AEROSPACE STANDARD

AS5900™	REV. D
Issued 2003-02 Revised 2020-08 Superseding AS5900C	

(R) Standard Test Method for Aerodynamic Acceptance of AMS1424 and AMS1428 Aircraft Deicing/Anti-Icing Fluids

RATIONALE

Changes to specification for revision D:

- Organizational, editorial, and style revisions.
- Modified note concerning non-glycol fluids to include AMS1428.
- Additional test temperatures for AMS1428 neat fluids.
- Change the high speed ramp acceptance criteria to a straight line.
- Two appendices explaining rational behind modifications to test temperatures and high speed ramp acceptance criteria.

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1. SCOPE

This SAE Aerospace Standard (AS) establishes the aerodynamic flow-off requirements and test procedures for AMS1424 Type I and AMS1428 Type II, III, and IV fluids used to deice and/or anti-ice aircraft.

The objective of this standard is to ensure acceptable aerodynamic characteristics of the deicing/anti-icing fluids as they flow off of aircraft lifting and control surfaces during the takeoff ground acceleration and climb. Aerodynamic acceptance of an aircraft ground deicing/anti-icing fluid is based upon the fluid's boundary layer displacement thickness (BLDT) 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) test plate. Testing is carried out in the temperature range at which the fluid, undiluted and diluted, is to be used in airline service.

NOTE: No additional testing is required for non-glycol fluids at this time. For more information about non-glycol fluids, please refer to AMS1424 and AMS1428.

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 +1 724-776-4970 (outside USA), www.sae.org.

AMS1424 Fluid, Aircraft Deicing/Anti-Icing, SAE Type I

AMS1428 Fluid, Aircraft Deicing/Anti-Icing, Non-Newtonian (Pseudoplastic), SAE Types II, III, and IV

ARP6852 Methods and Processes for Evaluation of Aerodynamic Effects of SAE-Qualified Aircraft Ground Deicing/Anti-Icing Fluids

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 D1193 Reagent Water

ASTM D1331 Surface and Interfacial Tension of Solutions of Surface-Active Agents

ASTM D1747 Refractive Index of Viscous Materials

ASTM D2196 Viscosity Measurements and Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscometer

ASTM E70 pH of Aqueous Solutions with the Glass Electrode

2.1.3 Other Publications

Beisswenger, A., Laforte, J.L., Tremblay, M.M., and Perron, J., "Investigation of a New Formulation Reference Fluid for Use in Aerodynamic Acceptance Evaluation of Aircraft Ground Deicing and Anti-Icing Fluid," prepared for the Federal Aviation Administration, under press, DOT/FAA/AR-06/50.

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

Hill, E.G. and Zierten, T.A., "Aerodynamic Effects of Aircraft Ground Deicing/Anti-Icing Fluids," Journal of Aircraft, Vol. 30, No. 1, Jan.-Feb., 1993, pp. 24-34.

2.2 Glossary

2.2.1 Abbreviations

BLDT Boundary layer displacement thickness

cm Centimeter

Hz Hertz

LAAT Lowest acceptable aerodynamic temperature

m Meter

mm Millimeter

Pa Pascal

pH Potential of hydrogen

RH Relative humidity

RPM Revolutions per minute

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

P3 Static pressure at Station 3

Tg Gas temperature (wind)

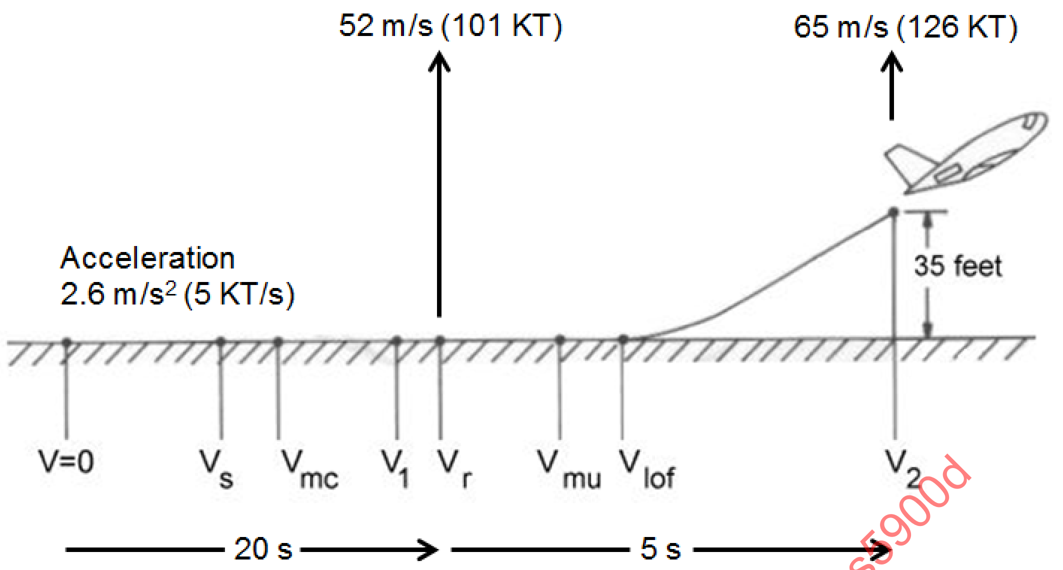
Tf	Fluid temperature (deicing/anti-icing fluid)
Tt	Target temperature
V	Average wind velocity in flow core (at Station 2)
Vi	Idle wind velocity
Vm	Maximum wind velocity
V_s	Start-up wind velocity
δ^*_d	BLDT over dry surface (at Station 3)
δ^*_f	BLDT over fluid-coated surface (at Station 3)
δ^*_{ave}	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. GENERAL INFORMATION

3.1 Description of Tests

The aerodynamic flow-off requirements and test procedures for AMS1424 Type I and AMS1428 Type II, III, and IV deicing/anti-icing fluids are described as follows:

a. The high speed ramp test is used to simulate large jet aircraft takeoffs, with rotation speeds exceeding 100 knots and a time from brake release to rotation speed greater than 20 seconds. The test is conducted at 65 m/s (126 knots), representing a nominal speed at which an aircraft may safely become airborne with one engine inoperative (V_2), after a 25 seconds acceleration at 2.6 m/s^2 (see Figure 1).



- V_s : Startup Velocity
- V_{mc} : Minimum control speed.
- V_1 : Takeoff decision speed. The speed beyond which the takeoff should no longer be aborted.
- V_r : Rotation speed. The speed at which the pilot begins to apply control inputs to cause the aircraft nose to pitch up, after which it will leave the ground.
- V_{mu} : Minimum unstick speed.
- V_{lof} : Lift-off speed.
- V_2 : The speed of an aircraft at 35 ft. altitude when climbing with one engine inoperative.

Figure 1 - V speeds diagram for high speed ramp

b. The low speed ramp test is used to simulate commuter turbo-prop aircraft takeoffs, with rotation speeds between 60 knots and 100 knots, and a time from brake release to rotation speed between 15 seconds and 20 seconds. The test is conducted at 35 m/s (70 knots), representing the lift-off speed (V_{lof}), after a 17 seconds acceleration at 2.1 m/s² (see Figure 2).

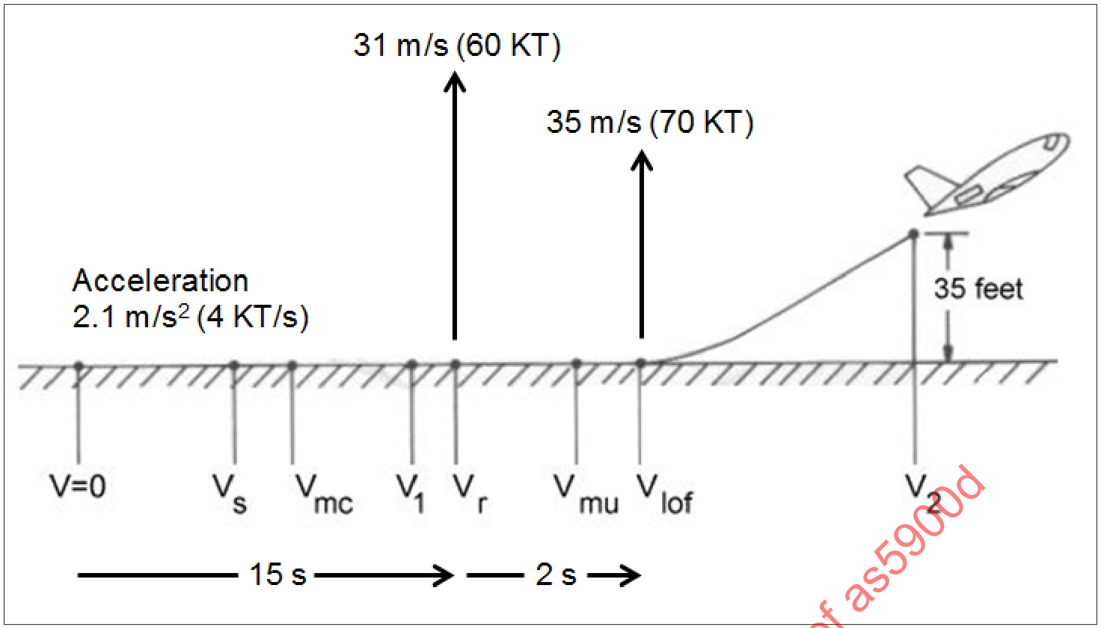


Figure 2 - V speeds diagram for low speed ramp (for speeds definition, see Figure 1)

NOTE: When compensating measures, such as increased rotation speeds, are used for turbo-prop aircraft takeoff procedures, the high speed ramp can apply.

3.2 Reference Fluids

3.2.1 High Speed Ramp Reference Fluid

The fluid shall be homogeneous with:

a. A refractive index, as determined at 20 °C ± 3 °C in accordance with ASTM D1747, of 1.4276 ± 0.0005, and

b. A viscosity, as measured with a Brookfield LV viscometer at 6 rpm LV1 spindle in accordance with ASTM D2196 at 0 °C, of 150 mPa·s ± 25 mPa·s.

Table 1 - High speed ramp reference fluid

Component	Percent by Weight (%w/w)
Propylene glycol	68.0 ± 0.1
Tripropylene glycol	20.0 ± 0.1
Demineralized water	12.0 ± 0.1

3.2.2 Low Speed Ramp Reference Fluid

The low speed ramp reference fluid consists of the high speed ramp reference fluid, as described in 3.2.1, diluted 75% by volume fluid and 25% by volume water, with a refractive index as determined at 20 °C ± 3 °C in accordance with ASTM D1747, of 1.4081 ± 0.0005.

3.3 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 7.

If results from testing in accordance with this test method are to be used to verify that an aircraft ground deicing/anti-icing fluid complies with the acceptance criteria described in Section 7, 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 facility/site. Such test facilities/sites shall be qualified at five-year intervals by submitting current data, which demonstrate that, the facility, instrumentation, procedures, supporting resources, and staff continues to produce acceptable data. The facility/site must be independent from fluid manufacturer.

3.4 Safety Hazards

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

4. TEST FACILITY REQUIREMENTS

The following describes a facility used to measure the aerodynamic flow-off acceptability of deicing/anti-icing fluids. Testing shall be performed in a horizontal duct having the following geometry, flow characteristics, and instrumentation. In addition, the technical capability of the facility/site shall also include the ability to obtain the data required in this section. The test facility shall have access to adequate transducer calibration facilities to ensure accuracy and precision requirements, and trained personnel to execute the test method.

4.1 Calibration and Test Equipment

All temperature sensors, humidity sensors, electronic balances, anemometers, and timing devices shall be maintained in a known state of calibration by means of a documented process. Each instrument used as a reference shall be calibrated by a certified laboratory which uses primary standards that are directly traceable to the U.S. National Institute of Standards and Technology and/or the National Research Council of Canada, or any other recognized national standards organization.

4.2 Test Duct Description

4.2.1 Material

The composition of the test duct shall be Plexiglas.

4.2.2 Dimensions

See Figure 3.

4.2.3 Tolerances

Linear dimensions: ±2% S_2/S_3: 0.927 ± 0.010.

4.2.4 Design Features

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

4.2.4.1 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.

4.2.4.2 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.

4.3 Test Duct Gas Flow Core Characteristics

4.3.1 Test Gas

The test gas used should be air, nitrogen, or another suitable gas proven to have no adverse effect on the overall testing method.

4.3.2 Temperature Measurement

The gas temperature during tests shall be measured at Station 2 approximately 5 mm below the ceiling using copper-constantan thermocouples with a 0.2 mm wire diameter and a measuring junction of approximately 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.

4.3.2.1 Temperature Range

The test gas temperature range shall be 0 °C to approximately -40 °C.

4.3.2.2 Temperature Stability

The test duct shall either be thermally insulated or be installed within the test section and capable of being pre-cooled to ensure thermal equilibrium of the test duct during a test run.

The temperature in the test duct shall be ±2 °C of the target temperature, with a continuous flow ≥60 seconds, 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.

4.3.2.3 Temperature Spatial Uniformity

The temperature spatial uniformity shall be ±1 °C.

4.3.3 Gas Pressures

4.3.3.1 Total Pressure, P_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.

4.3.3.2 Inlet Static Pressure, P_2

Inlet static pressure, P_2, is 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.

4.3.3.3 Outlet Static Pressure, P_3

Outlet static pressure, P_3, is measured using a 3 mm diameter flush orifice tapped into the middle of the ceiling at Station 3.

4.3.3.4 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 Hz 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.

4.3.4 Gas Velocity

The velocity of the gas in the test duct is that at Station 2. Velocity shall be computed using Equation 1 (see 6.4.2.1).

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

4.3.4.1 Velocity Range

4.3.4.1.1 For High Speed Ramp Tests

The high speed ramp velocity range shall be: $V \le 5$ m/s to 65 m/s ± 5 m/s within t = 25 seconds ± 2 seconds, 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 seconds after start, and maintained for 30 additional seconds (see Figure 4). Prior to the flow acceleration, the duct flow shall be capable of a 5 minute settling period with a velocity ≤5 m/s.

4.3.4.1.2 For Low Speed Ramp Tests

The low speed ramp velocity range shall be: $V \le 5$ m/s to 35 m/s ± 3 m/s within t = 17 seconds ± 1 second, 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 seconds after start, and maintained for 40 additional seconds (see Figure 5). Prior to the flow acceleration, the duct flow shall be capable of a five minute settling period with a velocity ≤5 m/s.

4.3.4.2 Velocity Spatial Uniformity

Vertical and lateral: $\Delta U/U_\infty \le \pm$ 0 .005.

Longitudinal: $\Delta U \le$ -1 m/s/m ± 0.008 U_∞/m.

4.3.4.3 Turbulence

Turbulence shall be ≤ 0.005 ($\Delta U/U_\infty$) and may be measured using hot wire or film sensors or other means in accordance with commonly accepted wind tunnel practices.

4.3.5 Relative Humidity

Relative humidity shall be 70% ± 30%, measured with wet bulb-dry bulb thermometers. If an equivalent device is utilized, it shall be regularly calibrated against wet bulb-dry bulb thermometers.

4.4 Test Fluid Temperature Measurement

The test fluid temperature shall be measured at Station 3 within the test fluid, approximately 1 mm above the floor.

4.5 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.

4.6 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 with 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 example facility is shown in Figure 6.

5. TEST FLUID REQUIREMENTS

5.1 General

Fluids submitted for testing shall be experimental fluids or fluids which are representative of production fluids, 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 of AS5901, but unsheared. A volume of about 1 L 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 D1193, Type IV. The manufacturer shall mark each fluid sample container with the company name, product name, lot number, location, and date of manufacture.

5.2 Fluid Identification

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

5.2.1 Viscosity

Viscosity shall be measured by Brookfield LV viscometer, or equivalent, at 0.3 rpm, 6 rpm, and 30 rpm with the appropriate spindle in accordance with ASTM D2196 (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 all tested fluid dilutions.

5.2.2 Surface Tension

The surface tension of the undiluted fluid shall be determined at 20 °C ± 3 °C in accordance with ASTM D1331.

5.2.3 Refractive Index

The refractive index of the undiluted fluid shall be determined at 20 °C ± 3 °C in accordance with ASTM D1747.

5.2.4 pH

The pH of the undiluted fluid shall be determined at 20 °C ± 3 °C in accordance with ASTM E70.

6. TEST PROCEDURE

6.1 Test Requirements

Boundary layer displacement thickness (BLDT) measurements shall be made of the test fluid, of the dry test duct, and of the high speed ramp reference fluid, as described in 3.2.1 for the high speed ramp tests or of the low speed ramp reference fluid, as described in 3.2.2 for low speed ramp tests.

Each tested dilution of AMS1424 Type I fluid shall be tested at selected fluid temperatures including 0 °C, -10 °C, and -20 °C, and to the lowest acceptable aerodynamic temperature (LAAT) identified by the fluid manufacturer (if lower than -20 °C), in approximately 10 °C increments. If the LAAT is not known, the fluid manufacturer may provide an estimate of the LAAT.

For AMS1428 Type II, III, and IV fluids, the neat fluid shall be tested at selected fluid temperatures including 0 °C, -10 °C, and -20 °C, and to the LAAT identified by the fluid manufacturer, in approximately 10 °C increments. The 75/25 and 50/50 fluid dilutions shall be tested at selected test temperatures including 0 °C, -10 °C, and to the LAAT of the corresponding dilution, as identified by the fluid manufacturer.

Three BLDT measurements shall be made within ±3 °C at each target temperature to improve data precision and accuracy. Measurements of the dry test duct BLDT 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 (see 6.2 for information on test sequence for BLDT measurements).

For the initial qualification and first requalification of AMS1428 Types II, III, and IV neat fluids (initially qualified after December 31, 2020), one BLDT measurement shall be made at every 2.5 °C increment down to the LAAT. No dry BLDT or reference fluid BLDT measurements are required at these additional temperatures. For fluids with initial qualification prior to December 31, 2020, these additional temperatures are performed for the next two requalifications instead. The testing facility retains the right to request additional measurements at any time during initial qualification and requalification processes before qualifying a fluid.

These additional data are necessary to ensure sufficient data points to obtain complete knowledge of the fluid BLDT dependence on temperature. This procedure provides for measurements of different saddle points for non-linear cases and is intended to capture the maximum BLDT values. The additional data will facilitate comparison of the fluid results among its requalifications. For a more detailed rationale on the addition of 2.5 °C, see Appendix A.

6.2 Test Run Sequence

6.2.1 Select Target Temperatures

Select the target temperatures as detailed at 6.1.

6.2.2 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 (minimum 12 hours) in a cold chamber; second, once the fluid has been poured on the test duct floor, a 5 minute setting period under a wind velocity hereafter referred to as idle velocity, denoted V_i.

6.2.3 Pre-Cooling of Test Facility

The test facility shall be pre-cooled to achieve test gas and structural thermal stability at the target temperature.

6.2.4 Fluid Water Content Measurement

The fluid's refractive index shall be measured prior to and after each test run, and the fluid's water content change for each tested dilution shall be reported.

6.2.5 Application of Fluid to Test Duct Floor

Approximately 1 L of fluid should be poured onto the test duct floor, and the fluid film shall be leveled at 2 mm using a calibrated scraper, with the film extending from Station 1 to Station 2. Excess fluid may be scraped downstream of Station 2 toward the circuit drain, spreading the excess fluid to avoid fluid buildup at the exit of the test duct.

6.2.6 Fluid Settling Conditions

The test duct and circuit shall be secured, and the fluid shall be subjected to a 5 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.

6.2.7 Takeoff Velocity Time History

The fluid shall be subjected to a simulated aircraft takeoff velocity time history by accelerating the test duct gas flow in accordance with 6.2.7.2 below (also shown in Figure 4 for high speed ramp tests and in Figure 5 for low speed ramp tests). Measurements of t, RH, T_f, T_g, (P_1 - P_2), and (P_2 - P_3) shall be simultaneously recorded.

6.2.7.1 Startup Velocity

The startup velocity, denoted V_s, shall range from 0 to 5 m/s.

6.2.7.2 Acceleration

a. For high speed ramp tests: From t = 0 second to t = 2 seconds ± 2 seconds, wind velocity shall increase to V_s. From t = 2 seconds ± 2 seconds to t = 25 seconds ± 2 seconds, wind velocity shall increase from V_s up to V_m. From t = 25 seconds ± 2 seconds up to 60 seconds wind velocity shall remain constant, equal to V_m (see Figures 1 and 4).

b. For low speed ramp tests: From t = 0 second to t = 2 seconds ± 2 seconds, wind velocity shall increase to Vs. From t = 2 seconds ± 2 seconds to t = 17 seconds ± 1 second, wind velocity shall increase from Vs up to Vm. From t = 17 seconds ± 1 second up to 60 seconds wind velocity shall remain constant, equal to Vm (see Figures 2 and 5).

6.2.7.3 Maximum Velocity

a. For high speed ramp tests: Maximum wind velocity, denoted V_m, shall be equal to 65 m/s ± 5 m/s.

b. For low speed ramp tests: Maximum wind velocity, denoted V_m, shall be equal to 35 m/s ± 3 m/s.

6.2.7.4 BLDT Measurement

The BLDT is obtained by measuring the pressure differences (P_1 - P_2) and (P_2 - P_3) (see Figure 7) at a sampling rate of 10 Hz for the duration of the test.

6.2.8 Termination of Test Run

At time t = 60 seconds, the wind velocity shall be reduced to 0 m/s as quickly as possible.

6.2.9 Residual Fluid Analysis

The fluid remaining on the test duct floor shall be tested for water content using refractive index comparison (compare fluid prior to and after each test run).

6.2.10 Fluid Final Thickness Measurements

6.2.10.1 Type I

Final fluid thickness shall be calculated by determining the average thickness of fluid remaining on the lower plate of the test section. The final thickness of the fluid shall not exceed 400 µm for the high speed ramp test and 600 µm for the low speed ramp test. Measurements shall be taken within 5 minutes of the end of the test at three locations along the flat plate, as follows:

1. On the centerline, 1400 mm ± 10 mm from leading edge of plate.

2. On the centerline, 750 mm ± 10 mm from leading edge of plate.

3. At 750 mm ± 10 mm from leading edge of plate and 2.5 mm ± 0.5 mm from the inside wall of the duct.

6.2.10.2 Types II, III, and IV

Fluid elimination shall be calculated by determining the average thickness of fluid remaining on the lower plate of the test section. At least 74% of the fluid shall be eliminated during the high speed ramp test and 57% during the low speed ramp test. Measurements shall be taken within 5 minutes of the end of the test at the same location than for Type I fluids.

6.2.11 Data Processing

The measured data shall be processed as discussed in 6.4.

6.3 Test Cautions

6.3.1 Safety Hazards

See 3.4 concerning safety hazards.

6.3.2 Frost

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

6.3.3 Variation of Water Content

Dehydration of fluids prior to and during testing may significantly affect the results 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 D1747, 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.

6.3.4 Irregular BLDT Data

The δ^*_d (t) curve for all the dry runs shall be carefully analyzed to detect whether or not it shows evidence of irregular behavior. Irregular behavior includes the following:

6.3.4.1 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. This would result from a progressive deposit of frost on test section walls.

6.3.4.2 Constant BLDT Data

A constant value of BLDT with time during the last 30 seconds of a dry run for high speed ramp tests, or during the last 40 seconds 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.

6.4 Data Processing

6.4.1 Test Data Description

6.4.1.1 Required 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. An example for high speed ramp tests is given in Figure 7 and for low speed ramp tests, in Figure 8.

6.4.1.2 Average Data

The specific results of a given test shall consist of BLDT and fluid temperature values averaged over the period at the end of the acceleration; i.e., between the 27th and 33rd seconds of a high speed ramp test, or between the 19th and 21st seconds of a low speed ramp test.

6.4.2 Calculation Methods

6.4.2.1 Velocity

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

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

where:

ρ = gas density

S_1 = area of Station 1

S_2 = area of Station 2

6.4.2.2 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 of the test runs. The average BLDT over the test duct perimeter (δ^*_{ave}) is evaluated at Station 3 using Equation 2, obtained from the application of mass conservation and Bernoulli equations.

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

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 of the test section walls are in the same dry state, and the previous expression (Equation 2) yields the value of the BLDT for every single point around the perimeter:

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

On the other hand, when the test duct floor is covered with a layer of deicing/anti-icing fluid but the top and sides are not, the BLDT is not constant over the perimeter at Station 3. Instead, the BLDT assumes one 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 a perimeter-weighted average of δ^*_d and δ^*_f, the following relationship can be obtained:

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

where:

b = width of the bottom flat plate

This relationship 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:

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

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 Equation 1, the value of δ^*_d to be used in Equation 4.

6.4.2.3 Temperature

Temperature data are produced by calibration of the thermocouples (see 4.3.2).

6.4.2.4 Relative Humidity

Relative humidity data are produced by calibration of the wet bulb-dry bulb thermometers (see 4.3.5).

6.5 Test Bias Accuracy and Precision

6.5.1 General Accuracy

A measure of accuracy of the overall procedure is provided by test duplication. Expected accuracy for δ^*_f values (at a given precise temperature) is about ±0.1 mm. Consequently, taking into account the temperature sensitivity of the results (approximately 0.2 mm/°C), the δ^*_f and δ^*_f values from repeated (duplicate) tests performed at temperatures within ±1 °C shall be within ±0.3 mm.

6.5.2 Dry BLDT Bias

The dry BLDT value will vary with temperatures because of the variation in Reynolds Number. Nonetheless, it 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 mm and 2.8 mm values correspond to theoretical expected values, and the variation from those values can be considered as a general bias of the facility, normally due to the initiation condition of the boundary layer.

6.5.3 Fluid BLDT Bias

Since the dry BLDT value is used in the candidate fluid’s 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.

7. DEICING/ANTI-ICING FLUID ACCEPTANCE CRITERIA

7.1 Fluid Acceptance Criteria

7.1.1 High Speed Ramp Tests

The maximum acceptable δ^*_f value as a function of temperature is established according to dry and reference results (see 6.1). The δ^*_{-20} value is used as the upper limit for BLDT values. This value is:

$$\delta^*_{-20} = \delta^*_r - 0.18(\delta^*_r - \delta^*_d)_{-20} \quad \text{(Eq. 6)}$$

where:

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

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

NOTE: For more information on the modification of the high speed ramp acceptance criteria in revision D of this document, see Appendix B.

7.1.2 Low Speed Ramp Tests

The maximum acceptable δ^*_f value as a function of temperature is established according to dry and reference results (see 6.1). The δ^*_{-20} value is used as the upper limit for BLDT values. This value is:

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

where:

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

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

7.2 Fluid Acceptance Criteria Background

7.2.1 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 deicing/anti-icing fluids, refer to ARP6852, Appendix A.

NOTE: For more detailed information on the modification of the high speed ramp acceptance criteria in revision D of this document, see Appendix B.

7.2.2 Low Speed Ramp Tests

For more detailed information on the correlation between this standard and the work carried out on two-dimensional typical small turbo-prop aircraft wing models tested to determine lift loss due to the use of aircraft ground anti-icing/deicing fluids, refer to ARP6852, Appendix B, and Transport Canada Document TP11811E (see 2.1.3, Louchez et al.), and their attendant bibliographies.

7.3 Fluid Acceptance

7.3.1 Initial Testing

A deicing/anti-icing fluid is acceptable at an “averaged test temperature” if none of the independent BLDT measurements is greater than the acceptance criteria as defined in 7.1, given that it meets the maximum thickness requirement of AMS1424 for Type I or the elimination requirement of AMS1428 for Types II, III, and IV. The averaged 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 9), and the fluid manufacturer shall be informed that the fluid cannot be used in that temperature.

7.3.2 Re-Testing

If any data point fails to meet the specified acceptance criteria, disposition of the data point may be based upon three additional data points for each non-conforming data point. Failures of any re-test 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.

7.4 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.

8. TEST RESULTS

Test results shall consist of the following:

- A data sheet containing the fluid identification parameters defined in 5.2 (see Figure 9).
- A tabulation summarizing the BLDT measurements for each fluid, with the corresponding dry-wall BLDT measurements (see Figure 10).
- Data from each test run (see Figure 7 for a high speed ramp test and Figure 8 for a low speed ramp test).
- A graphic presentation of the test fluid, reference fluid, and dry test duct BLDT measurements, along with the fluid acceptance criteria described in 7.1 (see Figure 11 for a high speed ramp test and Figure 12 for a low speed ramp test).
- Lowest acceptable aerodynamic temperature (LAAT) of each tested fluid dilution.
- Statement from the aerodynamic acceptance test facility regarding acceptability of the fluid with respect to the requirements of Section 7.
- Evaluation of water content variation in the test fluid during the test run; a cautionary statement shall be issued if the water content variation is in excess of ±2%.

9. REPORT

The report of the test results shall contain the following:

- The fluid manufacturer's identification statement, as described in 5.1.
- If results from testing in accordance with this standard are to be used for SAE qualification of an aircraft deicing/anti-icing fluid, which requires that the fluid comply with the acceptance criteria described in Section 7, 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 3.3.
- If results from testing in accordance with this standard are to be used for SAE qualification of an aircraft deicing/anti-icing fluid, which requires that the fluid comply with the acceptance criteria described in Section 7, the report shall include a statement attesting independence of the aerodynamic acceptance test facility from fluid manufacturer, as discussed in 3.3.
- The report shall include the fluid manufacturer's product name cross-referenced to the aerodynamic acceptance facility's reference.
- The test results, as described in Section 8.

10. NOTES

10.1 Revision Indicator

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 document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

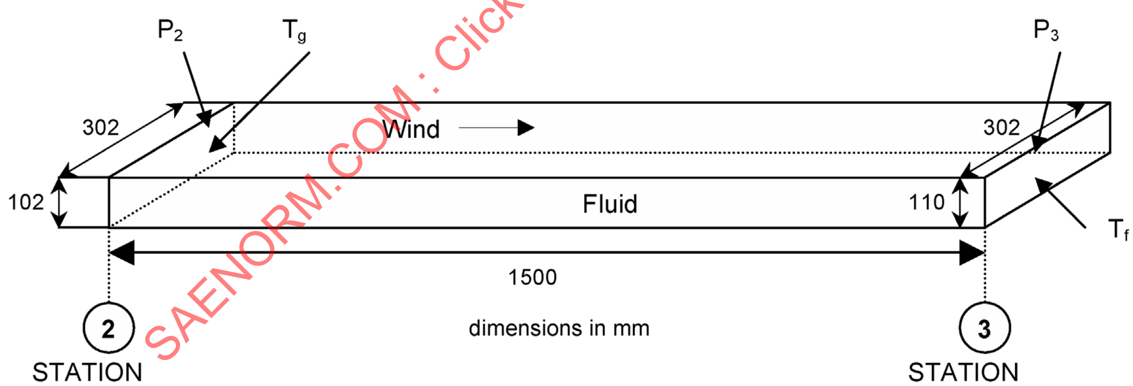


Figure 3 - Test duct schematic

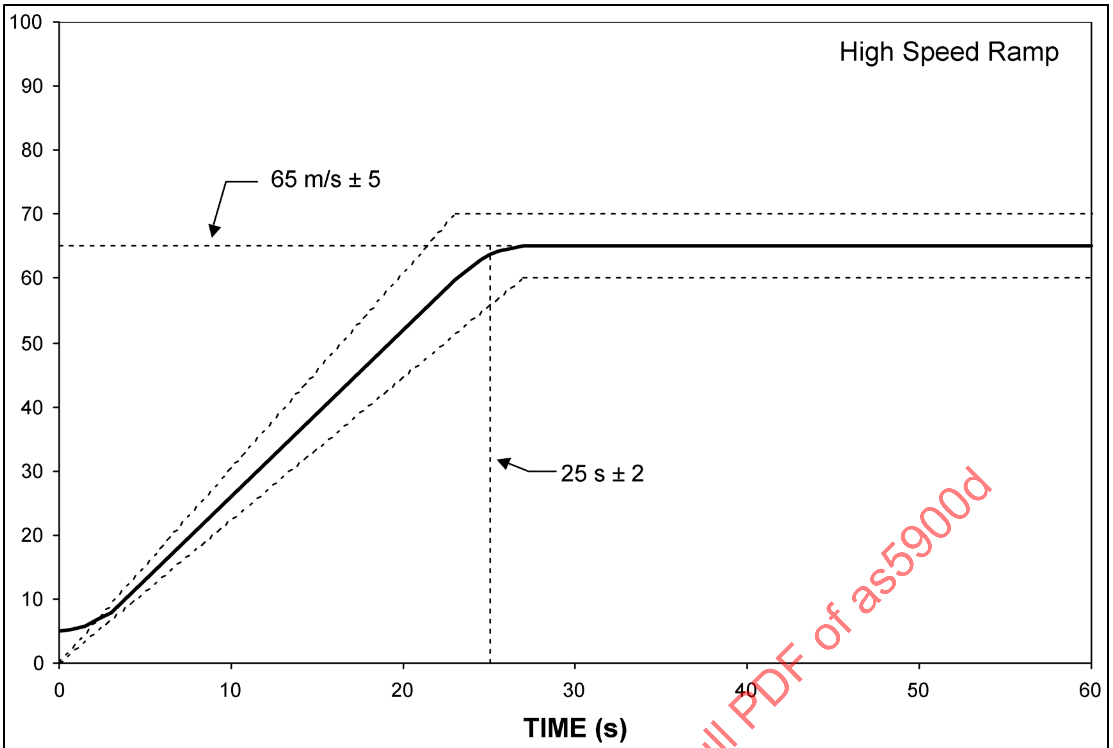


Figure 4 - Takeoff ground acceleration simulation for high speed ramp

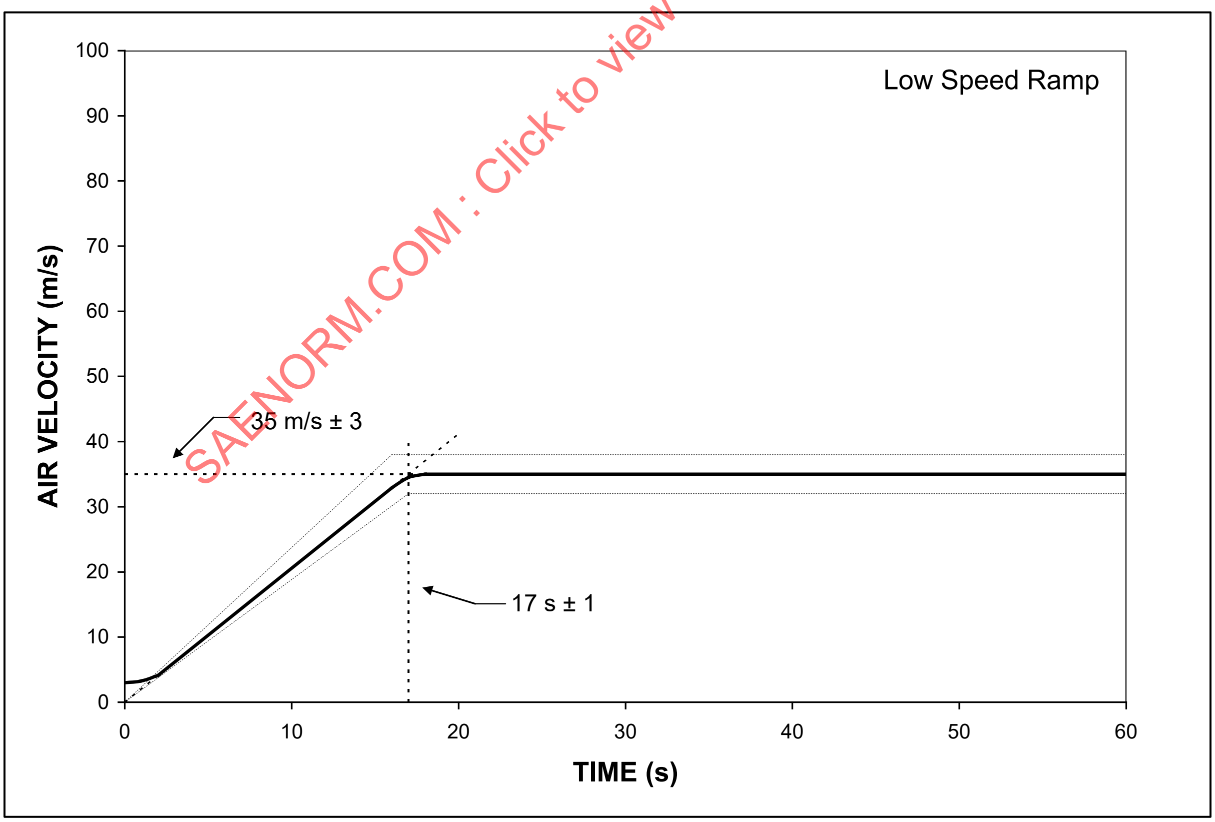
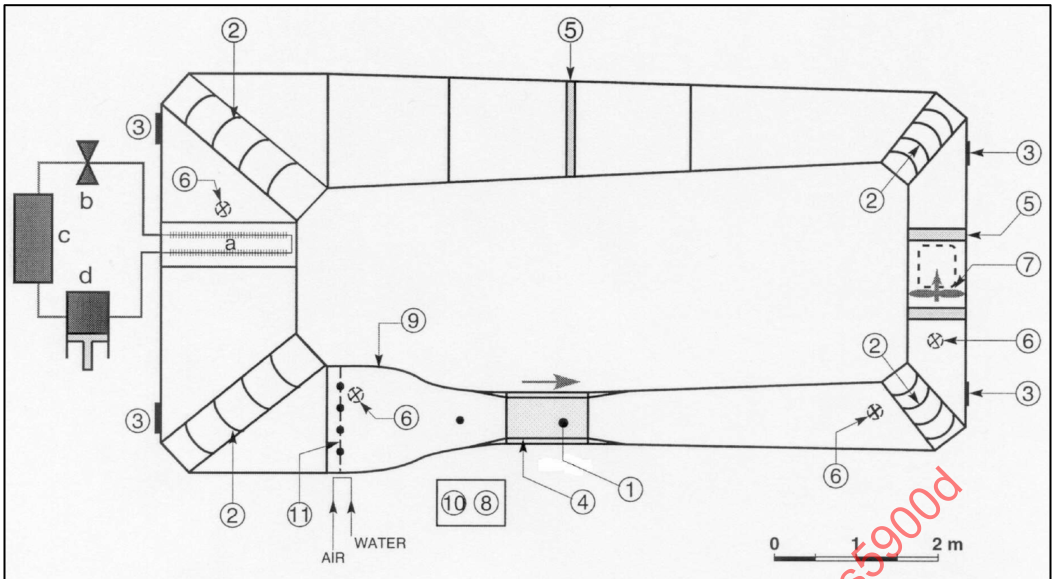


Figure 5 - Takeoff ground acceleration simulation for low speed ramp



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 6 - Example of facility schematic

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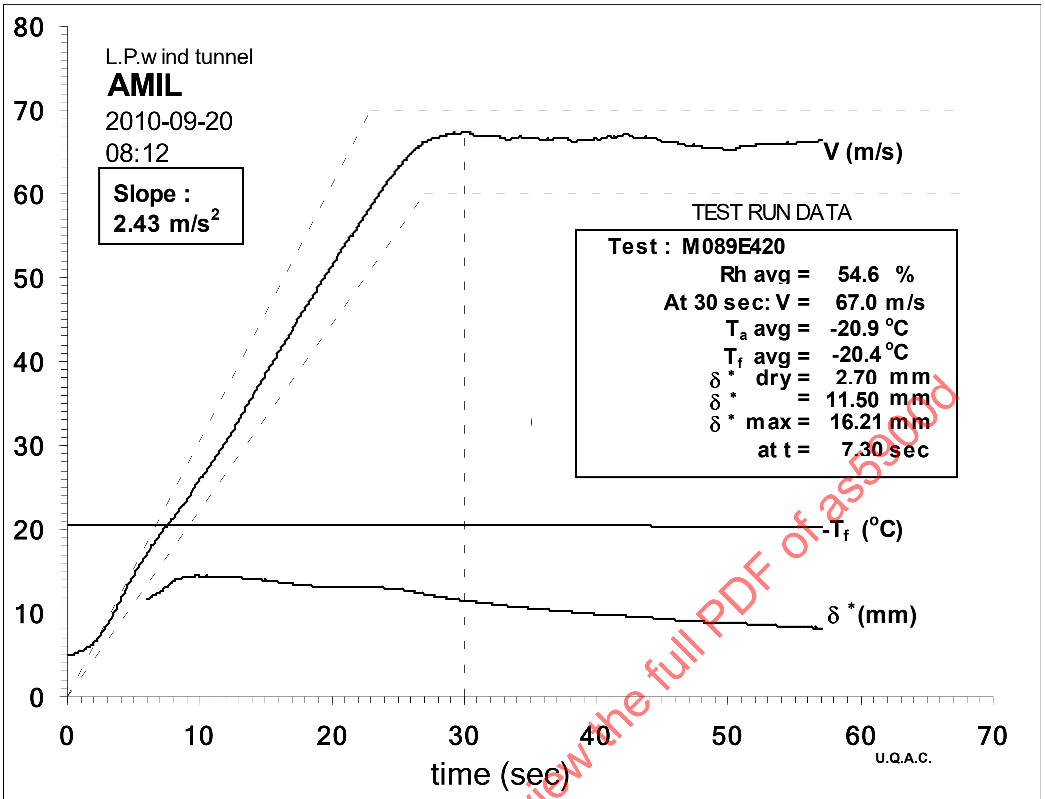

CRITICAL TIME TEST DATA AVERAGED OVER ONE SECOND

time Sec	T_a °C	T_f °C	Rh %	P_1-P_2 "H_2O	V m/s	P_2-P_3 "H_2O	δ * mm
27	-21.4	-20.4	51.3	12.61	67.4	2.53	12.18
28	-21.3	-20.4	51.7	12.37	66.7	2.41	11.96
29	-21.3	-20.4	51.7	12.65	67.5	2.34	11.58
30	-21.3	-20.4	52.3	12.45	66.9	2.28	11.50
31	-21.2	-20.4	52.6	12.79	67.8	2.26	11.24
32	-21.2	-20.4	52.7	12.44	66.9	2.15	11.10
33	-21.2	-20.4	53.0	11.75	65.0	2.04	11.13

Averages between 27 and 33 seconds:

30	-21.3	**-20.4**	52.2	12.47	67.0	2.28	**11.50**

Test Duct Dimensions :

S2 = 30814.039 mm² S3 = 33213.753 mm² B3 = 302.108 mm C3 = 824.433 mm

Figure 7 - Example of data acquired during high speed ramp test run

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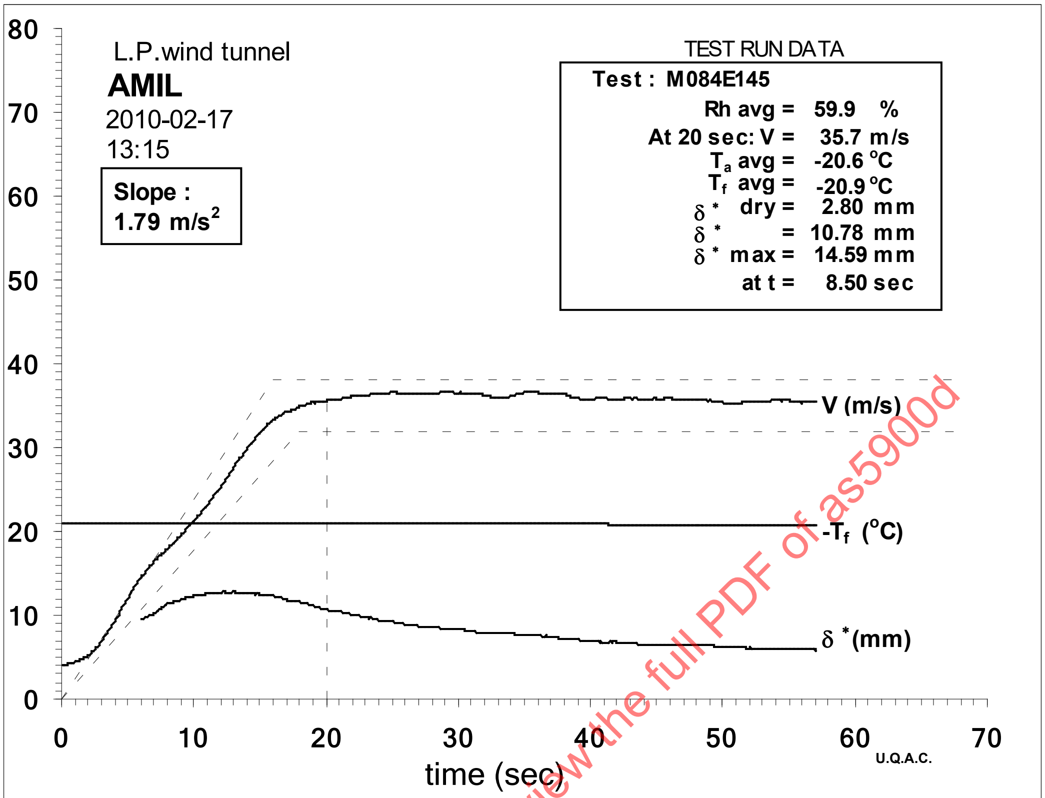

CRITICAL TIME TEST DATA

time Sec	T_a °C	T_f °C	Rh %	P_1-P_2 "H_2O	V m/s	P_2-P_3 "H_2O	δ * mm
19	-20.9	-21.0	57.6	3.40	35.0	0.57	10.91
20	-20.8	-21.0	57.6	3.54	35.7	0.60	10.99
21	-20.9	-21.0	57.7	3.67	36.4	0.57	10.33

Averages :

20	-20.8	**-21.0**	57.6	3.54	35.7	0.59	**10.78**

Test Duct Dimensions :

S2 = 30874.292 mm² S3 = 33317.997 mm² B3 = 302.311 mm C3 = 825.043 mm²

Figure 8 - Example of data acquired during low speed ramp test run

Company Name	Product	Color	Manufacture Location	Manuf. Date	AMIL Label	Recep. Date
AMIL	Reference Fluid lot #	Colorless	Saguenay, Quebec (Canada)			

	Apparent Surface Tension (± 0.5)		pH (± 0.1)		Refractive Index (± 0.0002)	
Fluid	T °C	dynes/cm	T °C	Value	T °C	Value
	Not required					

Fluid	Temp	0.3 RPM			6 RPM			30 RPM		
	(°C)	Viscosity	Accuracy	Spindle #	Viscosity	Accuracy	Spindle #	Viscosity	Accuracy	Spindle #
	20	< 20	200	1	7	10	1	7.4	2	1
	0	< 20	200	1	14	10	1	14.0	2	1
	-10	20	200	1	22	10	1	22.0	2	1
	-20	40	200	1	42	10	1	42.0	2	1
	-30	100	200	1	87	10	1	87.0	2	1

Fluid	Temp	0.3 RPM			6 RPM			30 RPM		
	(°C)	Viscosity	Accuracy	Spindle #	Viscosity	Accuracy	Spindle #	Viscosity	Accuracy	Spindle #
	20	< 20	200	1	4	10	1	4.0	2	1
	0	< 20	200	1	7	10	1	7.6	2	1
	-10	< 20	200	1	12	10	1	12.2	2	1
	-20	20	200	1	21	10	1	21.2	2	1
	-25	20	200	1	25	10	1	25.2	2	1

Fluid	Temp	0.3 RPM			6 RPM			30 RPM		
	(°C)	Viscosity	Accuracy	Spindle #	Viscosity	Accuracy	Spindle #	Viscosity	Accuracy	Spindle #
	20	40	200	1	34	10	1	34.0	2	1
	0	160	200	1	157	10	1	157.0	2	1
	-10	440	200	1	435	10	1	440	10	2
	-20	1 400	1000	2	1 390	50	2	1 400	40	3
	-30	3 700	1000	2	3 675	50	2	3 692	40	3

Figure 9 - Example of test fluid identification sheet

TEST CODE	T_a °C	T_f °C	Rh %	t_o (1) µm	t_{end} (2) µm	FE(3) %	WC(4) %	V(5) m/s	δ* mm
I374A491	-0.1	0.0	94.8	2067	68	96.7	6.94*	67.1	3.69
I374A490	-0.8	-0.4	89.0	2067	76	96.3	6.29*	66.8	3.75
I374A489	-0.9	-0.5	88.2	2067	58	97.2	6.29*	66.8	3.75
I374E501	-20.9	-20.4	51.9	2000	152	92.4	0.16	67.5	6.17
I374E502	-20.9	-20.9	53.7	1867	152	91.9	0.16	66.9	6.15
I374E503	-20.7	-21.0	56.7	1867	152	91.9	0.16	67.1	6.16
I374H505	-33.5	-32.0	43.4	1867	211	88.7	0.16	67.6	9.06
I374H507	-34.0	-32.4	42.7	1800	229	87.3	-0.65	66.9	9.16
I374H504	-34.1	-32.5	41.9	1933	236	87.8	0.00	66.9	9.23
I374H506	-34.3	-32.8	42.5	1800	211	88.3	-2.10*	67.1	9.29

*caution : value outside the ± 2% range

Acceptance Criteria :

D_0 = 8.89 mm D_{-10} = 9.37 mm D_{-15} = 9.61 mm D_{-20} = 9.85 mm

1. Thickness of the fluid measured at the beginning of the test
2. Thickness of the fluid measured at the end of the test
3. Fluid Elimination
4. Water Change
5. Air velocity 30 seconds after the beginning of the test

TEST CODE	T_a (°C)	T_f (°C)	Rh (%)	V (m/s)(1)	δ^*_{dry} (mm)
DRY_A450	0.2	1.9	92.8	65.7	2.71
DRY_A452	0.7	0.9	95.8	65.7	2.74
DRY_A453	-0.1	0.7	89.6	65.6	2.74
DRY_A451	-0.7	0.3	79.0	66.0	2.74
DRY_C454	-10.6	-8.3	77.5	65.8	2.72
DRY_C455	-10.3	-8.4	63.0	65.6	2.72
DRY_C456	-10.4	-9.0	64.2	65.6	2.73
DRY_D458	-15.4	-13.9	61.4	65.6	2.72
DRY_D459	-15.4	-14.0	62.3	65.8	2.72
DRY_D457	-16.4	-14.5	73.4	65.7	2.72
DRY_E465	-19.7	-18.5	55.4	65.3	2.74
DRY_E464	-19.9	-18.6	55.0	65.2	2.75
DRY_E463	-20.8	-19.1	60.9	65.8	2.76
DRY_F461	-25.6	-23.7	58.4	64.7	2.74
DRY_F462	-25.9	-24.0	56.3	64.4	2.75
DRY_F460	-26.1	-24.8	66.9	65.6	2.68
DRY_H468	-33.5	-31.6	59.2	65.4	2.70
DRY_H466	-34.0	-32.6	50.5	66.0	2.67
DRY_H467	-34.0	-32.7	50.1	65.7	2.65

1. Air velocity 30 seconds after the beginning of the test

Figure 10 - Example of test data summary