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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 1428D

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Superseding AMS 1428C

(R)

Fluid, Aircraft Deicing/Anti-icing, Non-Newtonian (Pseudoplastic), SAE Types II, III, and IV

1. SCOPE:

1.1 Form:

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

1.1.1 Classification: Deicing/anti-icing fluids covered by this specification are classified as follows:

TABLE 1 - Classification

Fluid SAE Type	Anti-icing Performance Use Table 2 (3.2.4.1)	Aerodynamic Performance Use Annex	Color Applicable if Requested
Type II	II	B	Water white/pale straw
Type III	III	C	To be determined
Type IV	IV	B	Green

Consult aircraft manufacturer's Maintenance Manual and Service letters to determine any restrictions relating to the use of deicing/anti-icing fluids meeting this specification for the type and model of aircraft being treated. See also latest edition of ARP4737.

1.1.2 Fluids defined as non-Newtonian 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. Typically such fluids 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.

1.1.3 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.

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1.2 Application:

These fluids may be used as follows:

a. Unheated and undiluted, or diluted 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 used with the unheated and undiluted fluid as step two

1.2.1 Consult aircraft manufacturer's maintenance manual and service letters to determine any restrictions relating to the use of deicing/anti-icing fluids for type and model of aircraft being treated. Refer also to ARP4737.

1.3 Precautions:

1.3.1 The lowest operational use temperature (LOUT) for SAE Type II, III, and IV fluids shall be determined for the neat (undiluted) fluid and for each intended use dilution and is the lowest temperature at which the fluid has been tested and certified as acceptable in accordance with the appropriate aerodynamic acceptance test (3.2.5) while still maintaining the 7 °C (13 °F) freezing point temperature buffer (see ARP4737). The fluid manufacturers' literature shall clearly state the LOUT for the neat fluid and intended use dilutions.

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 mists should be avoided. Consult the fluid manufacturers' Material Safety Data Sheet for further information.

1.3.3 Caution should be exercised in the use of glycol-water deicing/anti-icing solutions in and around electrical/electronic circuitry with noble metal coated wiring or terminals which could make 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. Fluids based on glycol shall contain an inhibitor to minimize this potential fire hazard.

1.3.4 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 Slipperiness: Slippery conditions may exist on the ground, or equipment following the deicing/anti-icing procedure.

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 issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

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
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-0.20Mn (AZ31B-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 4916	Titanium Alloy Sheet, Strip, and Plate, 8Al-1Mo-1V
AMS 5045	Steel Sheet and Strip, 0.25 Carbon, Maximum, Hard Temper
AMS 5886	Alloy, Corrosion and Heat Resistant, Bars, Forgings and Rings, 50Ni-20Cr-20Co-5.8Mo-2.2Ti-0.45Al, Consumable Electrode or Vacuum Induction Melted 2100 °F (1149 °C) Solution Heat Treated
ARP4737	Aircraft Deicing/Anti-icing Methods with Fluids for Large Transport Aircraft

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

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 4052	Density and Relative Density of Liquids by Digital Density Meter
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 DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-PRF-25690	Plastic, Sheets and Formed Parts, Modified Acrylic Base, Monolithic, Crack Propagation Resistant
MIL-P-83310	Plastic Sheet, Polycarbonate Transparent

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

2.5 OECD Publications:

Available from Organization for Economic Co-operation and Development, 2 rue André Pascal, Cedex 16, 75016 Paris, France.

OECD Guidelines for Testing Chemicals

3. TECHNICAL REQUIREMENTS:

3.1 Material:

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

3.1.1 Fluids based on non-glycol freezing point depressants shall be tested as follows: Two pieces of AMS 5886 bar, 35 mm diameter and 15 mm long shall have one end of each machined flat. An 8.5 mm drill shall then be used to drill a centered hole 6.5 mm deep in one end to allow the milling of a cup shaped depression. A 12.5 mm bull nosed end mill shall be used to open up the drilled hole to produce a 7 mm deep depression. The cup shall then be finished by improving the surface with 600, 180, and 6 micron diamond paste. The cups shall be cleaned and degreased using a suitable solvent and allowed to dry. One cup shall be filled with the candidate test fluid, the other with water conforming to ASTM D 1193 Type IV, both test pieces shall then be placed in an oven at 105 °C ± 2 (221 °F ± 5). The fluid shall then be allowed to evaporate by progressive increase in oven temperature at the rate of 10 °C (25 °F) per minute to a final temperature of 250 °C ± 5 (428 °F ± 10) where they shall be held at this temperature for 15 minutes ± 1. Test pieces shall then be transferred to an air furnace set at 1040 °C ± 10 (1904 °F ± 25) and held at this temperature for 2 hours ± 5 minutes.

Test pieces shall be removed and allowed to cool to ambient temperature. Microscopic examination of the polished cups at 500X shall be undertaken - no corrosion worse than control shall be evident in the candidate test fluid cup.

The report shall include photographs of both cups after testing and the candidate test fluid cup shall be identified.

3.1.2 Toxicity: The user shall ensure the fluid meets all local, State, and/or Federal toxicity regulations. The information to satisfy the Federal, State, and Provincial requirements shall be provided by the manufacturer, and for local requirements, upon request, from the user.

3.1.3 Appearance: Fluid, as received by purchaser, shall be homogeneous, uniform in color, see Table 1, and free from skins, lumps, and foreign materials which would be detrimental to usage of the product. Fluid may be clear or translucent - as described by the manufacturer.

3.1.4 Environmental Information: Formulated fluid shall be tested in accordance with APHA “Standard Methods for the Examination of Water and Waste Water”. The manufacturer shall provide results for not less than the following:

3.1.4.1 Biochemical Oxygen Demand (BOD) of fluid shall be determined. The test solution shall be incubated at 20 °C (68 °F) for 5, 15, 20, or 28 days dependent upon the method chosen.

3.1.4.2 Total Oxygen Demand (TOD) or Chemical Oxygen Demand (COD) of the fluid, expressed in kilograms of oxygen per kilogram of fluid.

3.1.4.3 Biodegradability: This characteristic can be approximated by determining the ratio of BOD and TOD or COD. The percent of fluid biodegraded can be calculated by dividing BOD by TOD or COD, and shall be reported for all incubation time periods.

3.1.4.4 Aquatic Toxicity: Formulated fluids shall be tested in accordance with EPA 40 CFR 797.1300 and 794.14, revised July 1, 1989, or OECD (Organization for Economic Cooperation and Development Guidelines for Testing of Chemicals), methods 202 and 203 using test species required by regulatory agencies for permitted discharges. Examples include fathead minnows, daphnia magna and rainbow trout. The LC_{50} concentration, (the highest concentration at which 50% of the organisms do not survive the test period) shall be stated in milligrams per liter.

3.1.5 Trace Contaminants: Report the presence, in percentages by weight or parts per million by weight, of sulfur, halogens, phosphate, nitrate, and heavy metals (lead, chromium, cadmium, and mercury). Report the test method used and detection limits.

3.2 Physical Properties:

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

3.2.1 Fluid as Received in Neat 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, Method C, or ASTM D 4052.

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 (to simulate long term heated storage without water loss): Prior to aging, as in 3.2.2.1.1 and 3.2.2.1.2 the sample shall be visually examined to determine freedom from insoluble deposits. Determine the pH in accordance with 3.2.1.3. Determine the viscosity at 0 °C (32 °F), in accordance with 3.2.3.1.1. Determine the refractive index, in accordance with 3.2.1.4.

3.2.2.1.1 Transfer 800 ± 10 ml of fluid into a 1 liter glass jar, fitted with a well-closed screw cap, with polyethylene seal. Transfer the closed jar containing the sample of fluid to a circulating air oven or heated oil or water bath. Elevate the temperature to 70 °C ± 2 (158 °F ± 4). Maintain the samples in this environment for 30 days.

3.2.2.1.2 After 30 days, remove the jar containing the fluid sample from the heated environment and examine the contents for evidence of separation, precipitation, or insoluble deposits. Report any evidence of these factors. Allow the sample to cool to 20 °C ± 2 (68 °F ± 4). Invert the container through four complete cycles, remove the lid and retest for refractive index as in 3.2.2.4 and record the result. If, after aging, the refractive index has been increased by more than 0.0020 the test is invalid, as water has been allowed to evaporate during the test. If the refractive index is within the limits, test for viscosity at 0 °C (32 °F) as in 3.2.3.1.1, and pH (3.2.1.3) and record the results. Compare results to those recorded before aging. The viscosity shall neither be reduced by more than 20% nor be increased by more than 10% from the original readings. The pH of the aged fluid determined as in 3.2.1.3, shall be within ±0.5 units of the unaged sample. Fluid aged as above shall be tested in accordance with Annex A (WSET only) - one set of three plates. Report the result of the test.

3.2.2.2 Exposure to Dry Air (to simulate fluid behavior following overnight exposure to dry air): The fluid, after exposure to a dry air environment which results in weight reduction of 20% ± 1 shall have a viscosity not exceeding 500 mPa·s when measured at 3.0 rpm and with spindle LV1 with sample at 20 °C ± 2 (68 °F ± 4) using the method described in 3.2.3.1.2.

3.2.2.2.1 Pour approximately 800 ml of fluid into a pre-weighed glass tray with the following approximate dimensions 200 x 200 x 50 mm. Weigh the tray and contents to the nearest 2 grams, record the weight. Place this tray with its contents into an environment with air temperature at 23 °C ± 3 (73 °F ± 6) and the relative humidity not greater than 50% and preferably in the 30 to 45% range. Periodically weigh the tray and contents and when the weight of the fluid is 20% ± 1 lower than initial weight, pour 500 ml ± 10 of the fluid into a 600 ml beaker. Allow to cool to 20 °C ± 2 (68 °F ± 4) and test for viscosity.

3.2.2.3 Dry-out by Exposure to Cold Dry Air (to simulate fluid dry-out in cold air on the ramp and on the aircraft including aerodynamically quiet areas): Using a cold chamber, position three plates, inclined at an angle of 2 degrees from the horizontal. Pour 100 to 150 ml on each plate. Set the air and plate temperatures at 1 °C ± 1 (30 °F ± 2). Relative humidity less than 40%, and the air moving from the top over the surface towards the bottom of the plates at approximately 2.5 m/s (4.4 to 4.6 mph). Maintain these conditions until the fluid has dried or for 24 hours. Examine the remaining residues, and report appearance as follows:

a. Gel, gum (tacky feel), hard granular solid, or peelable film - not acceptable.
b. Remove plates from cold chamber and allow them to warm to 5 °C ± 2 (41 °F ± 4) and rinse each plate with 500 ml water, conforming to ASTM D 1193 Type IV, at 15 °C ± 10 (59 °F ± 18) from a 1 liter squeeze bottle. Report appearance of plate after rinsing. Only plates free of residue are acceptable.

3.2.2.4 Successive Dryout and Rehydration (to simulate the formation of dried residues and for such to form gels upon rehydration): Fluid shall be tested in accordance with Annex D and results reported.

3.2.2.5 Thin Film Thermal Stability (to simulate heated leading edge dryout): 40 to 50 ml of the fluid shall be poured on to each of two unpainted aluminum or aluminum alloy test panels, approximately 152.5 x 50 mm (6 x 2 inches). After 5 minutes, the panels shall be placed, inclined at an angle of 10 degrees from the horizontal, in an oven maintained at 95 °C ± 2 (203 °F ± 4). After 60 minutes ± 1, remove the panels, allow to cool to ambient temperature, and inspect. Report the appearance.

a. Gel, gum (tacky feel), hard granular solid or peelable film - not acceptable.
b. Rinse each plate with 500 ml water conforming to ASTM D 1193 Type IV at 15 °C ± 10 (59 °F ± 18) from a 1 liter squeeze bottle positioned not closer than 20 cm from the surface. Report the appearance of the plates after rinsing. Only plates free of residue are acceptable.

3.2.2.5.1 Repeat test as in 3.2.2.5 except the oven temperature shall be at 48 °C ± 2 (118 °F ± 5). Report results of both tests.

3.2.2.6 Storage Stability (to simulate storage in tanks): Prior to the start of this test, the viscosity shall be determined at 20 °C (68 °F), in accordance with 3.2.3.1.1. The fluid shall be tested in accordance with ASTM F 1105, except that the sample shall be protected from exposure to UV light. On completion of the test, the fluid shall be retested for viscosity as before and the result compared to the original values. Both results shall fall within the limits determined in 3.2.3.1.

3.2.2.7 Shear Stability: The anti-icing performance tests as in 3.2.4 shall start within two hours after the product has been sheared, but not within the first 20 minutes after shearing using the laboratory method as in 3.2.2.7.1.

3.2.2.7.1 Pour 500 ml ± 5 at 20 °C ± 1 (68 °F ± 2) into a 600 ml, straight-sided glass vessel, 85 mm ± 0.5 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).

3.2.2.8 Hard Water Stability: The fluid, diluted 1:1 with standard hard water made up as in 3.2.2.8.1 and aged as in 3.2.2.8.2, shall show no evidence of insoluble deposit, and the pH shall not vary by more than ±0.5 units from a fresh unaged sample, if after aging the refractive index has increased by more than ±0.002 at 20 °C ± 3 (68 °F ± 4) from a fresh unaged sample, the test is invalid as water has been allowed to evaporate during the test. A sample of the fluid, after hard water stability testing, shall be tested in accordance with Annex A (WSET only) using one set of three plates, and the results reported.

3.2.2.8.1 Composition of Hard Water: Dissolve 400 mg ± 5 calcium acetate dihydrate ($Ca[C_2H_3O_2]_2{\cdot}2H_2O$), and 280 mg ± 5 magnesium sulfate heptahydrate ($MgSO_4{\cdot}7H_2O$), both of analytical reagent quality, in 1 liter of ASTM D 1193, Type IV, water.

3.2.2.8.2 Place 800 ml ± 10 of the diluted fluid into a 1 liter container with a polyethylene lined screw cap. Place container in an oven or oil or water bath and raise the temperature to 95 °C ± 1 (203 °F ± 2). Allow the samples to remain in this elevated temperature environment for 30 days. Remove, and allow to cool to 20 °C ± 1 (68 °F ± 2). Inspect as in 3.2.2.6. From these samples sufficient fluid will be retained to test as in Annex A (WSET only) using one set of three plates. Report the result of this test.

3.2.2.9 Tendency to Foam: At the option of the user, the vendor shall demonstrate that fluid as supplied or in intended use dilutions and heated to intended use temperatures, applied through commercial deicing/anti-icing vehicle systems to an inclined flat or curved surface, preferably an aircraft wing or horizontal stabilizer, at pressures and flow rates normal for the intended use, does not cause foam which does not rapidly collapse, and fluid surface shall not have the appearance of snow or slush.

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 1.1.2 and 1.1.3 and are specified to ensure the flow of the film when sufficient 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, when tested in accordance with 3.2.2.2 and 3.2.2.3. Fluids of all types shall be tested as in 3.2.3.1.1.

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 any neat fluid as supplied shall fall within the limits of the high and low viscosity values defined by the pre-production samples (4.2.3) and the viscosity limits shall be reported. For quality control purposes the manufacturer shall specify the typical viscosity range a user can expect to obtain from fluid being delivered for use.

3.2.3.1.1 Viscosity Measurement: The sample will not be shaken prior to testing. Test at 20 °C (68 °F), 0 °C (32 °F) and in 10 °C (18 °F) increments down to the lowest usable temperature identified by the manufacturer. The viscosity shall be measured using a Brookfield LV viscometer at 0.3, 6 and 30 rpm. The viscosity may be measured using the Brookfield small sample adapter or as specified in 3.2.3.1.2. The report shall state if the small sample adapter was used for the equipment in 3.2.3.1.2 and shall detail the spindle size, container size, volume of fluid employed, and the rotation duration. In case of dispute the method described in 3.2.3.1.2 shall prevail.

3.2.3.1.2 Using a Brookfield LV viscometer fitted with the guard leg and using a sample of approximately 500 ml or sufficient quantity to accommodate the selected spindle and guard leg, contained in an 85 mm diameter, straight sided 600 ml beaker. The test shall be run using the appropriate spindle in accordance with ASTM D 2196, Method B, except the samples shall not be shaken. The reporting requirements are the same as in 3.2.3.1.1.

3.2.4 Anti-icing Performance:

3.2.4.1 Water Spray Endurance Test (WSET), and High Humidity Endurance Test (HHET): When tested in accordance with Annex A the neat fluid, sheared as in 3.2.2.7 shall form a film which will protect against the formation of frozen deposits within the failure zone depicted in Figure 4 of Annex A for the times listed in Table 2. Similarly, if the fluid is intended to be used diluted with water, it shall be diluted by volume to ratios of 75:25 and 50:50 with water conforming to 3.2.2.8.1 and sheared as in 3.2.2.7, shall protect as in Table 2. Confirmation shall be obtained from six panels, three panels from each of two successive test runs.

TABLE 2 - Minimum Anti-icing Performance

Fluid - SAE Type	& Dilution	WSET Time - Minutes	HHET Time - Hours
II	100:00	30	4
	75:25	20	2
	50:50	5	0.5
III	100:00	20	2
	75:25	Determine and report	Determine and report
	50:50	Determine and report	Determine and report
IV	100:00	80	8
	75:25	20	2
	50:50	5	0.5

3.2.4.2 High Water Spray Endurance Time (HWSET): The neat and sheared fluid shall be subject to a single test run (three treated plates) with the water spray adjusted to yield an ice catch, measured on the three untreated plates, of 20 g/dm^2/h with air and plate temperatures at -5 °C ± 0.5. The time that the fluid which will protect against the formation of frozen deposits within the failure zone depicted in Figure 4 of Annex A or the formation of slush on 10% of the plates' surface shall be reported.

3.2.4.3 Low Water Spray Endurance Time (LWSET): The neat and sheared fluid shall be subject to a single test run (three treated plates) with the water spray adjusted to 2 g/dm^2/h with air and plate temperatures adjusted to -19 °C ± 1 (-2 °F ± 2). The time that the fluid will protect against the formation of frozen deposits within the failure zone depicted in Figure 4 of Annex A or the formation of slush on 10% of the plates' surface shall be reported.

3.2.5 Aerodynamic Acceptance:

3.2.5.1 Criterion to Shear or Not to Shear the Fluid: If after shearing in accordance with 3.2.2.7.1 the apparent viscosity increases by more than 15% when tested in accordance with 3.2.3.1.1 at 0 °C (32 °F) at spindle speeds of 6, and 30 rpm, the fluid shall be sheared prior to testing. If the apparent viscosity is unchanged, or decreases, the fluid shall be tested in the unsheared state.

3.2.5.2 Aerodynamic Test: The fluid shall demonstrate acceptable aerodynamic performance when tested in accordance with Annex B and/or Annex C. Annex B is the approved aerodynamic test for fluids used on large transport type aircraft, and Annex C is the approved aerodynamic test for fluids used on lower takeoff rotation speed commuter aircraft. A fluid is acceptable for use on large transport jet aircraft if it meets the criteria defined in 8.3 of Annex B, and a fluid is acceptable for use on lower takeoff rotation speed commuter aircraft if it meets the criteria defined in section 8.3 of Annex C. Also see 1.2.1. Fluid and its volume/volume dilutions (defined in Table 2) shall be tested at temperatures ranging from 0 °C (32 °F) down to the lowest temperature requested by the fluid manufacturer, in approximately 10 °C (18 °F) degree intervals. For each fluid or dilution, a minimum of three tests shall be performed at each temperature.

3.2.5.3 Test with the Highest Viscosity Dilution: The dilution ratio which produces the highest viscosity, and the temperature at which this occurs shall be determined, and the fluid shall be tested according to Annex B or C as applicable, without further dilution. The report shall highlight these data.

3.2.5.4 Fluid Elimination: Fluid elimination, based on an initial thickness of 2 mm of fluid on the test duct floor, shall be not less than 74% at all tested temperatures for Type II and Type IV fluids, tested and calculated in accordance with Appendix B, and not less than 57% at all tested temperatures, for Type III fluids tested and calculated in accordance with Appendix C.

3.3 Fluid Tested Both Neat and as a Diluted Solution:

Tests shall be conducted using the neat fluid and using a solution made up of the neat fluid diluted 1:1 by weight with ASTM D 1193 Type IV, water.

3.3.1 Freezing Point: Shall be not higher than -32 °C (-26 °F) for the neat fluid. When diluted at a ratio of 1:1 by weight with ASTM D 1193, Type IV water, the freezing point shall be not higher than -10 °C (+14 °F), determined in accordance with ASTM D 1177. Report freezing points for neat and 1:1 by weight dilution with water conforming to ASTM D 1193 Type IV.

3.3.2 Effect on Aircraft Materials:

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

3.3.2.2 Total Immersion Corrosion: The fluid, tested in accordance with ASTM F 483, shall neither show evidence of corrosion of test panels nor cause a weight change of any test panel greater than shown in Table 3.

TABLE 3 - 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 tested in accordance with ASTM F 945, Method A.

3.3.2.4.1 Stress Corrosion Resistance: Fluid shall be tested in accordance with ASTM F 945, Method A using AMS 4916 specimens. Report shall detail the effect of fluid and the effect of control solution.

3.3.2.5 Hydrogen Embrittlement: The fluid shall be non-embrittling determined in accordance with ASTM F 519, Types 1a, or 1c or 2a. In case of dispute, the 1c bar shall be used.

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

3.3.2.6.1 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 Runway Concrete Scaling Resistance: The condition of the runway concrete surface shall have a rating not greater than 1 for 50 freeze-thaw cycles, determined in accordance with ASTM C 672, except that the concrete shall be air-entrained with an air content as in ASTM C 672, have a minimum cement content of 302 kg/m^3 ± 4.5 (510 lb/yd^3 ± 10) and a slump, 38 mm ± 13 (1.5 inches ± 0.5). A 25% ± 1 by volume solution of the neat fluid prepared using tap water shall be substituted for the specified calcium chloride. Performing more than one freeze-thaw cycle per day is acceptable.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

The vendor of the fluid shall supply all samples for conformance testing and shall be responsible for obtaining independent laboratory confirmation of conformance to the requirements of this specification. Each fluid sample container shall be clearly identified with the vendor's name, fluid name or code number and lot number, and manufacturing site address. 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: pH (3.2.1.3), refractive index (3.2.1.4), and viscosity at 20 and 0 °C ± 2 (68 and 32 °F ± 4 °F) at 0.3, 6, and 30 rpm are acceptance tests and shall be performed on each lot. Any Certificate of Analysis for a production lot shall contain these data.

4.2.2 Periodic Tests: Anti-icing performance (3.2.4), and aerodynamic performance (3.2.5) are periodic tests, and shall be performed on, or just prior to the second anniversary of initial testing, thereafter every two calendar years. Aerodynamic performance (3.2.5) shall be performed by an approved and autonomous test facility. Anti-icing performance (3.2.4) shall be performed by an autonomous facility, unless another facility is agreed upon between user and vendor.

4.2.3 Preproduction Tests: Two preproduction samples shall be submitted for testing. One designated as the high viscosity sample and the second as the low viscosity sample. Tests shall be performed prior to or on the initial shipment of the fluid to a purchaser (except for Storage Stability (3.2.2.6) which may be waived by the purchaser, to permit entry of a new product) and 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 Tests for all technical requirements shall be performed on the high viscosity sample.

4.2.3.1.1 The following tests shall be conducted on the low viscosity sample:

a. Viscosity shall be measured at 20 °C ± 2 (68 °F ± 4) and 0 °C ± 2 (32 °F ± 4), at 0.3, 6, and 30 rpm in accordance with 3.2.3.1.1.

b. WSET in accordance with 3.2.4.1.

c. Aerodynamic Performance in accordance with Appendix B for Type II and Type IV fluids, or Appendix C in the case of Type III fluid. The test shall consist of one data point, three runs, using the neat fluid. The test shall repeat the lowest temperature ±1 °C (2 °F), at which the high viscosity sample met the Aerodynamic Performance requirements.

4.2.3.2 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 vendor's 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 is 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 purchaser until full testing and approval has been received.

4.4.3 Whenever a fluid is to be produced at multiple locations, or 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), and by a single test run of three panels under WSET (3.2.4.1).

4.5 Reports:

4.5.1 Preproduction and Periodic Test Reports: The vendor of fluid shall furnish before the initial shipment a report showing the results of tests to determine conformance to all the technical requirements of this specification. These tests shall be performed by an approved and/or independent testing facility/facilities (see 4.2.2). The aerodynamic acceptance test facility shall determine and report the following properties from the sample of fluid submitted for testing:

a. Viscosity (3.2.3.1.1)
b. Refractive Index (3.2.1.4)
c. pH (3.2.1.3)
d. Surface Tension (3.2.1.5)

4.5.1.1 The reports shall include the quantity, lot number, AMS 1428D and manufacturer's product identification, and manufacturing location.

4.5.1.2 Subsequent reports covering tests carried out at two-year intervals shall compare the results obtained from previous (if any) testing, and to those referred to in the 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 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 non-conforming sample. Failure of any retest sample to meet the specified requirements shall be cause for rejection of the fluid represented. 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 acceptable to purchaser or shall be delivered in bulk.

5.1.1.1 A production lot of fluid may be packaged in several or various containers and be delivered under the basic approval provided lot identification is maintained.

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

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, labeling, and safe transportation of the fluid to ensure carrier acceptance and safe delivery.

5.1.4 For direct U.S. Military procurement, fluid shall be packaged, such that it is adequately protected from deterioration or physical damage during shipment from the source of supply to the procurement activity, or its designated receiving point, and (except for bulk) for a minimum storage period of 30 days from the date of delivery (or a period defined by the purchaser) unless otherwise designated in the contract or purchase order (see also 9.2).

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. SIMILAR SPECIFICATIONS:

ISO 11078 - 1992 Aerospace-Aircraft Deicing/Anti-icing non-Newtonian fluids, ISO Type II.

9. NOTES:

9.1 A change bar (**l**) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this specification. An (R) symbol to the left of the document title indicates a complete revision of the specification, including technical revisions. Change bars and (R) are not used in original publications, nor in specifications that contain editorial changes only.

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

a. AMS 1428D Title, and date of this specification
b. Type of fluid required or limitations (if applicable)
c. Size and type of containers desired
d. Quantity of fluid desired
e. Packaging requirements (See 5.1.3).

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

PREPARED UNDER THE JURISDICTION OF AMS COMMITTEE G-12

ANNEX A

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

A.1 SCOPE:

A.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, Type II, Type III and Type IV fluids.

A.1.2 This test may involve the use of hazardous materials, operations and equipment. This Annex 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.

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

A.2 REFERENCED DOCUMENTS:

A.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

A.2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 1193 Reagent Water

A.2.3 ISO Publication:

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

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

A.3 SUMMARY OF TEST:

A.3.1 This test describes how to determine the laboratory anti-icing performance of SAE Type I, Type II, Type III and Type IV 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 tests referred to in this Annex is as follows.

A.3.2 Water Spray Endurance Test:

This test involves pouring the fluid at 20 °C ± 5 onto an inclined test plate at -5 °C ± 0.5 and applying a cooled water spray in air at -5 °C ± 0.5. The water spray endurance is recorded as the time for ice formation to reach the failure zone as defined Figure A.4, when the following test conditions are used: water spray intensity is set to 5 g/dm^2 ± 0.2 g 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. This is verified by observation of the untreated or ice catch plate.

A.3.3 High Humidity Endurance Test:

This test involves pouring the fluid at 20 °C ± 5 onto an inclined test plate at -5 °C ± 0.5, when the air temperature is 0 °C ± 0.5 and the Relative Humidity (RH) is 96% ± 2. The high humidity endurance is recorded as the time for ice formation to reach the failure zone as defined in Figure A.4 under these conditions, when the ice formation corresponds to 0.3 g/dm^2/hour, 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). The duration of the test shall be at least two hours for SAE Type I and Type III, at least four hours for SAE Type II and at least eight hours for Type IV.

A.4 EQUIPMENT AND TEST PARAMETERS:

A.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. Other spray and humidity control equipment which meet the requirements of this Annex are acceptable.

A.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 1.0 m^3 for each 2.25 dm^2 of test panel area (or 8.0 m^3 for the minimum test plate dimensions described in A.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 sending 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 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 A.5.4.2. 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 0.3 g/dm^2/hour ± 0.05 at the end of the test, if the test lasts less than 10 hours, and 0.3 g/dm^2/hour ± 0.1 if the test lasts more than 10 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 or electronic data acquisition system as a means of checking the environmental control characteristics of the test chamber throughout the course of a test run.

A.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 0.5 micro/m 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 plate shall measure 30 x 10 cm and shall be clearly marked with the failure zone as defined in Figure A.4. A permanent ink marking pen shall be used to delineate the failure zone.

A.4.3 (Continued):

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 exposed 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.

A.4.4 Spray Equipment:

A.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:

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

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

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

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 as follows:

A.4.4.2 For Typical 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 A1. 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 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 A2 for a schematic layout of this system.

A.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.

A.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).

A.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.

A.5 CALIBRATION OF TEST EQUIPMENT:

A.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.

A.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.

A.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.

A.5.4 Water Droplet Size:

A.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.

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

A.5.4.3 The following methods can be used to determine the droplet sizes referred to in A.5.4.1 and A.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 mPa·s at 20 °C, spread to a thickness of about 500 mm 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.

A.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 in Table A1 and Table A2:

TABLE A1 - 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/dm^2 ± 0.2 per hour
Test Duration	30 minutes minimum

TABLE A2 - 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
Test Duration	4 hours minimum
Frost Accumulation	0.3 g/dm^2/hour ± 0.05

There are two ways to assess the ice catch.

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.

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 g ± 0.2 for each hour of the water spray test and 0.3 g/hour ± 0.05 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.

A.6 TEST PROCEDURE:

A.6.1 Test Plate Cleanliness:

The test plates shall be free of all visible contamination, smears, or stains, except for the lines marking the failure zone (Figure A4). Any contamination shall be removed by washing and thoroughly drying. Between test runs using the same candidate fluid, a 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 lead to premature failure indications.

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

A.6.3 The candidate test fluid shall have been sheared, within the time limit, in accordance to the specification for the respective SAE Type fluid before the test is to commence. The candidate test fluid shall be at ambient temperature, in the range of 15 to 25 °C. For each test panel to be coated with the fluid, prepare 115 mL or 120 g for each test run. If more fluid is required, the quantity of fluid actually used will be mentioned in the report qualification statement.

A.6.4 Pour the fluid onto each test plate in turn in the order shown in Figure A3. 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 failure zone (Figure A4), record the time of this event. When the water spray or humidity generator is turned off, 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 failure zone 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 failure zone shall be recorded on the report.

A.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 variation between the holdover time averages of two water spray endurance tests performed with the same candidate fluid is 20% of the holdover time average for a Type I fluid and 10% for a Type II, Type III or Type IV fluid.

A.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 shall also appear on the test document:

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

Condition of fluid - Neat as supplied to test facility, or diluted with hard water as defined in the specification and subsequently sheared in accordance with specification giving the dilution as a ratio - example: SAE Type II diluted 75:25 with water.

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.

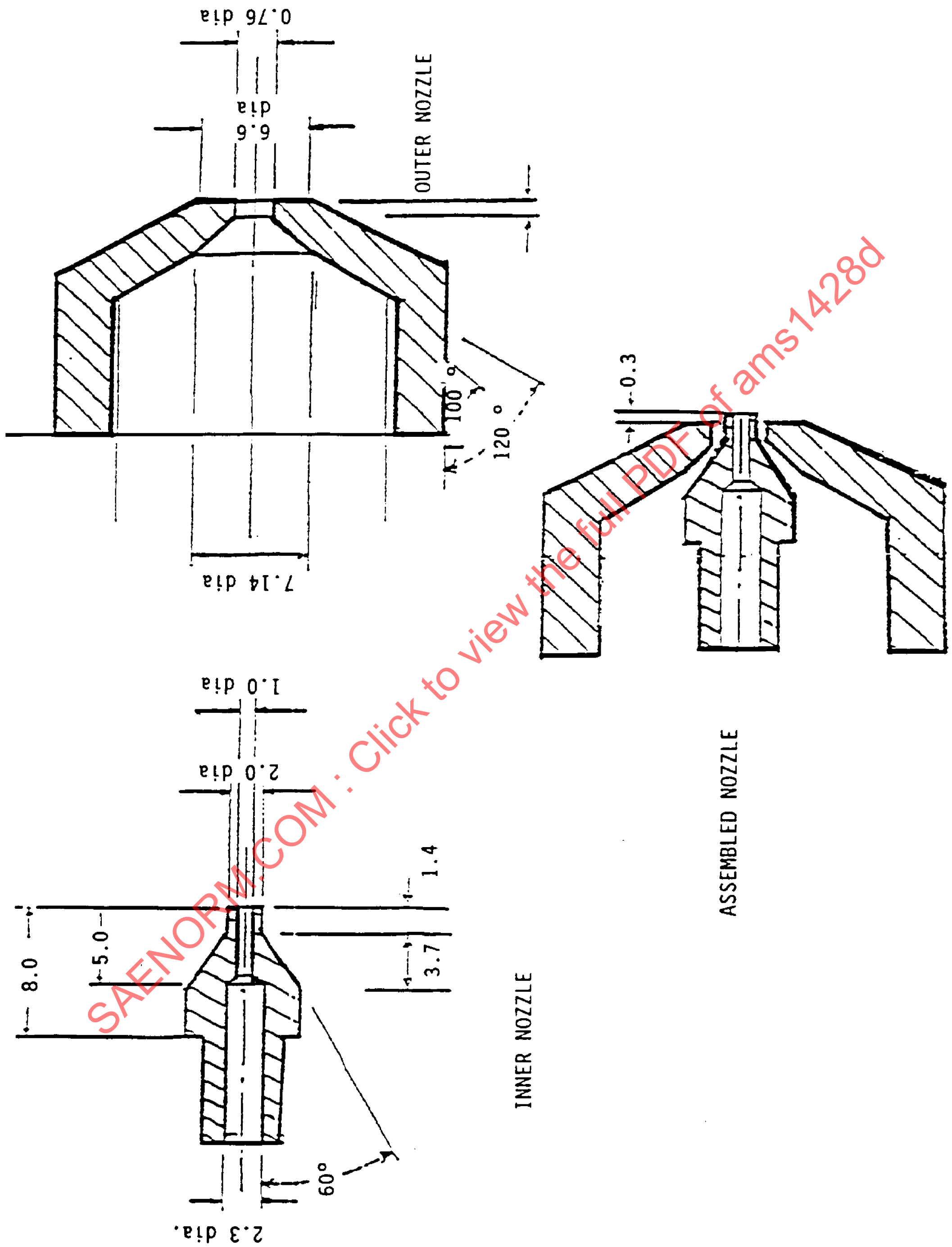

FIGURE A1 - Spray Nozzle (All dimensions mm)

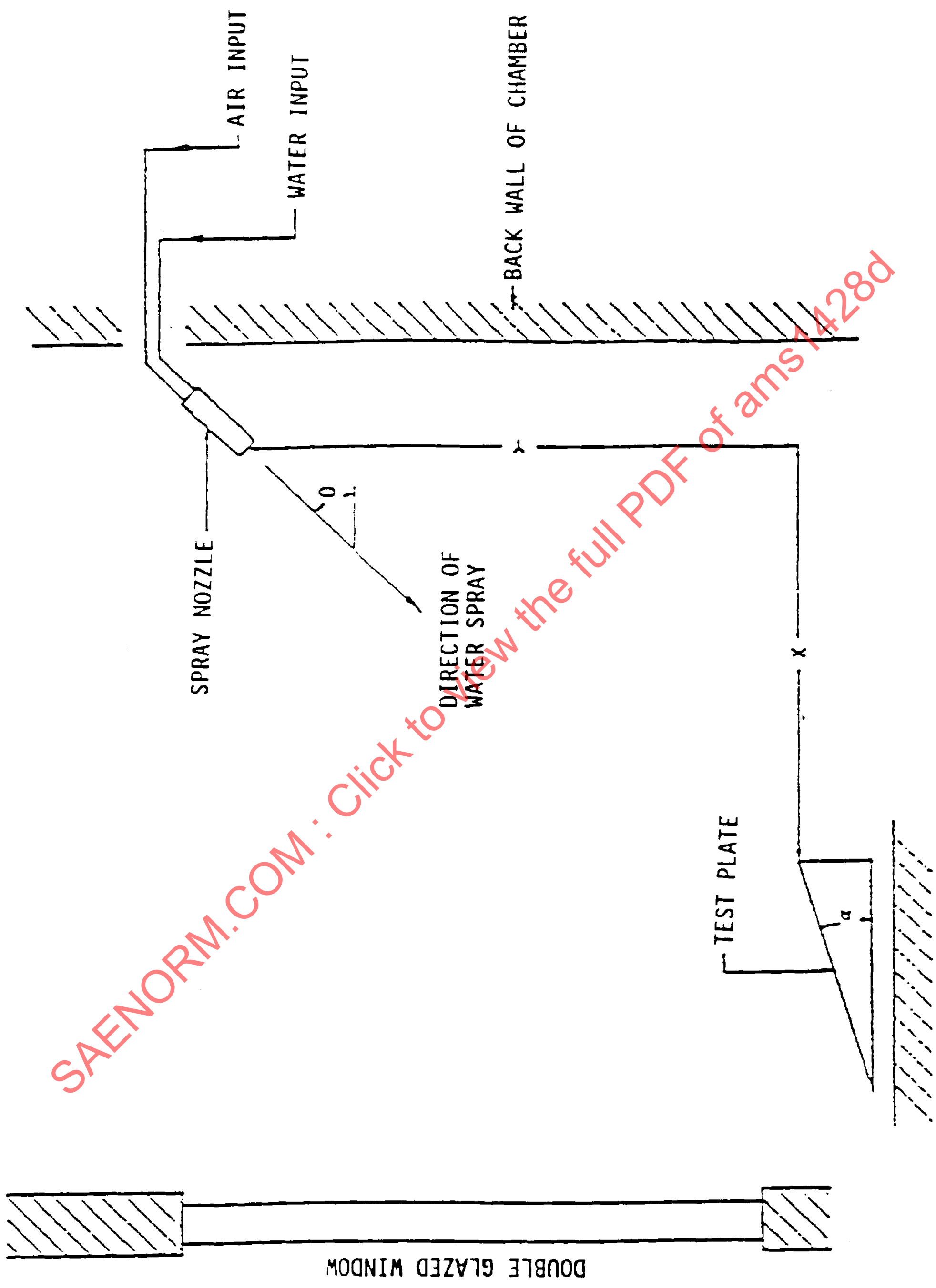

FIGURE A2 - Schematic Cross-Section of Spray Equipment

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.

FIGURE A3 - Anti-Icing Calibration Tests - Proposed Order of Fluid Application to a Frosticator Having 6 Test Panels

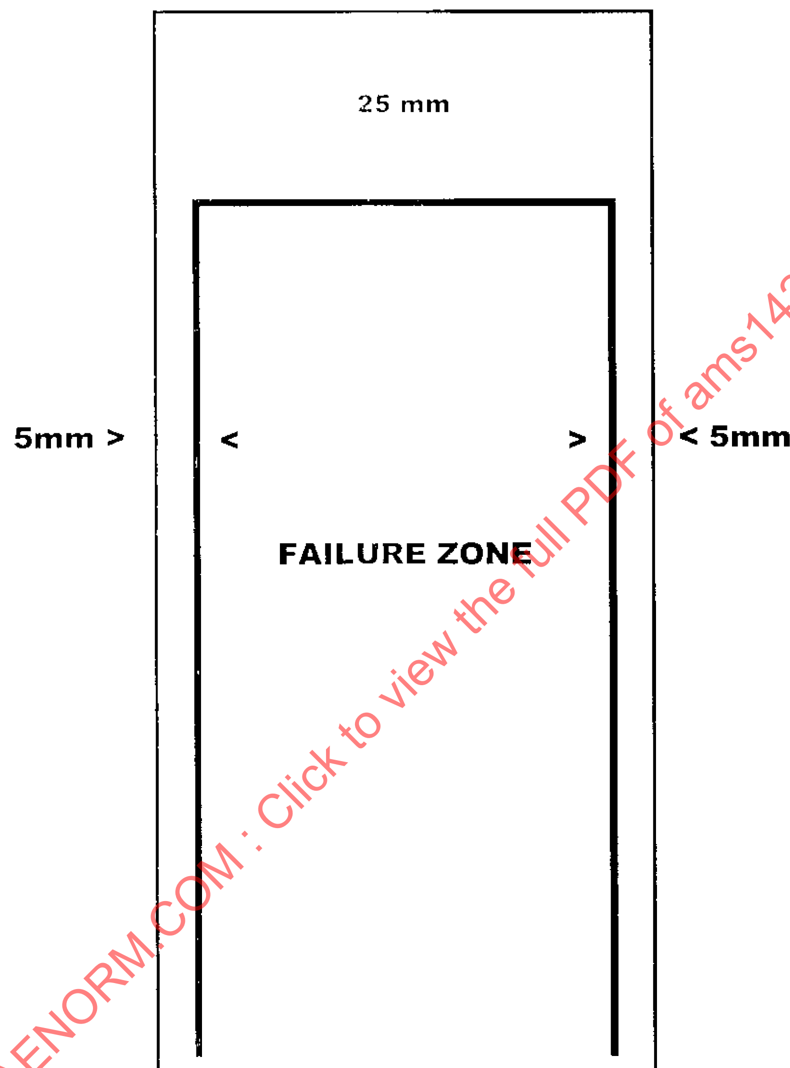

FIGURE A4 - Failure Zone

ANNEX B

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

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LIST OF FIGURES

B.1 SCOPE:

B.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 takeoff 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.

B.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 B.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 B.8, substantiation that the facility and associated staff and resources satisfy the requirements of this test method shall be documented and submitted to the Performance Review Institute, 161 Thornhill Road, Warrendale, PA 15086-7527, 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.

B.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.

B.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 takeoff. 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.

B.3 REFERENCED DOCUMENTS:

B.3.1 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

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

B.3.2 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

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

B.4 GLOSSARY:

B.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

B.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

B.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 B.8 of this document, substantiation that the facility is autonomous of fluid manufacturers and complies with the following requirements shall be documented and submitted to the Performance Review Institute, 161 Thornhill Road, Warrendale, PA 15086-7527, 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 B.6.2, adequate transducer calibration facilities to ensure accuracy and precision requirements, and trained personnel to effect the test method.

B.5.1 Test Duct Description:

B.5.1.1 Dimensions: Figure B1

B.5.1.2 Tolerances:

Lineal dimensions: ≤ ±2%
S_2/S_3: 92.7 ± 1%

B.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 ≤ 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.

B.5.2 Test Duct Gas Flow Core Characteristics:

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

B.5.2.2 Temperature Range: 0 °C to approximately -25 °C, or the test fluid minimum usable temperature

B.5.2.3 Temperature Stability: ≤ ±2 °C of the target temperature with a continuous flow ≥60 seconds, except ≤ ±1 °C between the 27th and 33rd seconds of a test run.

B.5.2.4 Temperature Spatial Uniformity: ≤ ±1 °C

B.5.2.5 Velocity Range: $0 = V \leq 0.5$ m/s to 65 m/s ± 5 within t = 25 seconds ± 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, 30 seconds after start, and maintained for 30 additional seconds. (See Figure B2.) Prior to the flow acceleration, the duct flow shall be capable of a five minute settling period with a velocity ≤5 m/s.

B.5.2.6 Turbulence: ≤ 0.005 ($\Delta U/U_\infty$)

B.5.2.7 Velocity Spatial Uniformity:

Vertical and lateral: $\Delta U/U_\infty \leq \pm 0.005$
Longitudinal: $\Delta U \leq -1$ m/s/m ± 0.008 U_∞/m

B.5.2.8 Relative Humidity: 70% ± 30

B.5.3 Test Facility Thermal Stability:

B.5.3.1 Test Duct: The test duct shall be thermally insulated or within the test facility circuit flow and capable of being precooled to ensure thermal equilibrium of the test duct structure during a test run.

B.5.3.2 Test Facility Circuit: Circuit thermal insulation shall ensure the test duct temperature characteristics of Sections B.5.2.

B.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.

B.5.5 Instrumentation:

B.5.5.1 Temperature and Relative Humidity:

B.5.5.1.1 Test Duct Gas Temperature: Measured at Station 2 approximately 5 mm below the ceiling.

B.5.5.1.2 Test Fluid Temperature: Measured at Station 3 within the test fluid, approximately 1 mm above the floor.

B.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.

B.5.5.1.4 Relative Humidity: Wet bulb-dry bulb thermometers or equivalent which are regularly calibrated against wet bulb-dry bulb thermometers.

B.5.5.2 Test Duct Gas Pressures:

B.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.

B.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.

B.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.

B.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 second 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.

B.5.5.3 Test Duct Gas Velocity and Turbulence:

B.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 B1.

$$V = \sqrt{\frac{2}{\rho}(P_1 - P_2) \Big/ \left[1 - \left(\frac{S_2}{S_1}\right)^2\right]} \qquad \text{(Eq. B1)}$$

Because of possible pressure leaks and losses, a calibrated pitot-static probe shall be periodically used to verify use of Equation B1.

B.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.

B.5.6 Example Facility:

An example facility consists of a closed circuit, refrigerated wind tunnel with a 0.5 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 B3.

B.6 TEST FLUID REQUIREMENTS:

B.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. A volume of about 1 liter of the lot is required for one test run. The fluid shall be tested undiluted and in dilutions of 75% neat fluid to 25% water, and at 50% neat fluid to 50% water. Samples to be tested in diluted form shall be diluted by the testing facility, using water conforming to ASTM D 1193, Type IV. The manufacturer shall mark each fluid sample container with the company name, product name, lot number, location and date of manufacture.

B.6.2 Fluid Identification:

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

B.6.2.1 Viscosity: Viscosity shall be measured using a Brookfield LV viscometer, fitted with the guardleg and appropriate spindle at 0.3, 6, and 30 rpm, in accordance with ASTM D 2196, Method B (except the samples shall not be shaken). Test at 20 °C (68 °F), 0 °C (32 °F), and in 10 °C (18 °F) increments down to the lowest usable temperature identified by the manufacturer. The report shall clearly state the size and type of spindle used.

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

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

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

B.7 TEST PROCEDURE:

B.7.1 Test Requirements:

Boundary layer displacement thickness (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 in conjunction with the fluid measurements for a minimum of 36 BLDT measurements. Paragraph B.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 sequence of B.7.2, deleting the steps involving the fluid.

B.7.2 Test Run Sequence:

B.7.2.1 Select Target Temperatures:

B.7.2.2 Pre-cool Test Fluid: Prior to testing, 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.

B.7.2.3 Pre-cool Test Facility: Pre-cool the test facility to achieve test gas and structural thermal stability at the target temperature.

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

B.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.

B.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 ≤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.

B.7.2.7 Subject Fluid to a Simulated Aircraft Takeoff Velocity Time History: Accelerate the test duct gas flow as shown on Figure B2 and simultaneously record t, RH, T_f, T_g, (P_1 - P_2), and (P_2 - P_3).

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

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

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

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

B.7.2.9 Residual Fluid Analysis: (Water content) Sample fluid remaining on the test duct floor for water content using refractive index comparison.

B.7.2.9.1 Fluid elimination shall be calculated from determining the average thickness of fluid remaining on the lower plate of the test section. Measurements shall be taken within 5 minutes of the end of the test at THREE locations along the flatplatte, as follows:

1. on centerline 1400 ± 10 mm from leading edge of plate
2. on centerline 750 ± 10 mm from leading edge of plate
3. at 750 ± 10 mm and 2.5 ± 0.5 mm from front long edge of plate

B.7.2.10 Data Processing: Process measured data (See B.7.4).

B.7.3 Test Cautions:

B.7.3.1 Safety Hazards: See B.1.3 concerning safety hazards.

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

B.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.

B.7.3.4 Irregular BLDT Data: The δ^*_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:

B.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.

B.7.3.4.2 Constant BLDT Data: A constant value of BLDT with time during the last 30 seconds of a dry 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, the results of the following tests with fluids are discarded and tests must be repeated for 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, 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.

B.7.4 Data Processing:

B.7.4.1 Test Data Description:

B.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 B4.

B.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.

B.7.4.2 Calculation Methods:

B.7.4.2.1 Velocity: See B.5.5.3.1

B.7.4.2.2 BLDT: The BLDT on the test duct floor, at Station 3, is evaluated from the measurement of the two pressure differences (P_1 - P_2) and (P_2 - P_3), recorded as functions of time during all the test runs. The average BLDT over the test duct perimeter δ^*_{ave} is evaluated at Station 3 using the following relation, obtained are from application of mass conservation and Bernoulli equations (See Equation B2):

$$\delta^*_{ave} = \frac{1}{c}\left[S_3 - S_2\sqrt{\frac{(P_1 - P_2)}{(P_1 - P_2) + (P_2 - P_3)}}\right] \quad \text{(Eq. B2)}$$

where:

c = duct perimeter at Station 3
S_2 = area of Station 2
S_3 = area of Station 3

When no fluid is present on the bottom flat plate, all four test section walls are in the same dry state and the previous expression (B2) yields the value of the BLDT on a dry wall;

$$\delta^*_d = \delta^*_{ave} \text{ (with no fluid)} \quad \text{(Eq. B3)}$$

On the other hand, when the test duct floor is covered with a layer of deicing/anti-icing fluid and the top and sides are not, the BLDT is not constant over the perimeter at Station 3. Indeed it assumes a value δ^*_f on the lower surface and another value δ^*_d on the dry sides and top walls. Expressing the previously determined δ^*_{ave} as perimeter-weighted average of δ^*_d and δ^*_f, the following relation can be obtained (See Equation B4):

$$\delta^*_f = \frac{c}{b}\left[\delta^*_{ave} - \left(\frac{c-b}{c}\right)\delta^*_d\right] \quad \text{(Eq. B4)}$$

where b is the width of the bottom flat plate. This relation is used to derive the BLDT over a wet surface, δ^*_f, from the measurement of δ^*_{ave} carried out as explained with fluid on the test duct lower surface, provided an expression for δ^*_d has been previously determined by a number of "dry" runs carried out without any fluid in the test section. More precisely, these dry runs yield the value of δ^*_d and are used to determine the constant in the following empirical formula (See Equation B5):

$$\delta^*_d = \text{const}\left(\frac{V}{\nu}\right)^{1/5} \quad \text{(Eq. B5)}$$

where:

V = tunnel air velocity at Station 2
ν = kinematic viscosity of the gas

For data reduction of a test with fluid in the test section, Equation B5 is used to evaluate, as function of the instantaneous velocity determined by (B1), the value of δ^*_d to be used in Equation B4.

B.7.4.2.3 Temperature: Data produced by calibration of the thermocouples (See B.5.5.1).

B.7.4.2.4 Relative Humidity: Data produced by calibration of the wet bulb-dry bulb thermometers (See B.5.5.4).

B.7.5 Test Bias Accuracy and Precision:

B.7.5.1 General Accuracy: A measure of accuracy of the overall procedure is provided by test duplication. Expected accuracy on δ^*_f value (at a given precise temperature) is about ±0.1 mm. Consequently, taking into account the temperature sensitivity of the results (about 0.2 mm/°C), the δ^*_f value from various identical tests performed at temperatures within ±1 °C shall be within ±0.3 mm.

B.7.5.2 Dry BLDT Bias: The dry BLDT value will vary with temperatures because of the variation in Reynolds Number, but shall be 2.5 mm ± 0.4. The nominal 2.5 mm value correspond to theoretical expected value and the variation from that value can be considered as a general bias of the facility, generally due to the initiation condition of the boundary layer.

B.7.5.3 Fluid BLDT Bias: Since the dry BLDT value is used in the candidate fluid BLDT value, the related bias on δ^*_f is ±0.5 mm. This quantifies the variations which may occur, for a given fluid, between acceptable facilities.

B.8 DE-ICING/ANTI-ICING FLUID ACCEPTANCE CRITERIA:

B.8.1 Fluid Acceptance Criteria:

The maximum acceptable δ^*_f value as function of temperature is established according to dry and reference results (See B.7.1). Values δ^*_{-20} and δ^*_0 are used as that upper limit for BLDT values. These values are:

$$\delta^*_0 = \delta^*_r + 0.71\,(\delta^*_r - \delta^*_d) \text{ at } 0\ °C \qquad \text{(Eq. B6)}$$

$$\delta^*_{-20} = \delta^*_r - 0.18\,(\delta^*_r - \delta^*_d) \text{ at } -20\ °C \qquad \text{(Eq. B7)}$$

where:

δ^*_r = the reference BLDT value at 0 °C for Equation B6 and at -20 °C for Equation B7, obtained by interpolation from a straight line fitting of the reference BLDT values measured at 0, -10, -20 and -25 °C

δ^*_d = the average of all dry BLDT values measured

B.8.2 Fluid Acceptance Criteria Background:

For more detailed information on the correlation between this standard and the work carried out on both two and three dimensional typical large jet transport models tested to determine lift loss due to the use of aircraft ground anti-icing/deicing fluids, see Boeing Document D6-55573, and its attendant bibliography.

B.8.3 Fluid Acceptance:

A deicing/anti-icing fluid is acceptable at a test temperature if none of the independent BLDT measurements is greater than the acceptance criteria as defined in B.8.1. This test temperature is the average of the three lowest temperatures of the acceptable data points. The temperature ranges at which the fluid and its dilutions are found to be acceptable shall be reported in the fluid qualification statement of the report. If a fluid specimen is found unacceptable over a range of temperatures, such findings shall be explicitly stated in the prescribed report, (See Section B.10), and the fluid manufacturer informed that the fluid not be used in that temperature range or that the airframe manufacturer be consulted prior to using the fluid within the unacceptable temperature range.

B.8.3.1 Retesting: If any data point fails to meet the specified acceptance criteria, disposition of the data point may be based on three additional data points for each nonconforming data point. Failure of any retest data point to meet the acceptance criteria shall be cause for failure of the fluid for that test temperature. All data points shall be reported.

B.8.4 Continued Acceptance of Test Fluid:

To maintain compliance with this specification, the fluid shall be tested when initially certified and thereafter biannually in its undiluted and diluted forms in accordance with this standard and shall continually demonstrate acceptable aerodynamic flow-off characteristics. With respect to this standard, a change in fluid formulation or properties constitutes a new fluid and compliance with this standard must be reconstituted. Fluids produced under license from the manufacturer of an original fluid which complies with this standard shall be required to independently show compliance herewith if the licensed fluid is tendered as meeting this standard. Compliance can be inferred for the licensed fluid if documentation is provided which validates that the original and licensed fluids are identical.

B.9 TEST RESULTS:

Test results shall consist of the following.

B.9.1 Test Fluid Identification Data Sheet:

A data sheet containing the fluid identification parameters defined in B.6.2 (See Figure B5).

B.9.2 BLDT Measurement Summary:

Tabulation summarizing the BLDT measurements for each fluid with the corresponding dry wall BLDT measurements (See Figure B6).

B.9.3 Test Run Data:

Data from each test run (See Figure B4).

B.9.4 Test Fluid Acceptance Data:

A graphic presentation of the test fluid, reference fluids, and dry test duct BLDT measurements, along with the fluid acceptance criteria described in B.8.1 (See Figure B7).

B.9.5 Test Fluid Acceptance Statement:

Statement from the aerodynamic acceptance test facility regarding acceptability of the fluid with respect to requirements of Section B.8.

B.9.6 Water Content Variation:

Evaluation of water content variation in the test fluid during the test run shall be reported. A cautionary statement shall be issued if the water content variation is in excess of ±2%.

B.10 REPORTS:

The report of the test results shall contain the following:

B.10.1 Fluid Manufacturer's Information:

Manufacturer's test fluid identification statement described in B.6.1.

B.10.2 Aerodynamic Acceptance Test Facility Information:

B.10.2.1 Test Facility Qualification Statement: If results from testing in accordance with this standard are to be used to certify that an aircraft deicing/anti-icing fluid complies with the acceptance criteria described in Section 8, the report shall include a statement from the aerodynamic acceptance test facility that the facility meets the requirements of this standard and has been found qualified by the Performance Review Institute, 161 Thornhill Road, Warrendale, PA 15086-7527, as discussed in B.1.2 and B.5.4.

B.10.2.2 Test Facility Autonomy Statement: If results from testing in accordance with this standard are to be used to certify that an aircraft deicing/anti-icing fluid complies with the acceptance criteria described in Section B.8, the report shall include a statement attesting independence of the aerodynamic acceptance test facility from fluid manufacturers, as discussed in Section B.5.

B.10.2.3 Fluid Code Identification: Manufacturer's product name cross referenced with the aerodynamic acceptance facility reference.

B.10.2.4 Test Results: As discussed in Section B.9.

B.11 KEY WORDS:

Aerodynamic acceptance, aircraft ground deicing/anti-icing, deicing/anti-icing fluids, fluid flow-off

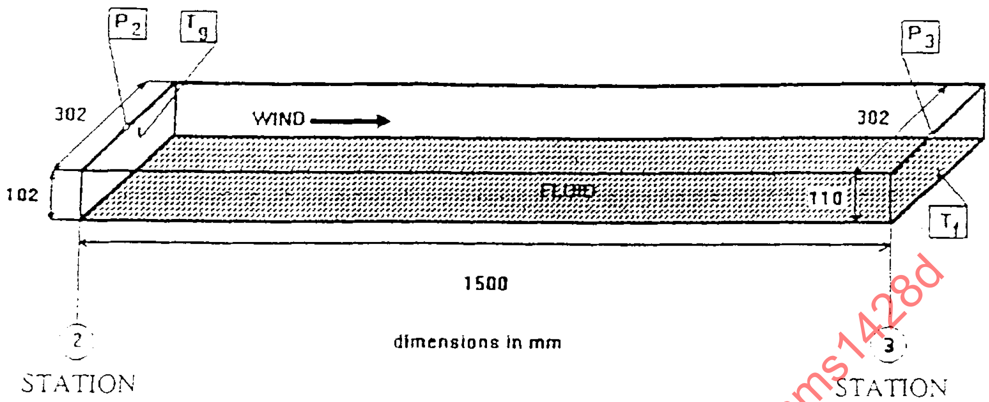


FIGURE B1 - Test Duct Schematic

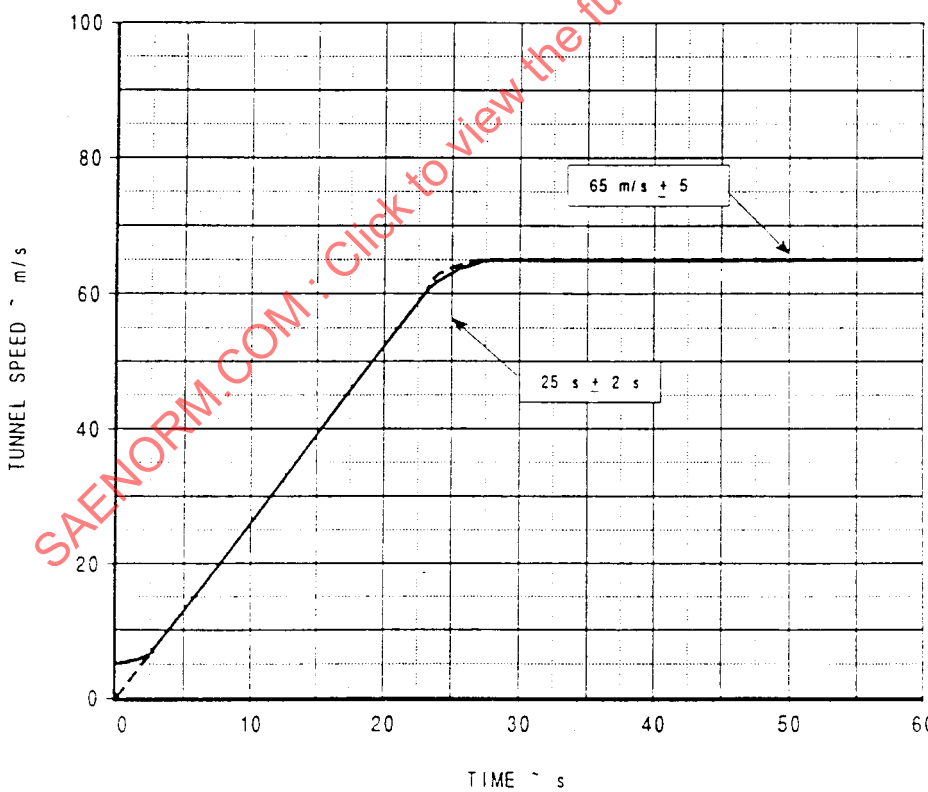
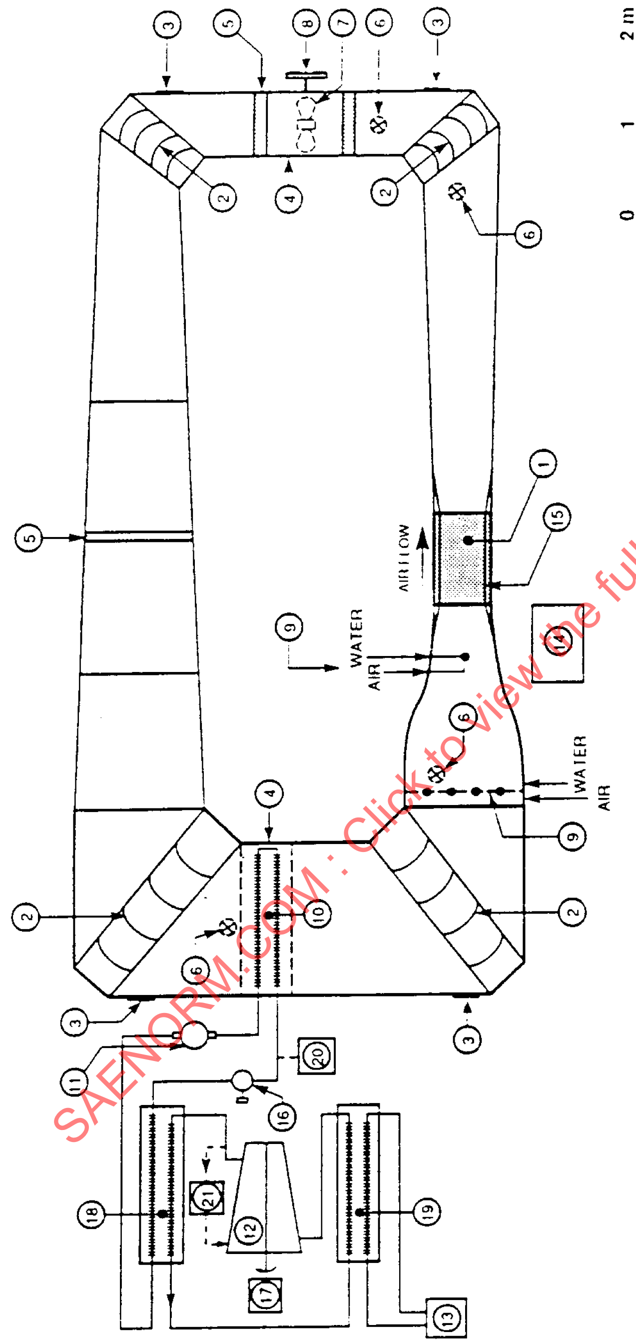
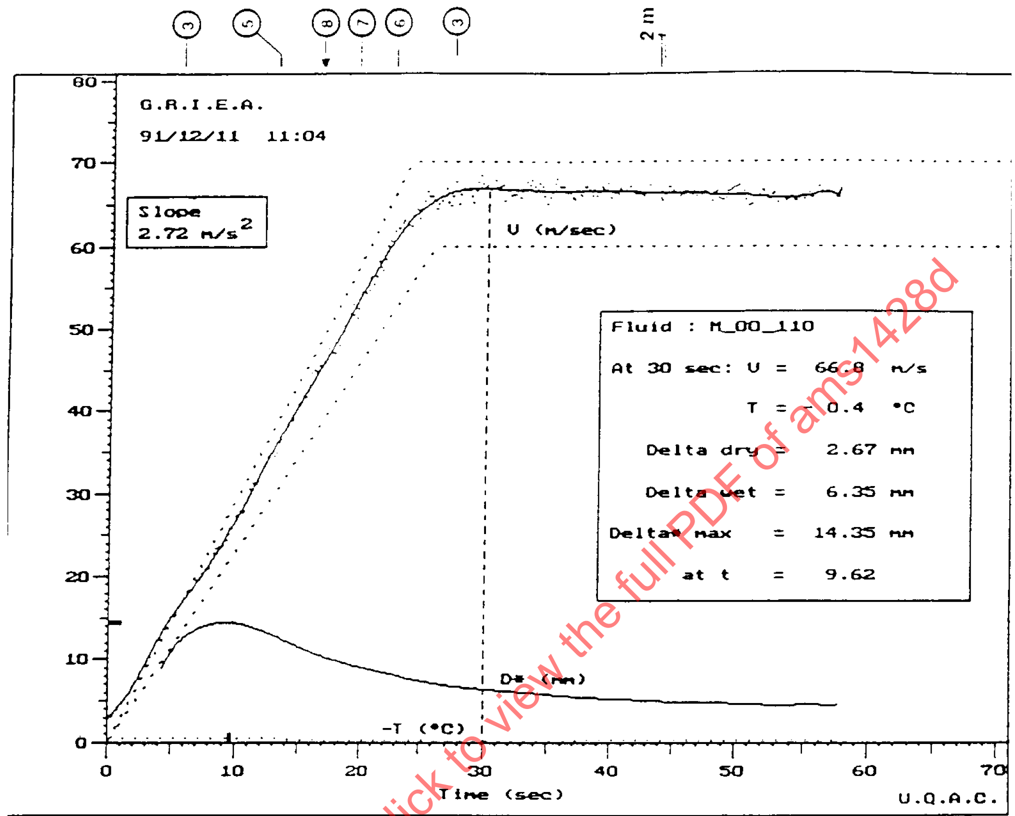


FIGURE B2 - Takeoff Ground Acceleration Simulation



1	TEST SECTION / TEST DUCT	12	COMPRESSOR (30 TONS)
2	CORNER DEFLECTORS	13	WATER MAIN
3	SIDE OPENING	14	PANNEL CONTROL
4	MOTOR SECTION	15	SIDE PANEL
5	FLEXIBLE JUNCTION	16	BY PASS 3-WAY VALVE
6	DRAIN	17	MOTOR DRIVE
7	FAN AND MOTOR	18	FREON/GLYCOL HEAT EXCHANGER
8	MOTOR CONTROL	19	FREON/WATER HEAT EXCHANGER
9	SPRINKLERS	20	TEMPERATURE CONTROLLER
10	AIR/GLYCOL HEAT EXCHANGER	21	ON/OFF CONTROLLER
11	GLYCOL PUMP		

FIGURE B3 - Example of Facility Schematic



Time sec	Speed m/s	P_1-P_2 "H_2O	P_2-P_3 "H_2O	Delta* mm	T_A °C	T_F °C
27.06	66.0	11.43	0.56	6.82	-1.4	-0.2
28.02	66.3	11.52	0.54	6.73	-1.5	-0.1
28.98	66.7	11.67	0.48	6.49	-1.5	-0.1
29.94	67.1	11.79	0.44	6.29	-1.5	-0.2
31.00	66.7	11.67	0.41	6.18	-1.5	-0.1
32.06	66.1	11.44	0.39	6.11	-1.6	-0.2
33.02	67.2	11.82	0.35	5.91	-1.6	-0.2
Averages						
30.04	66.6	11.62	0.45	6.35	-1.5	-0.2

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FIGURE B4 - Example of Data Acquired During Test Run

NUMBER	COMPANY	DESIGNATION	GRIEA LABEL	RECEIVED
1				
2				
3				

TABLE 3 - SURFACE TENSION, pH AND REFRACTIVE INDEX

NO	SURFACE TENSION		pH		RI	
	T(°C)	dynes/cm	T(°C)	VALUE	T(°C)	VALUE
1	20	34.7	20	6.89	20	1.4280
2	20	39.6	20	9.55	20	1.4275
3	20	39.4	20	9.47	20	1.4282

BROOKFIELD VISCOSITY (mPa s)

TEMPERATURE (°C)	0.3 RPM			6 RPM			30 RPM		
	Reading	F	visc.	Reading	F	visc.	Reading	F	visc.
	A.								
+20°C	5.2	1000	5200	23.7	50	1185	61.5	10	615
0°C	7.0	1000	7000	37.3	50	1865	99.9	10	999
-10°C	4.5	1000	4500	31.1	50	1555	93.7	10	937
-20°C	1.5	1000	1500	18.6	50	930	70.8	10	708
-25°C	1.4	1000	1400	18.2	50	910	74.3	10	743
	B.								
+20°C	0.2	200	40	3.3	10	33	18.4	2	36.8
0°C	0.6	200	120	13.8	10	138	69.7	2	139.4
-10°C	1.9	200	380	32.1	10	321	32.5	10*	325
-20°C	4.2	200	840	84.0	10	840	87.8	10*	878
-25°C	7.6	200	1520	32.1	50*	1605	-	-	-
	C.								
+20°C	0.5	200	100	3.6	10	36	18.8	2	37.6
0°C	0.9	200	180	14.1	10	141	70.4	2	140.8
-10°C	1.8	200	360	33.1	10	331	34.1	10*	341
-20°C	4.5	200	900	86.7	10	867	94.5	10*	945

FIGURE B5 - Example of Test Fluid Identification Sheet

FLUID IDENTIFICATION

NUMBER	COMPANY	DESIGNATION	GRIEA LABEL	RECEIVED

AERODYNAMIC PERFORMANCE TEST DATA

	Test Code	T_A °C	T_F °C	Rh %	V at 30 s m/s	δ mm
DRY	FPD-212	0.6		42.9		2.78
A341	FP-424	1.0	0.1	45.0	65.9	8.51
A341	FP-425	2.6	0.1	46.0	65.4	8.52
A341	FP-426	-1.3	-1.7	54.8	65.5	8.60
DRY	FPD-213	-2.2		55.0		2.80
DRY	FPD-214	-9.1		70.5		2.71
A341	FP-427	-11.0	-10.3	67.3	65.8	8.83
A341	FP-428	-10.8	-9.8	65.2	65.2	9.10
A341	FP-429	-11.6	-11.4	66.4	66.7	8.05
A341	FP-439	-10.6	-9.7	63.1	65.9	8.47
A341	FP-440	-10.0	-10.3	65.1	65.7	8.43
DRY	FPD-216	-12.0		64.8		2.75
DRY	FPD-227	-14.4		67.8		2.75
A341	FP-441	-14.7	-12.6	66.7	65.7	9.05
A341	FP-442	-15.7	-13.3	66.5	65.6	9.04
A341	FP-443	-15.9	-14.7	66.8	65.6	9.06
DRY	FPD-228	-17.1		56.2		2.82
DRY	FPD-217	-21.7		60.5		2.75
A341	FP-430	-20.1	-20.1	62.6	65.9	8.94
A341	FP-431	-17.5	-19.0	67.4	65.7	8.88
A341	FP-432	-21.8	-21.1	58.7	65.9	9.21
DRY	FPD-218	-21.8		53.6		2.76
DRY	FPD-222	-26.2		55.2		2.77
A341	FP-433	-26.5	-24.5	53.2	64.7	9.80
A341	FP-434	-24.4	-23.6	58.5	64.9	9.55
A341	FP-435	-26.7	-25.6	54.1	65.3	9.59
DRY	FPD-221	-26.4		50.3		2.78
DRY	FPD-225	-30.0		47.0		2.72
A341	FP-436	-31.4	-29.3	47.8	63.3	10.53
A341	FP-437	-30.4	-28.4	48.8	64.4	10.48
A341	FP-438	-30.7	-29.7	50.4	63.9	10.51
DRY	FPD-223	-31.7		48.7		2.73

0°C	0.9	200	180	14.1	10	141	70.4	2	140.8
-10°C	1.8	200	360	33.1	10	331	34.1	10*	341
-20°C	4.5	200	900	86.7	10	867	94.5	10*	945
-25°C	7.7	200	1540	31.1	50*	1555	-	-	-

* SPINDLE #2

FIGURE B6 - Example of Test Data Summary

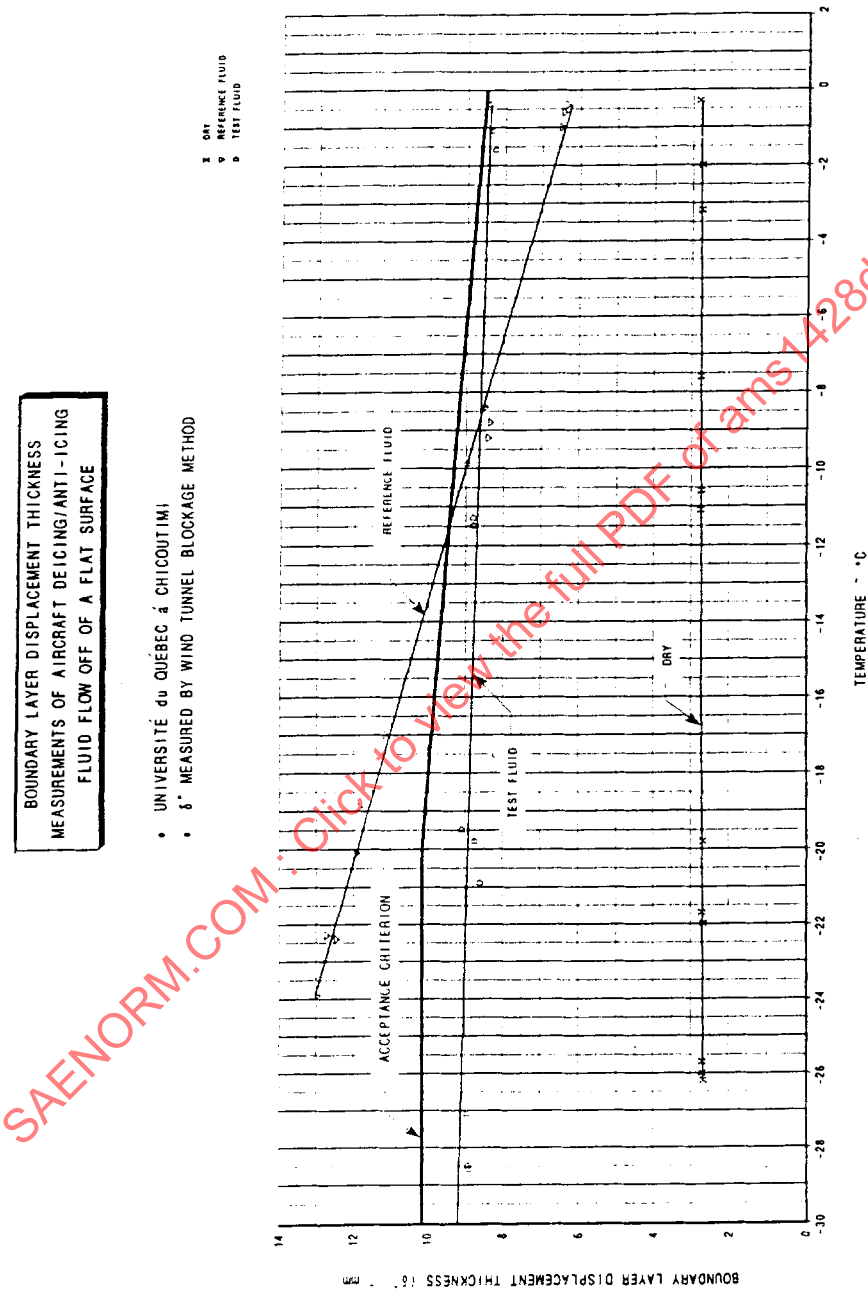

FIGURE B7 - Example of Test Report Results Summary

ANNEX C

STANDARD TEST METHOD FOR AERODYNAMIC ACCEPTANCE OF
COMMUTER TYPE AIRCRAFT GROUND DE-ICING/ANTI-ICING FLUIDS

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LIST OF FIGURES

C.1 SCOPE:

C.1.1 Objective:

This standard establishes the aerodynamic flow-off requirements for fluids used to deice and/or anti-ice commuter type aircraft while on the ground and when no compensating measures are taken in the aircraft takeoff procedure. The takeoff rotation speeds generally exceed approximately 60 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.

C.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 C.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 C.8, substantiation that the facility and associated staff and resources satisfy the requirements of this test method shall be documented and submitted to the Performance Review Institute, 161 Thornhill Road, Warrendale, PA 15086-7527, 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.

C.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.

C.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 takeoff. 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.

C.3 REFERENCED DOCUMENTS:

C.3.1 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

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

C.3.2 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-A-8243 Anti-icing and De-icing-Defrosting Fluid

C.3.3 Other Publications:

"Boundary Layer Evaluation of Anti-Icing Fluids for Commuter Aircraft", Louchez, P. R., Laforte J.-L. and Bouchard, G. (UQAC), prepared for Transportation Development Centre, Policy and Co-ordination, Transport Canada, TP11811E, August 1994

C.4 GLOSSARY:

C.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

C.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^*_{-20}	maximum acceptable value for δ^*_f at -20 °C
ρ	gas density mass per unit volume

C.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 C.8, substantiation that the facility is autonomous of fluid manufacturers and complies with the following requirements shall be documented and submitted to the Performance Review Institute, 161 Thornhill Road, Warrendale, PA 15086-7527, 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 C.6.2, adequate transducer calibration facilities to ensure accuracy and precision requirements, and trained personnel to effect the test method.

C.5.1 Test Duct Description:

C.5.1.1 Dimensions: Figure C1

C.5.1.2 Tolerances:

Lineal dimensions: ≤ ±2%
S_2/S_3: 92.7 ± 1%

C.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 ≤ 3.3 mm at Station 3, at 35 m/s. 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.

C.5.2 Test Duct Gas Flow Core Characteristics:

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

C.5.2.2 Temperature Range: 0 °C to approximately -25 °C, or the test fluid minimum usable temperature.

C.5.2.3 Temperature Stability: ≤ ±2 °C of the target temperature with a continuous flow ≥60 seconds, except ≤ ±1 °C between the 17th and 23rd seconds of a test run.

C.5.2.4 Temperature Spatial Uniformity: ≤ ±1 °C

C.5.2.5 Velocity Range: 0 = V ≤ 0.5 m/s to 35 m/s ± 3 within t = 17 seconds ± 1, following a constant acceleration of 2.1 m/s^2 (measured at Station 2) with a minimum flow velocity of 35 m/s ± 3, 30 seconds after start, and maintained for 30 additional seconds (See Figure C2.) Prior to the flow acceleration, the duct flow shall be capable of a five minute settling period with a velocity ≤5 m/s.

C.5.2.6 Turbulence: ≤0.005 ($\Delta U/U_\infty$)

C.5.2.7 Velocity Spatial Uniformity:

Vertical and lateral: $\Delta U/U_\infty \leq \pm 0.005$
Longitudinal: $\Delta U \leq -1$ m/s/m ± 0.008 U_∞/m

C.5.2.8 Relative Humidity: 70% ± 30

C.5.3 Test Facility Thermal Stability:

C.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.

C.5.3.2 Test Facility Circuit: Circuit thermal insulation shall ensure the test duct temperature characteristics of Sections C.5.2.

C.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.

C.5.5 Instrumentation:

C.5.5.1 Temperature and Relative Humidity:

C.5.5.1.1 Test Duct Gas Temperature: Measured at Station 2 approximately 5 mm below the ceiling.

C.5.5.1.2 Test Fluid Temperature: Measured at Station 3 within the test fluid, approximately 1 mm above the floor.

C.5.5.1.3 Temperature Sensor: Copper constantan thermocouples of a 0.2 mm diameter wire with a measuring junction 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.

C.5.5.1.4 Relative Humidity: Wet bulb-dry bulb thermometers or equivalent which are regularly calibrated against wet bulb-dry bulb thermometers.

C.5.5.2 Test Duct Gas Pressures:

C.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.

C.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.

C.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.

C.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 second 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.

C.5.5.3 Test Duct Gas Velocity and Turbulence:

C.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 C1.

$$V = \sqrt{\frac{2}{\rho}(P_1 - P_2) \Big/ \left[1 - \left(\frac{S_2}{S_1}\right)^2\right]} \qquad \text{(Eq. C1)}$$

Because of possible pressure leaks and losses, a calibrated pitot-static probe shall be periodically used to verify use of Equation C1.

C.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.

C.5.6 Example Facility:

An example facility consists of a closed circuit, refrigerated wind tunnel with a 0.5 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 C3.

C.6 TEST FLUID REQUIREMENTS:

C.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. A volume of about 1 liter of the lot is required for one test run. The fluid shall be tested undiluted and in dilutions of 75% neat fluid to 25% water, and at 50% neat fluid to 50% water. Samples to be tested in diluted form shall be diluted by the testing facility, using water conforming to ASTM D 1193, Type IV. The manufacturer shall mark each fluid sample container with the company name, product name, lot number, location and date of manufacture.

C.6.2 Fluid Identification:

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

C.6.2.1 Viscosity: Viscosity shall be measured using a Brookfield LV viscometer, fitted with the guardleg and appropriate spindle at 0.3, 6, and 30 rpm, in accordance with ASTM D 2196, Method B (except the samples shall not be shaken). Test at 20 °C (68 °F), 0 °C (32 °F), and in 10 °C (18 °F) increments down to the lowest usable temperature identified by the manufacturer. The report shall clearly state the size and type of spindle used.

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

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

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