SAE Aerospace
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AEROSPACE STANDARD

SAE AS5900 REV. B

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Superseding AS5900A

(R) Standard Test Method for Aerodynamic Acceptance of SAE AMS 1424 and SAE AMS 1428 Aircraft Deicing/Anti-icing Fluids

RATIONALE

This revision of the document reflects the following changes: (a) inclusion of a note regarding possible extra testing for non-glycol based fluids, (b) new simpler, easier to make and more reproducible formulations for the high speed and low speed reference fluids, yet with viscosities similar to the old reference fluids, and (c) modifications of definitions and testing conditions for clarity.

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1. SCOPE

1.1 Objective

This SAE Aerospace Standard (AS) establishes the aerodynamic flow-off requirements for SAE AMS 1424 Type I and SAE AMS 1428 Type II, III and IV fluids used to deice and/or anti-ice aircraft:

a. with takeoff rotation speeds exceeding approximately 100 knots, with time from brake release to rotation speed greater than 20 s, typical for large transport type jet aircraft. This procedure is referred to as the High Speed Ramp Test.

   and/or

b. with takeoff rotation speeds exceeding approximately 60 knots, with time from brake release to rotation speed greater than 15 s typical for commuter type aircraft. This procedure is referred to as the Low Speed Ramp Test.

   NOTE: When compensating measures, such as increase in rotation speed, are used in the aircraft takeoff procedure, the High Speed Ramp can apply.

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.

NOTE: These test methods are based on glycol-based fluids, additional testing may be required for non-glycol-based fluids.

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 6. 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 6, 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, or equivalent qualified third party reviewers, to qualify the technical suitability and competency of the test site/facility. Such test site/facilities shall be qualified at five-year intervals by submitting current data, which demonstrate that, the facility, procedures, supporting resources, and staff continues to produce acceptable data.

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.

1.4 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.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-49790 (outside USA), www.sae.org.

AMS 1424 Deicing/Anti-icing Fluid, Aircraft SAE Type I

AMS 1428 Fluid, Aircraft Deicing/Anti-icing material, Non-Newtonian (Pseudoplastic), SAE Types II,III and IV

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

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

2.1.3 High Speed Ramp Reference Fluid

TABLE 1

Component	Percent by Weight
Propylene glycol	68.0 ± 0.1
Tripropylene glycol	20.0 ± 0.1
Demineralized water	12.0 ± 0.1

The fluid shall be homogeneous with:

a. A refractive index, as determined at 20 °C ± 3 °C in accordance to ASTM D 1331, of 1.4276 ± 0.0005

b. A viscosity, as measured with a Brookfield LV viscometer at 6 rpm LV1 spindle in accordance with ASTM D 2196 at 0 °C, of 150 mPa·s ± 25 mPa·s

2.1.4 Low Speed Ramp Reference Fluid

The High Speed Reference Fluid as described in 2.1.3 diluted 75 vol% fluid and 25 vol% water with a refractive index, as determined at 20 °C ± 3 °C in accordance to ASTM D 1331, of 1.4081 ± 0.0005.

2.1.5 Other Publications

Investigation of a New Formulation Reference Fluid for Use in Aerodynamic Acceptance Evaluation of Aircraft Ground Deicing and Anti-icing Fluid. Beisswenger, A., Laforte, J.-L., Tremblay, M.-M., and Perron, J. prepared for the Federal Aviation Administration, under press

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

Aerodynamic Acceptance Test for Aircraft Ground Deicing/Anti-icing Fluids, Boeing Document N° D6-55573, Prepared by Renton Division Aerodynamics Engineering, August 1992.

2.2 Glossary

2.2.1 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

2.2.2 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)

V_i idle wind velocity

V_m maximum wind velocity

V_s 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

3. 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 6 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, or equivalent qualified third party reviewers, 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 4.2, adequate transducer calibration facilities to ensure accuracy and precision requirements, and trained personnel to effect the test method.

3.1 Test Duct Description

3.1.1 Dimensions

See Figure 1.

3.1.2 Tolerances

Lineal dimensions: ≤ ±2%
S_2/S_3: 0.927 ± 0.010

3.1.3 Design Features

The test duct floor shall be horizontal, while the ceiling shall slope upward linearly 8 mm from Station 2 to Station 3.

a. for High Speed Ramp Tests duct surfaces shall be hydraulically smooth, resulting in a dry BLDT ≤ 3.0 mm at Station 3, at 65 m/s ± 5 m/s.

b. for Low Speed Ramp Tests duct surfaces shall be hydraulically smooth, resulting in a dry BLDT ≤ 3.3 mm at Station 3, at 35 m/s ± 3 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.

3.2 Test Duct Gas Flow Core Characteristics

3.2.1 Test Gas

Air, nitrogen, or suitable gas proven to have no adverse effect on the overall testing method.

3.2.2 Temperature Range

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

3.2.3 Temperature Stability

≤ ±2 °C of the target temperature with a continuous flow ≥ 60 s, except ≤ ±1 °C between the 27th and 33rd seconds for a High Speed Ramp Test run or between the 17th and 23rd seconds for a Low Speed Ramp Test run

3.2.4 Temperature Spatial Uniformity

≤ ±1 °C

3.2.5 Velocity Range

a. For High Speed Ramp Tests:

Velocity Range: 0 = V ≤ 0.5 m/s to 65 m/s ± 5 m/s within t = 25 s ± 2 s, following a constant acceleration of 2.6 m/s^2 (measured at Station 2) with a minimum flow velocity of 65 m/s ± 5 m/s, 30 s after start, and maintained for 30 additional seconds (see Figure 2). Prior to the flow acceleration, the duct flow shall be capable of a 5 min settling period with a velocity ≤ 5 m/s.

b. For Low Speed Ramp Tests:

Velocity Range: 0 = V ≤ 0.5 m/s to 35 m/s ± 3 m/s within t = 17 s ± 1 s, following a constant acceleration of 2.1 m/s^2 (measured at Station 2) with a minimum flow velocity of 35 m/s ± 3 m/s, 20 s after start, and maintained for 40 additional seconds (see Figure 3). Prior to the flow acceleration, the duct flow shall be capable of a five minute settling period with a velocity ≤ 5 m/s.

3.2.6 Turbulence

≤ 0.005 ($\Delta U/U_\infty$)

3.2.7 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

3.2.8 Relative Humidity

70% ± 30%

3.3 Test Facility Thermal Stability

3.3.1 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 during a test run.

3.3.2 Test Facility

Circuit thermal insulation shall ensure the test duct temperature characteristics of 3.2.

3.4 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.

3.5 Instrumentation

3.5.1 Temperature and Relative Humidity

3.5.1.1 Test Duct Gas Temperature

Measured at Station 2 approximately 5 mm below the ceiling.

3.5.1.2 Test Fluid Temperature

Measured at Station 3 within the test fluid, approximately 1 mm above the floor.

3.5.1.3 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.

3.5.1.4 Relative Humidity

Wet bulb-dry bulb thermometers or equivalent, which are regularly calibrated against wet bulb-dry bulb thermometers.

3.5.2 Test Duct Gas Pressures

3.5.2.1 Total Pressure, P_1

May be measured as the static pressure in the settling chamber immediately upstream of the test duct, Station 1, using a 3 mm diameter flush orifice tapped into the chamber sidewall if the velocities are low, in accordance with standard wind tunnel practice.

3.5.2.2 Inlet Static Pressure, P_2

Measured using a 3 mm diameter flush orifice tapped into the middle of the ceiling at Station 2, free of flow disturbances from the Station 2 temperature probe.

3.5.2.3 Outlet Static Pressure, P_3

Measured using a 3 mm diameter flush orifice tapped into the middle of the ceiling at Station 3.

3.5.2.4 Pressure Sensor

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

3.5.3 Test Duct Gas Velocity and Turbulence

3.5.3.1 Velocity

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

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

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

3.5.3.2 Turbulence

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

3.6 Example Facility

An example facility consists of a closed circuit, refrigerated wind tunnel with a 0.5 m x 0.5 m test section. The test duct is inserted in the test section of the wind tunnel. The test duct may be fitted with a short inlet convergent to achieve required maximum speed, and a long diffuser to avoid large power losses due to wake effects. The facility has a settling chamber fitted with honeycomb and/or grids and a 9:1 contraction ratio separates this chamber and the wind tunnel test section entrance in order to provide good airflow quality. A 50 hp fan drive motor with variable RPM is controlled, by computer, via the time signal of the difference between actual wind velocity and required value. Refrigeration is obtained via a heat exchanger placed upstream of the settling chamber; a two stage Freon-glycol refrigeration circuit powered by a 75 hp compressor provides adequate temperature setting (-30 °C). A schematic of the suggested facility is shown in Figure 4.

4. TEST FLUID REQUIREMENTS

4.1 General

Fluids submitted for testing shall be experimental fluids or fluids which are representative of production fluids being commercially offered as complying with this test method, shall have been manufactured during the previous three months, shall be from the same lot submitted for the water spray endurance test and the high humidity endurance test, but unsheared with respect to the requirements of the water spray and high humidity endurance tests. A volume of about 1 liter of the lot is required for one test run. 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.

4.2 Fluid Identification

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

4.2.1 Viscosity

Viscosity shall be measured by Brookfield LV viscometer, or equivalent, at 0.3, 6, and 30 rpm with the appropriate spindle in accordance with ASTM D 2196 (except that the samples shall not be shaken), at 20 °C, 0 °C, and in 10 °C increments down to the lowest usable temperature identified by the fluid manufacturer. The viscosity may be measured with the Brookfield small sample adapter, the report shall state whether it was used and detail the spindle size, container size, volume of fluid employed and the rotation duration. Viscosity measurements will be made for both the undiluted fluid and all tested dilutions.

4.2.2 Surface Tension

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

4.2.3 Refractive Index

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

4.2.4 pH

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

5. TEST PROCEDURE

5.1 Test Requirements

Boundary layer displacement thickness (BLDT) measurements shall be made of the test fluid, of the dry test duct and

a. the High Speed Ramp Reference Fluid as described in 2.1.3 for the High Speed Ramp Tests.

b. the Low Speed Ramp Reference Fluid as described in 2.1.4 for Low Speed Ramp Tests.

Each fluid shall be tested at selected fluid temperature including 0, -10 (in the case of Type II, III and IV fluids) and -20 °C, or to the lowest usable test fluid temperature identified by the fluid manufacturer (if lower 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. Paragraph 5.2 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 5.2, deleting the steps involving the fluid.

5.2 Test Run Sequence

5.2.1 Select Target Temperatures

5.2.2 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 5-min setting period under a wind velocity hereafter referred to as idle velocity, and denotes V_i.

5.2.3 Pre-cool Test Facility

Pre-cool the test facility to achieve test gas and structural thermal stability at the target temperature.

5.2.4 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.

5.2.5 Apply Fluid to Test Duct Floor

Pour approximately 1 L 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.

5.2.6 Subject Fluid to Settling Conditions

Secure the test duct and circuit and subject the fluid to a 5-min 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.

5.2.7 Takeoff Velocity Time History

Subject fluid to a simulated aircraft takeoff velocity time history. Accelerate the test duct gas flow as shown in Figure 2 for High Speed Ramp Tests or as shown in Figure 3 for Low Speed Ramp Tests and simultaneously record t, RH, T_f, T_g, (P_1 - P_2), and (P_2 - P_3).

5.2.7.1 Start Up

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

5.2.7.2 Acceleration

a. For High Speed Ramp: From t = 0 s to t = 2 s ± 2 s, wind velocity shall increase to V_s. From t = 2 s ± 2 s to t = 25 s ± 2 s, wind velocity shall increase from V_s up to V_m. From t = 25 s ± 2 s up to 60 s wind velocity shall remain constant, equal to V_m.

b. For Low Speed Ramp: From t = 0 s to t = 2 s ± 2 s, wind velocity shall increase to V_s. From t = 2 s ± 2 s to t = 17 s ± 1 s, wind velocity shall increase from V_s up to V_m. From t = 17 s ± 1 s up to 60 s wind velocity shall remain constant, equal to V_m.

5.2.7.3 Maximum Velocity

a. For High Speed Ramp: Maximum wind velocity, denoted V_m, shall be equal to 65 m/s ± 5 m/s.

b. For Low Speed Ramp: Maximum wind velocity, denoted V_m, shall be equal to 35 m/s ± 3 m/s.

5.2.8 Terminate Test Run

At time t = 60 s wind velocity is brought to 0 m/s as quickly as possible.

5.2.9 Residual Fluid Analysis

Sample fluid remaining on the test duct floor for water content using refractive index comparison.

5.2.10 Fluid Elimination

Type I: No requirement.

Type II,III, and IV: 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 min of the end of the test at THREE locations along the flat plate as follows:

1. on centerline 1400 mm ± 10 mm from leading edge of plate

2. on centerline 750 mm ± 10 mm from leading edge of plate

3. at 750 mm ± 10 mm and 2.5 mm ± 0.5 mm from front long edge of plate

5.2.11 Data Processing

Process measured data (see 5.4).

5.3 Test Cautions

5.3.1 Safety Hazards

See 1.3 concerning safety hazards.

5.3.2 Frost

The formation of frost within the test duct will significantly affect the results obtained and, therefore, must be prevented.

5.3.3 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's 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.

5.3.4 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:

5.3.4.1 Increasing BLDT Data

A BLDT increasing with time during the last 30 s 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.

5.3.4.2 Constant BLDT Data

A constant value of BLDT

a. with time during the last 30 s of a dry run for High Speed Ramp Tests

b. with time during the last 40 s of a dry run for Low Speed Ramp Tests

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.

5.4 Data Processing

5.4.1 Test Data Description

5.4.1.1 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 s duration of the test. An example for a High Speed Ramp Tests is given in Figure 5 and for a Low Speed Ramp Tests in Figure 6.

5.4.1.2 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 a High Speed Ramp Tests, or between the 19th and 21st second of a Low Speed Ramp Tests. These values are BLDT and fluid temperature.

5.4.2 Calculation Methods

5.4.2.1 Velocity

See 3.5.3.1.

5.4.2.2 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 from the application of mass conservation and Bernoulli equations (See Equation 2):

$$\delta^*_{ave} = \frac{1}{c}\left[S_3 - S_2\sqrt{\frac{(P_1 - P_2)}{(P_1 - P_2) + (P_2 - P_3)}}\right] \qquad \text{(Eq. 2)}$$

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 (2) yields the value of the BLDT on a dry wall:

$$\delta^*_d = \delta^*_{ave}(\text{with no fluid}) \qquad \text{(Eq. 3)}$$

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 4):

$$\delta^*_f = \frac{c}{b}\left[\delta^*_{ave} - \left(\frac{c-b}{c}\right)\delta^*_d\right] \qquad \text{(Eq. 4)}$$

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 5):

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

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 5 is used to evaluate, as a function of the instantaneous velocity determined by 1, the value of δ^*_d to be used in Equation 4.

5.4.2.3 Temperature

Data produced by calibration of the thermocouples (see 3.5.1).

5.4.2.4 Relative Humidity

Data produced by calibration of the wet bulb-dry bulb thermometers (see 3.5.1.4).

5.5 Test Bias Accuracy and Precision

5.5.1 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 and δ^*_r values from various identical tests performed at temperatures within ±1 °C shall be within ±0.3 mm.

5.5.2 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 mm for High Speed Ramp Tests and 2.8 mm ± 0.4 mm for Low Speed Ramp Tests. The nominal 2.5 and 2.8 mm values correspond to theoretical expected values 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.

5.5.3 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.

6. DEICING/ANTI-ICING FLUID ACCEPTANCE CRITERIA

6.1 Fluid Acceptance Criteria

a. For High Speed Ramp Tests:

The maximum acceptable δ^*_f value as a function of temperature is established according to dry and reference results (see 5.1). Values δ^*_{-20} and δ^*_0 are used as that upper limit for BLDT values. These values are:

$$\delta^*_0 = \delta^*_r + 0.71\,(\delta^*_r - \delta^*_d)_0 \qquad \text{(Eq. 6)}$$

$$\delta^*_{-20} = \delta^*_r - 0.18\,(\delta^*_r - \delta^*_d)_{20} \qquad \text{(Eq. 7)}$$

where:

δ^*r = Reference BLDT value at 0 °C for Equation 6 and at -20 °C for Equation 7, obtained by interpolation from a straight line fitting of the reference BLDT values measured at 0, -10, -20, and -25 °C

δ^*_d = Average of all dry BLDT values measured

b. For Low Speed Ramp Tests:

The maximum acceptable δ^*_f value as a function of temperature is established according to dry and reference results (see 5.1). The δ^*_{-20} value is used as that upper limit for BLDT values. This values is:

$$\delta^*_{-20} = 1.12\delta^*_r - 0.19\,(\delta^*_r - \delta^*_d)_{-20} \qquad \text{(Eq. 8)}$$

where:

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

δ^*_d = Average of all dry BLDT values measured

6.2 Fluid Acceptance Criteria Background

a. For High Speed Ramp Tests:

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. For Low Speed Ramp Tests:

For more detailed information on the correlation between this standard and the work carried out on two dimensional typical small aircraft wing models tested to determine lift loss due to the use of aircraft ground anti-icing/deicing fluids, see Transport Canada Document TP11811E, and its attendant bibliography.

6.3 Fluid Acceptance

6.3.1 Initial Testing

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 6.1 given it meets elimination requirement of AMS 1428 for Type II, III and IV. 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 8) 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.

6.3.2 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.

6.4 Continued Acceptance of Test Fluid

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 that 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.

7. TEST RESULTS

Test results shall consist of the following.

7.1 Test Fluid Identification Data Sheet

A data sheet containing the fluid identification parameters defined in 4.2 (see Figure 7).

7.2 BLDT Measurement Summary

Tabulation summarizing the BLDT measurements for each fluid with the corresponding dry wall BLDT measurements (see Figure 8).

7.3 Test Run Data

Data from each test run (see Figure 5 for a High Speed Ramp Test and Figure 6 for a Low Speed Ramp Test).

7.4 Test Fluid Acceptance Data

A graphic presentation of the test fluid, reference fluid, and dry test duct BLDT measurements, along with the fluid acceptance criteria described in 6.1 (see Figure 9 for a High Speed Ramp Test and Figure 10 for a Low Speed Ramp Test).

7.5 Test Fluid Acceptance Statement

Statement from the aerodynamic acceptance test facility regarding acceptability of the fluid with respect to requirements of Section 6.

7.6 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%.

8. REPORT

The report of the test results shall contain the following:

8.1 Fluid Manufacturer's Information

Manufacturer's fluid identification statement described in 4.1.

8.2 Aerodynamic Acceptance Test Facility Information

8.2.1 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 6, 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 1.2 and 3.4.

8.2.2 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 6, the report shall include a statement attesting independence of the aerodynamic acceptance test facility from fluid manufacturers, as discussed in Section 3.

8.2.3 Fluid Code Identification

Manufacturer's product name cross-referenced with the aerodynamic acceptance facility reference.

8.2.4 Test Results

As discussed in Section 7.

9. NOTES

9.1 The change bar (I) 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 document. An (R) symbol to the left of the document title indicates a complete revision of the document.

9.2 Key Words

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

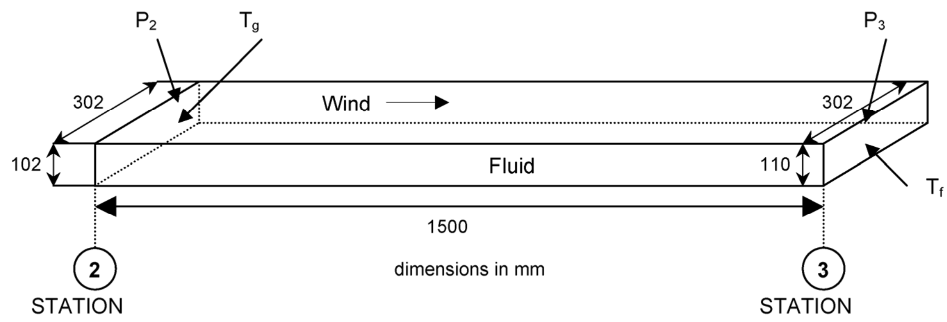


FIGURE 1 - TEST DUCT SCHEMATIC

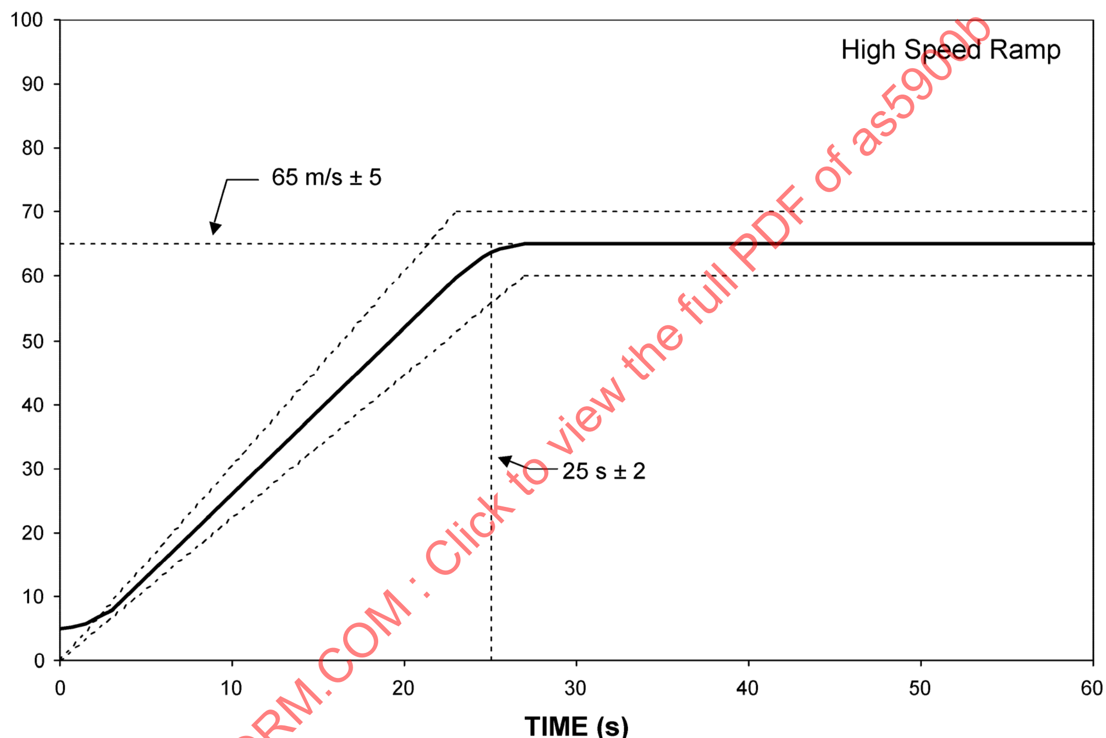


FIGURE 2 - TAKEOFF GROUND ACCELERATION SIMULATION FOR HIGH SPEED RAMP

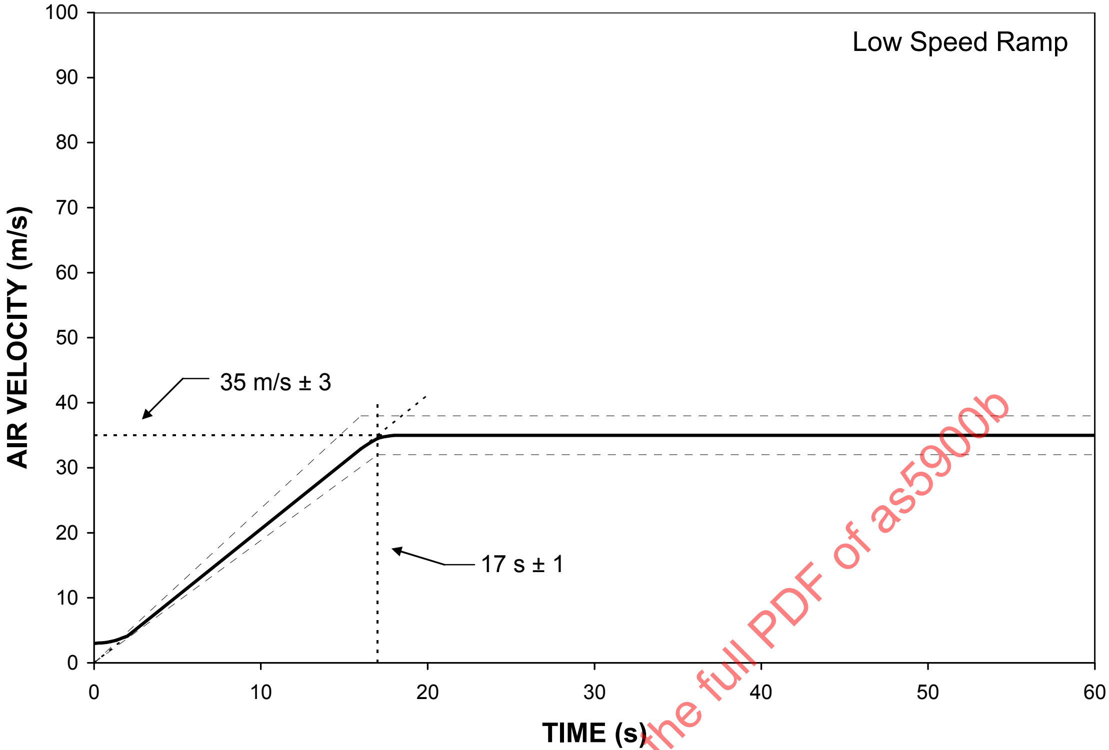
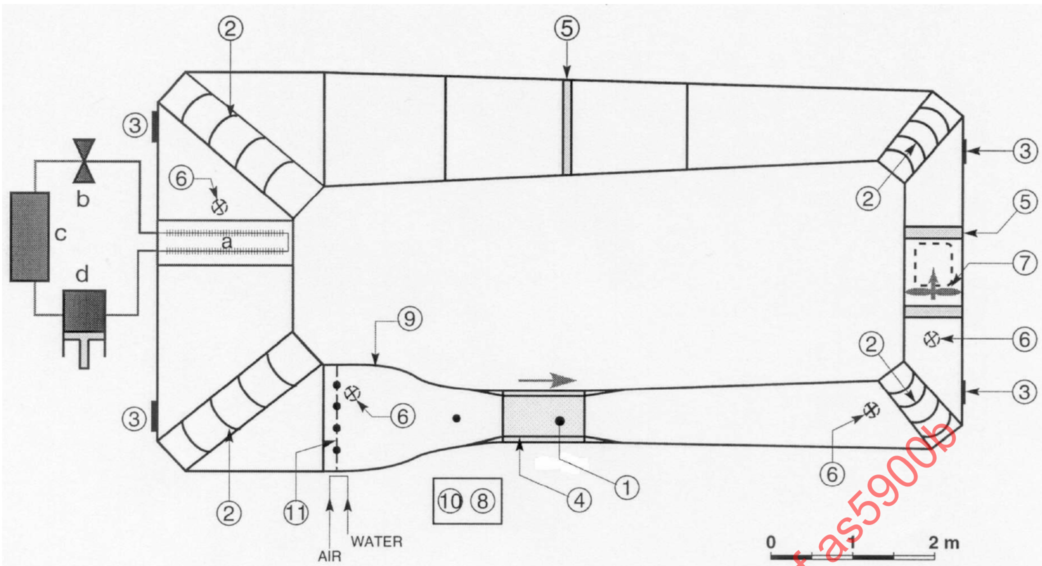


FIGURE 3 - TAKEOFF GROUND ACCELERATION SIMULATION FOR LOW SPEED RAMP



1	TEST SECTION		REFRIGERATING SYSTEM
2	CORNER VANES	a	EVAPORATOR
3	ACCESS DOORS	b	EXPANSION VALVE
4	ACCESS PANELS	c	CONDENSER
5	THERMAL EXPANSION JOINTS	d	COMPRESSOR (75 hp)
6	DRAIN		
7	FAN AND MOTOR		
8	MOTOR CONTROL PANEL		
9	CONTRACTION CONE		
10	CONTROL CONSOLE		
11	SPRAY NOZZLES		

FIGURE 4 - EXAMPLE OF FACILITY SCHEMATIC