUIREMENTS

6.1 General

Fluids submitted for testing shall be experimental fluids or fluids which are representative of production fluids being commercially offered as complying with this test method, shall have been manufactured during the previous three months, shall be from the same lot submitted for the water spray endurance test and the high humidity endurance test, but unsheared with respect to the requirements of the water spray and high humidity endurance tests. Approximately, a volume of about 1 liter of the lot is required for one test run and approximately 50 liters for a test. The fluid shall be tested undiluted and in dilutions of 75% neat fluid to 25% water, and at 50% neat fluid to 50% water. Those samples to be tested in diluted form shall be diluted by the testing facility, using water conforming to ASTM D 1193. The manufacturer shall include with the fluid samples submitted for testing a statement which identifies the product name or reference number, lot number, and date of manufacture.

6.2 Fluid Identification

The aerodynamic acceptance testing facility shall identify the fluid by testing for the following:

6.2.1 Viscosity: Viscosity shall be measured in accordance with ASTM D 2196 at 20 °C, 0 °C, and in 10 °C increments down to the lowest usable temperature identified by the fluid manufacturer. Viscosity measurements will be made for both the undiluted fluid and all tested dilutions.

6.2.2 Surface Tension: Surface tension of the undiluted fluid shall be determined at 20 °C ± 3 in accordance with ASTM D 1331.

6.2.3 Refractive Index: Refractive index of the undiluted fluid shall be determined at 20 °C ± 3 in accordance with ASTM D 1747.

6.2.4 pH: pH of the undiluted fluid shall be determined at 20 °C ± 3 in accordance with ASTM E 70.

7. TEST PROCEDURE

7.1 Test Requirements:

BLDT measurements shall be made of the test fluid, the reference deicing fluid MIL-A-8243, Type 1, and of the dry test duct. Each fluid shall be tested at selected fluid temperature including 0 to -20 °C, or to the coldest usable test fluid temperature identified by the fluid manufacturer if colder than -20 °C, in approximately 10 °C increments. Each fluid shall be tested at a minimum of three target temperatures (not necessarily the exact same temperatures). Three BLDT measurements shall be made within ± 3 °C at each target temperature to improve data precision and accuracy. BLDT measurements of the dry test duct shall also be made immediately prior to and after each target temperature sub-set of fluid BLDT measurements. A minimum set of nine BLDT measurements shall be performed for each fluid and a minimum of six dry test duct BLDT measurements shall be performed in conjunction with the fluid measurements for a minimum of 36 BLDT measurements. 7.2 describes the test sequence for one BLDT measurement (test run) of a fluid; for measurement of the dry test duct BLDT, ensure that the test duct is free of any fluid and follow the sequences of 7.2, deleting the steps involving the fluid.

7.2 Test Run Sequence

7.2.1 Select target temperatures

7.2.2 Pre-Cool Test Fluid: Prior to testing, a pre-cooling of the fluid is required to achieve target temperature during the test. However, the fluid should never experience partial freezing in order to avoid possible irreversible rheological changes. Consequently, fluid temperature shall be maintained, at all times at a minimum of 5 °C above the freezing point during the pre-cooling procedure. The pre-cooling of the fluid generally consists of two steps: first, a long storage in a cold chamber; second, once the fluid has been laid on the test duct floor, a five-minute setting period under a wind velocity hereafter referred to as idle velocity, and denoted V_i.

7.2.3 Pre-cool Test Facility: Pre-cool the test facility to achieve test gas and structural thermal stability at the target temperature. Efficient testing is typically obtained by beginning testing at the coldest target temperature.

7.2.4 Measure Fluid Water Content: Measure the fluid's refractive index to ensure that the fluid's water content is within ± 1% of the fluid manufacturer's specifications.

7.2.5 Apply Fluid to Test Duct Floor: Pour approximately 1 liter of fluid onto the test duct floor and level the fluid film at 2 mm using a calibrated scraper, with the film extending from Station 1 to Station 2. Excess fluid may be scraped down stream of Station 2 toward the circuit drain, spreading the excess fluid to avoid fluid build up at the exit of the test duct.

7.2.6 Subject Fluid to Settling Conditions: Secure the test duct and circuit and subject the fluid to a five minute settling period with the test duct gas velocity $\leq$ 5 m/s to obtain gas and fluid temperatures close to the target temperature. Temperatures of the gas and fluid shall be within ± 2 °C at the end of the settling period. The duct gas flow shall not cause visually detectable motion of the test fluid.

7.2.7 Subject Fluid to a Simulated Aircraft Take-off Velocity Time History: Accelerate the test duct gas flow as shown on Figure 2 and simultaneously record t, RH, T_f, T_g, $(P_1 - P_2)$, and $(P_2 - P_3)$.

7.2.7.1 Start Up: The start up wind velocity, denoted V_s, shall range from 0 to 5 m/s.

7.2.7.2 Acceleration: From t = 0 s to t = 2 s ± 2, wind velocity shall increase to V_s. From t = 2 s ± 2 to t = 25 s ± 2, wind velocity shall increase from V_s up to V_m. From t = 25 s ± 2 up to 60 s wind velocity shall remain constant, equal to V_m.

7.2.7.3 Maximum Velocity: The maximum wind velocity, denoted V_m, shall be equal to 65 m/s ± 5.

7.2.8 Terminate Test Run: At time t = 60 s wind velocity is brought to 0 m/s as quickly as possible.

7.2.9 Residual Fluid Analysis: Sample fluid remaining on the test duct floor for water content.

7.2.10 Data Processing: Process measured data, see 7.4.

7.3 Test Cautions:

7.3.1 Safety Hazards: See 1.3 concerning safety hazards.

7.3.2 Frost: The formation of frost within the test duct will significantly effect the results obtained and therefore must be prevented.

7.3.3 Variation of Water Content: Dehydration of fluids prior and during testing may significantly affect the result obtained and shall therefore be prevented. Consequently, all fluids shall be kept in containers suitably capped to prevent the evaporation of water prior to being applied to the test plate. Measurement of the fluid sample refractive index immediately after the test shall be performed according to ASTM D 1797 and the variation of the water content from that measured immediately before the test (using a refractive index - dilution calibration curve) shall be derived and reported.

7.3.4 Irregular BLDT Data: The $\delta^*_d(t)$ curve for all the dry runs is carefully analyzed to detect whether or not it shows evidence of irregular behavior. Such irregular behavior results from the following:

7.3.4.1 Increasing BLDT Data: A BLDT increasing with time during the last 30 seconds of the run, when the tunnel velocity is constant, indicates a progressive roughening of the test section walls, as would result from a progressive deposit of frost on test section walls.

7.3.4.2 Constant BLDT Data: A constant value of BLDT with time during the last 30 seconds of the run, but significantly larger (more than 20%) than that for all other dry runs, indicates the existence of some roughening of the test section walls by frost deposit or spurious fluid accumulation. If such irregular behavior is noticed, then the results of the following tests with fluids are discarded and the tests possibility repeated with all the wet runs backed by two anomalous dry runs. In case a series of wet runs is bracketed by a normal (acceptable) initial dry run and an anomalous (unacceptable) final dry run, then the last wet runs are questionable while the initial runs are probably acceptable. Depending on how the results of these specific tests match the other tests of the same fluid at other temperatures, judgment is exercised to decide whether or not the result can be accepted.

7.4 Data Processing

7.4.1 Test Data Description

7.4.1.1 Desired Data: A time record of wind velocity (V), dry or fluid BLDT (δ^*_d or δ^*_f), fluid temperature (T_f) and relative humidity (RH) shall be provided for the 60 seconds duration of the test. Example is given in Figure 4.

7.4.1.2 Desired Average Data: The specific results of a given test shall consist of values averaged over the period at the end of the acceleration, i.e., between the 27th and 33rd second of the test. These values are BLDT and fluid temperature.

7.4.2 Calculation Methods:

7.4.2.1 Velocity: See 5.5.3.1