



AEROSPACE RECOMMENDED PRACTICE

ARP5945™

REV. B

Issued 2007-07
Revised 2025-02

Superseding ARP5945A

Endurance Time Test Procedures for SAE Type I Aircraft Deicing/Anti-Icing Fluids

RATIONALE

This document has been updated to reflect current practices for conducting endurance time tests with SAE Type I fluids. Notably, updates have been made to test materials used, and the section describing the criteria for conducting repeat tests in simulated freezing precipitation has been clarified.

Additional revisions have been made to meet the document harmonization and quality criteria issued by the SAE G-12 Steering Committee in October 2023. Specifically, the spellings of various technical terms have been revised to conform to the preferred spellings put forth by the committee. Finally, a page numbering issue in the previous version of the document has been corrected.

FOREWORD

This document describes the procedures to be employed in the conduct of endurance time testing of aircraft deicing/anti-icing fluids qualified under the requirements of AMS1424 (SAE Type I).

Endurance time can be defined as the time that a fluid can endure controlled and defined temperature and freezing precipitation conditions before attaining visual failure. These temperature and precipitation conditions were developed taking into consideration meteorological data. The resulting endurance time data were presented to the SAE G-12 Holdover Time Committee for examination and validation. If found to be acceptable, these data are used to update holdover time guidelines. Holdover time guidelines are published by the U.S. Federal Aviation Administration (FAA) and Transport Canada. Additional testing on the fluid may be required by the FAA or Transport Canada for inclusion in their guidelines.

This Aerospace Recommended Practice (ARP) provides detailed test procedures for laboratory endurance time testing in freezing fog, freezing drizzle, light freezing rain, rain on a cold-soaked wing, and snow. It also provides detailed test procedures for natural outdoor endurance time testing in snow and frost.

This version of the ARP includes two indoor laboratory snow procedures in addition to the outdoor natural snow procedure. Historically, laboratory-obtained endurance times were often shorter than those obtained through outdoor natural snow testing, most noticeably with higher rates of precipitation and/or colder temperatures. However, recent outdoor testing has demonstrated some discrepancies where outdoor results yielded shorter endurance times than laboratory results. Consequently, until a relationship between indoor and outdoor testing environments has been adequately characterized, the laboratory snow data should be examined on a case-by-case basis.¹

¹ As of May 2017, regulators do not accept solely generated laboratory snow testing results as a basis to derive/provide fluid-specific holdover times.

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Efforts to date to develop a laboratory test procedure for frost have been unsuccessful. A preliminary test procedure for natural frost testing is included in this version of the ARP. Natural frost testing is currently used to validate generic holdover times; it is not used to determine holdover times.

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1. SCOPE

1.1 Purpose

The purpose of this ARP is to provide the sample selection criteria and endurance time test procedures for SAE Type I aircraft deicing/anti-icing fluids required for the generation of endurance time data of acceptable quality for review by the SAE G-12 Holdover Time Committee.

A significant body of previous research and testing has indicated that all Type I fluids formulated with conventional glycols, as defined in 3.1.1 of AMS1424, perform in a similar manner from an endurance time perspective. This applies to Type I deicing/anti-icing fluids formulated with propylene glycol, ethylene glycol, and diethylene glycol only. As a result, Type I deicing/anti-icing fluids containing these glycol bases no longer require testing for endurance times. The methods described in this ARP shall be employed, however, if endurance time testing of a conventional glycol-based Type I deicing/anti-icing fluid is desired or requested by a fluid manufacturer, operator, or other organization. Fluids formulated with non-conventional glycol, as defined in 3.1.1 of AMS1424, and all non-glycol Type I deicing/anti-icing fluids must be tested for endurance times using the methods described in this ARP (as appropriate).

1.2 Examination of Endurance Time Data

Periodically, the SAE G-12 Holdover Time Committee examines endurance time test data of SAE Type I aircraft deicing/anti-icing fluids and validates, based on the endurance time data, if such fluids can be used in conjunction with generic Type I HOT guidelines. As the SAE G-12 Holdover Time Committee examines endurance time data, it will take into consideration the effects of natural variability of precipitation both in time and space to generate or adjust holdover time guidelines.

1.3 Limits

This ARP provides test procedures for laboratory simulation of freezing fog, freezing drizzle, light freezing rain, rain on a cold-soaked wing, and snow. It also provides test procedures for outdoor testing in natural snow and natural frost. Other forms of freezing/frozen precipitation are not addressed in this ARP.

1.4 Testing Agent(s)

1.4.1 Independence of the Testing Agent

The testing agent shall be independent of the fluid manufacturer and fluid vendor.

1.4.2 Role of the Testing Agent

The testing agent(s) shall coordinate activities related to the sample selection procedures (see Section [3](#)) and shall conduct endurance time testing (see Sections [4](#) to [12](#)) at a suitable facility on the selected fluid.

1.4.3 Sending Samples

Fluid samples for testing shall be sent to a designated testing agent for verification under the sample selection procedures. In turn, the testing agent, if the requirements of the applicable sample selection procedure are fulfilled, shall send the samples to the facility/site for endurance time testing.

1.5 Test Facility/Site

1.5.1 Independence of the Test Facility/Site

The test facility/site shall be independent of the fluid manufacturer and fluid vendor.

1.6 Units

The values stated in International System (SI) units are to be regarded as the standard.

1.7 Safety

While the materials, methods, applications, and processes described or referenced in this ARP may involve the use of hazardous materials, this ARP does not address the hazards that 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. 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
AMS4037	Aluminum Alloy, Sheet and Plate, 4.4Cu - 1.5Mg - 0.60Mn (2024; -T3 Flat Sheet, -T351 Plate), Solution Heat Treated
AMS4041	Aluminum Alloy, Sheet and Plate, Alclad, 4.4Cu - 1.5Mg - 0.60Mn (2024, -T3 Sheet/-T351 Plate with 1-1/2% Alclad), Solution Heat Treated, Cold Worked and Naturally Aged
AMS4462	Aluminum Alloy, Sheet and Plate, Alclad, 4.4Cu - 1.5Mg - 0.60Mn (Alclad 2024, -T3 Sheet, -T351 Plate) Solution Heat Treated, Cold Worked and Naturally Aged
AS5900	Standard Test Method for Aerodynamic Acceptance of AMS1424 and AMS1428 Aircraft Deicing/Anti-Icing Fluids
AS5901	Water Spray and High Humidity Endurance Test Methods for AMS1424 and AMS1428 Aircraft 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

2.1.3 ISO Publications

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

ISO 10012 Measurement management systems - Requirements for measurement processes and measuring equipment

2.1.4 Transport Canada Publications

Available from Transport Canada, Tower C, Place de Ville, 330 Sparks Street Ottawa, Ontario K1A 0N5, Tel: 1-800-305-2059, www.tc.gc.ca.

Transport Canada Holdover Time Guidelines (These are published every winter. Always use the latest issue.)

2.1.5 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

FAA Holdover Time Guidelines (These are published every winter. Always use the latest issue; search for "FAA Holdover Time" at www.faa.gov/other_visit/aviation_industry/airline_operators/airline_safety/deicing/.)

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

Godard, L. (1959). Procédé pour déterminer les dimensions des gouttelettes de brouillard ou de nuages, Bulletin de l'Observatoire du Puy-de-Dôme, 11-13. (English translation: Procedure for the Determination of Fog and Cloud Droplet Dimensions).

Godard, S. (1960). Mesure des gouttelettes de nuage avec un film de collargol. Bulletin de l'Observatoire du Puy-de-Dôme, 41-46. (English translation: Measurement of Cloud Droplets using a Colloidal Film).

Mason, B.J. (1971), *Physics of Clouds* (2nd ed.). Oxford University Press.

Guide to Meteorological Instruments and Methods of Observation, World Meteorological Organization (1983).

3. SAE TYPE I FLUID SAMPLES ELIGIBLE FOR ENDURANCE TIME TESTING

3.1 SAE Type I Fluids Required to Undergo Endurance Time Testing

A significant body of previous research and testing has indicated that all Type I fluids formulated with conventional glycols, as defined in 3.1.1 of AMS1424, perform in a similar manner from an endurance time perspective. This applies to Type I deicing/anti-icing fluids formulated with propylene glycol, ethylene glycol, and diethylene glycol only. As a result, Type I deicing/anti-icing fluids containing these glycol bases no longer require testing for endurance times. The methods described in this ARP shall be employed, however, if endurance time testing of a conventional glycol-based Type I deicing/anti-icing fluid is desired or requested by a fluid manufacturer, operator, or other organization. Fluids formulated with non-conventional glycol or with non-glycol, as defined in 3.1.1 of AMS1424, must be tested for endurance times using the methods described in this ARP (as appropriate). This is to ensure the endurance time performance of these fluids are similar to the performance of the Type I fluids used to generate the currently accepted Type I generic holdover times.

3.2 Requirements

3.2.1 Normal Batch

The sample shall be fluid taken from a batch in a form expected to be supplied to users by the vendor.

3.2.2 Ready-to-Use Fluid

If the fluid is intended for use undiluted (ready-to-use), the water spray endurance test (WSET) result of the sheared sample must not be less than 3 minutes. (In the normal qualification process, the WSET is performed on fluids that have been sheared in accordance with the methods outlined in 3.3.4 of AMS1424 for anti-icing performance tests. To ensure the candidate fluid fulfills the normal requirement of qualification, its WSET must be conducted on a sheared sample.)

3.2.3 Fluid Concentrate

If the fluid is intended for use as a dilution of a concentrate, the WSET result (as defined in AS5901) of a sheared 50/50 volume ratio of fluid and hard water (see [3.2.4](#)) must not be less than 3 minutes.

3.2.4 Composition of Hard Water

To make hard water, the following procedure shall be used: Dissolve 400 mg $\pm$ 5 mg calcium acetate dihydrate $\text{Ca}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 2\text{H}_2\text{O}$ and 280 mg $\pm$ 5 mg magnesium sulfate heptahydrate $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, both of analytical reagent quality, in 1 L of ASTM D1193 Type IV water. If calcium acetate dihydrate is not readily available, use calcium acetate monohydrate or anhydrous calcium acetate of analytical reagent quality and ensure the hard water has 82.6 mg/L Ca^{++} by atomic absorption (or equivalent method).

3.2.5 Manufacturer's Documentation

The fluid manufacturer shall send or make available the following documentation to the designated testing agent:

- a. The volume dilution versus freezing point data for the fluid (data needed to prepare the dilutions).
- b. The freezing point versus refraction at 20 °C data for the fluid (to check the correctness of dilutions).
- c. A manufacturer's safety data sheet (SDS) and/or other safety-related documentation as deemed appropriate.

3.3 Testing Agent Duties

3.3.1 Conduct WSET and Report WSET Results for Ready-to-Use Fluid

If the fluid is intended for use undiluted, the designated WSET testing agent shall:

- a. Perform a WSET on the sheared sample.
- b. Report the results to the manufacturer.

3.3.2 Conduct WSET and Report WSET Results on Fluid Concentrate

If the fluid is intended for use diluted, the designated WSET testing agent shall:

- a. Dilute the sample 50/50 by volume with hard water (see [3.2.4](#)).
- b. Conduct the WSET on the sheared, diluted fluid sample.
- c. Report the results to the manufacturer.

3.3.3 Check Documentation

The designated endurance time testing agent shall make sure they have on hand the manufacturer's documentation described in [3.2.5](#).

3.3.4 Check WSET

The designated endurance time testing agent shall ensure that endurance time testing is completed only with fluids with WSET results no less than 3 minutes.

3.4 Condition of the Sample to be Tested for Endurance Times

3.4.1 Freezing Point

If the fluid is intended for use diluted, the sample shall be tested at dilutions where the freezing point is 10 °C below the air temperature. The dilutions shall be prepared by the designated testing facility using hard water (see [3.2.4](#)).

3.4.2 Lowest Test Temperature

The test temperature shall not be lower than the lowest temperature associated with acceptable aerodynamic performance in accordance with AS5900, as reported in the qualification test report provided to the designated testing agent as part of the manufacturer's documentation. There is no reason to test below the lowest aerodynamic acceptance temperature of the fluid. Testing may be conducted below the lowest temperature with acceptable aerodynamic performance, but the fluid can't be used below this temperature.

3.4.3 Shear Level of Fluids Employed in Endurance Time Testing

Fluids whose sheared samples have met the WSET requirements of [3.3.1](#) or [3.3.2](#) may be tested for endurance times. The fluid shall be sheared in accordance with the methods outlined in 3.3.4.1 of AMS1424 for use in endurance time testing.

4. ENDURANCE TIME TEST - GENERAL

4.1 Purpose

This section of the ARP establishes the general minimum requirements for test equipment and test procedures used to carry out laboratory endurance time tests of aircraft deicing/anti-icing fluids under conditions of freezing fog, freezing drizzle, light freezing rain, and rain on a cold-soaked wing. The primary purpose for such a test method is to determine endurance time for these conditions under controlled laboratory conditions for SAE Type I fluids.

This section does not apply to natural snow or natural frost testing (see Sections [11](#) and [12](#)) or to laboratory snow testing (see Section [10](#)), except where noted otherwise.

4.2 Summary of the Tests

Fluids to be evaluated are applied to test plates exposed to freezing fog, snow, freezing drizzle, light freezing rain, and rain on a cold-soaked wing conditions. Endurance times are evaluated by measuring the minimum exposure time before a specified degree of freezing occurs.

4.3 General Versus Specific Requirements

This general section (see Section [4](#)) covers requirements that are common to laboratory conditions (except where otherwise noted). Sections [6](#) to [9](#) establish the specific requirements for each precipitation condition.

4.4 Testing Facility/Site Qualification

Substantiation that the testing facility and associated staff and resources satisfy the requirements of this endurance time test method, including calibration and measurement methods, shall be documented. Such documentation shall be kept for 3 years.

This requirement (see [4.4](#)) is also applicable to Sections [10](#), [11](#), and [12](#).

4.5 General Environmental Chamber Equipment

4.5.1 Air Temperature Sensor

The air temperature sensor shall be in proximity to the test plate, typically within 1.5 m of the side of the test plate, but outside the spray area (if any). The distance and position of the sensing device shall be reported.

4.5.2 Lighting

The test chamber shall be equipped with artificial lighting facilitating ice formation observation but positioned such that it does not interfere with air, fluid, and plate temperatures.

4.5.3 Data Acquisition System

The air temperature, plate temperature, and humidity sensors shall be linked to an electronic data acquisition system as a means of checking and recording the environmental characteristics of the test chamber and test plates throughout the course of a test run.

4.5.4 Temperature Control Equipment

The air temperature (for all conditions) and test plate temperature, if required by the test protocol, shall be maintained at the required level using heat exchangers connected to a temperature control system such as a solid state temperature sensor with a platinum resistance probe (100 Ω at 0 °C) coupled to a proportional temperature controller having a minimum resolution of 0.5 °C.

4.5.5 Air Distribution System

The air distribution system shall be comprised of a fan or fans to provide air recirculation through the main body of the test chamber and to the heat exchanger. Ducting for the passage of air at both the inlet and the outlet of 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 temperature level. Airflow shall be measured using a suitable anemometer or velocity meter (see [4.6.4](#)).

4.5.6 Water Supply for Nozzles

Water supplied to nozzles shall conform to ASTM D1193 Type IV water or a hardness of less than 300 ppm reported as CaCO_3 .

4.6 Calibration and Measurement Methods

4.6.1 Calibration of Standard Measuring Devices

All temperature sensors, humidity sensors, electronic balances, anemometers, velocity meters, and timing devices shall be maintained in a known state of calibration in accordance with recognized international standards, such as ISO 10012, by calibrating each instrument at least once every 6 months or whenever a piece of equipment is repaired, replaced, moved, or otherwise suspect. A written record of the calibrations shall be kept available.

4.6.2 Icing Intensity Measurement Methods

The following methods are intended to produce the same results.

4.6.2.1 Icing Intensity Measurement Methods Using Reference Ice-Catch Plates or Pans (Method A)

In most cases, the icing intensity on a test plate with fluid cannot be measured directly as the fluid and some of the precipitation will flow off of the test plate, preventing the weighing of the total precipitation for the duration of the test. Icing intensity is generally established by catching the precipitation with a specified number of so-called reference ice-catch plates or pans placed adjacent to the test plate and weighing the amount of precipitation for the duration of the test period. At least one example of an appropriate icing intensity measurement method using reference ice-catch plates or pans is given in this ARP for each of the conditions listed (see Sections [6](#) to [12](#)). This one example for each condition is called Method A to differentiate it from other icing intensity methods.

4.6.2.2 Icing Intensity Measurement Method Using Regression Analysis (Method B)

An alternative way of measuring icing intensity is to catch the precipitation a number of times at the very position of the test plate before and after the test and average the results. For this method, called Method B, at least two tests with fluid are performed and endurance times determined at each of the targeted rates. The results are analyzed using regression analysis to determine the endurance time at the targeted rates of precipitation. Examples of icing intensity using regression analysis (Method B) are described in Sections [6](#) and [11](#).

4.6.2.3 Other Icing Intensity Measurement Methods

Icing intensity measurement methods may differ from methods described in [4.6.2.1](#) or [4.6.2.2](#) depending on the specific configuration of the equipment (e.g., number of ice-catch plates or their geometry) used to create the various precipitation conditions.

4.6.2.4 Documentation

Each facility/site performing endurance time tests shall develop and document appropriate icing intensity measurement methods for each precipitation condition to ensure that the test conditions are within the specified limits. Reports issued by the facility/site shall describe the icing intensity measurement methods and their results.

4.6.3 Measurement Methods for Icing Intensity Variability Across Test Plates

4.6.3.1 Measurement Method for Intensity Variability Across a Test Plate (Used with Method A)

It is important to establish that icing intensity across each test plate is uniform and within specified limits. The icing intensity variability (uniformity or lack of uniformity) across each test plate can be established by periodically replacing the test plates with a specified number of pre-weighed ice-catch plates, weighing the precipitation, and calculating the range. The range is simply the highest value minus the lowest value and is a quantitative representation of the variability of precipitation data across each plate. This range must not exceed limits that are specified for each test condition. The measurement of the icing intensity variability across a test plate shall be run at least every 6 months or whenever a piece of equipment is repaired, replaced, moved, or otherwise suspect.

4.6.3.2 Measurement Method for Intensity Variability Across All Test Plates (Used with Method B)

This method is described in [6.2.2.3](#). The measurement of the icing intensity variability across all test plates shall be run every time tests are performed.

4.6.3.3 Other Methods for Measuring Icing Intensity Variability Across Test Plates

A facility/site may have specific equipment that requires a method for estimating the icing intensity variability across test plates differently than in [4.6.3.1](#) or [4.6.3.2](#). Such other methods are acceptable if they are shown to be equivalent or more conservative.

4.6.4 Horizontal Air Velocity Measurement

Horizontal air velocity shall be measured 50 mm above the surface of the test plate using a velocity meter or anemometer.

4.6.5 Water Droplet Size Measurement

Several methods are available to determine the water droplet size (median volume diameter). [Table 1](#) lists several acceptable methods as a function of droplet size. A description of the methods follows:

- a. **Slide Impact Method with Oil:** 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 an appropriate thickness, will be suitable for certain droplet sizes (see [Table 1](#) for appropriate thickness). The oil may be either a mineral oil or silicone oil. The droplet size is determined by direct observation under a microscope using an eyepiece with the appropriate graticule or from enlarged photographs of the slide.
- b. **Slide Impact Method with Colloidal Silver:** A sample of the water droplets from the precipitation is collected on a microscope slide coated with a colloidal silver solution. A thin film of 95% water and 5% colloidal silver is brushed over a microscope slide. Once the film is dry (about 30 seconds) it is exposed to the water spray, where it becomes permanently marked with the droplet imprints. The droplet diameter is one-third of the print diameter measured under a microscope using an eyepiece with the appropriate graticule or from enlarged photographs of the slide.
- c. **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 toward the surface of the test plate. Analysis of the diffraction patterns gives the size and the distribution of the droplets. Some equipment is capable of achieving this in real time.
- d. **Dye Stain Method:** Prepare discs by dusting filter paper discs with a water-activated, very finely divided powder form of methylene blue dye. The prepared discs are manually positioned under precipitation for a fixed time in order to acquire a droplet size pattern. A calibration curve is then used to convert from the measured diameter of the droplets on the pattern to the experimental median volume diameter.

Table 1 - Examples of water droplet size measuring methods

Droplet Size	Slide Impact with Oil (Required Oil Film Thickness)	Slide Impact with Colloidal Silver	Laser Diffraction	Dye Stain
5 µm		recommended		
20 µm	recommended (500 µm)	recommended	recommended	
200 µm	recommended (1000 µm)			recommended
1000 µm	recommended (2000 µm)			recommended

4.7 General Test Procedures

4.7.1 Test Plate Cleanliness

The test plates shall be free of all visible contamination, smears, or stains, except for markings used to estimate ice coverage. Between test runs, any contamination shall be removed. This can be achieved, for example, by washing with hot water immediately followed by an ethanol rinse (allow the plates to dry after rinsing and ensure they are at the appropriate temperature before use). It can also be achieved by removing all contamination by scraping and squeegeeing the plate and then washing the plate by applying the fluid to be tested and squeegeeing this fluid off before applying the fluid to test.

4.7.2 Appearance of Frozen Contamination

Failure is called when 30% of the plate is covered with frozen contamination. Appearance of this frozen contamination includes, but is not limited to:

- a. An ice front
- b. An ice sheet
- c. Slush, in clusters or as a front
- d. Disseminated fine ice crystals

- e. Frost on the treated surface
- f. Clear ice pieces partially or totally embedded in fluid
- g. Snow bridges on top of the fluid

4.7.3 Delayed Crystallization

Delayed crystallization may occur during the course of a test run (for all precipitation conditions except for snow, which is already crystalline) and is defined as a sudden (within 30 seconds) appearance of frozen contamination covering a large surface area of a test plate. If this sudden coverage exceeds the percentage of the test plate area that is considered to be a failure, the test is invalid and must be repeated. In the case of suspected delayed crystallization, if the test has been invalidated three times, the plate may be seeded at the center top edge of the plate with an ice crystal to initiate crystallization. Seeding consists of putting an ice crystal in contact with the fluid by means of a chilled metal rod (below 0 °C). If upon seeding, the frozen contamination area suddenly exceeds the percentage of the plate area that is considered to be a failure, the test is invalid.

4.7.4 Report

The report shall include:

- a. Name and address of the facility conducting the tests.
- b. Statement confirming that the test facility is autonomous of the manufacturer and vendor of the fluid.
- c. Date(s) the tests were conducted.
- d. Manufacturer's or vendor's name and address.
- e. Name or reference number and lot number of the fluid tested.
- f. Type of fluid (SAE Type I) and dilution tested (e.g., received SAE Type I concentrate; tested diluted 1:1 with hard water).
- g. Quantity of fluid applied to test plates, if different from the norm.
- h. Summary of test results and the icing intensity results for each test.
- i. Icing intensity measurement method, including ice-catch raw data.
- j. Method of estimation of failure area.
- k. Description of appearance of frozen contamination. For natural snow, report the form of the snow according to [11.4.6](#).
- l. Measurement method for icing intensity variability across test plates, its results (range), and date performed.
- m. Distance and location of air temperature sensor from test plates.
- n. For natural snow tests, orientation of the test stand and direction of the wind.

5. ENDURANCE TIME TEST - LABORATORY FROST

At this time a test procedure for laboratory frost is not available. It may be developed for future versions of this ARP.

6. ENDURANCE TIME TEST - FREEZING FOG

6.1 Freezing Fog Test Equipment and Test Parameters

6.1.1 Environmental Chamber Equipment and Plates

In addition to the requirements given in [4.5](#), environmental chamber and associated equipment requirements for freezing fog endurance time testing are given in [Table 2](#) and in the following paragraphs.

Table 2 - Requirements for freezing fog test equipment

Test Parameters	Requirements
Environmental Chamber	
Minimum volume	7 m ³ for each 300 mm x 500 mm test plate
Air temperature range	0 °C to at least -25 °C
Minimum temperature sampling rate	1 datum per minute
Horizontal air velocity	≤ 0.4 m/s
Relative humidity	> 40%
Test Plates	
Material (aluminum)	Aluminum alloy AMS4037, AMS4041, or AMS4462
Material (composite)	Carbon fiber cross weave fabric
Test plate dimensions	500-mm long x 300-mm wide x 3.2-mm thick
Angle	10.0 degrees ± 0.2 degree
Surface finish (aluminum)	Average surface roughness: Ra ≤ 0.5 µm
Surface finish (composite)	Painted white with aircraft-grade paint
Temperature at start of test	Within 0.5 °C of air temperature
Number of test plates	2 per fluid tested
Fluid application temperature	20 °C ± 5 °C
Ice-Catch Plates (Method A)	
Ice-catch plates	100 mm x 100 mm x 1.6-mm thick
Number of reference ice-catch plates	8 surrounding each test plate
Number of ice-catch plates for measuring icing intensity variability across test plates	12 per test plate
Ice-Catch Pans (Method B)	
Ice-catch pans	277 mm x 540 mm
Number of ice-catch pans	1 per test location
Spray Equipment	
Water supply temperature	Adjusted to produce supercooled water droplets
Water droplet median volume diameter	22 µm ± 5 µm

6.1.2 Test Plates

6.1.2.1 Tests shall be conducted on both aluminum and composite test plates. Specifics of the test plate materials and finishes are given in [Table 2](#).

6.1.2.2 Each test plate is removable and placed on a support that is housed within the environmental chamber.

6.1.2.3 Each test plate shall be equipped with a temperature sensor located on the underside of, or embedded within, the plate. This sensor shall be capable of measuring to an accuracy of ±0.5 °C and shall be linked to an electronic data acquisition system.

6.1.2.4 Method A

The test plate support is set up in such a way that it can accommodate eight ice-catch plates per test plate. The ice-catch plates shall be adjacent to, but not in contact with, each test plate. The test plate support face shall be inclined from the horizontal as specified in [Table 2](#). The test plate shall be placed on the support such that the fluid can freely flow off all edges of the plate. The test stand should be designed as to minimize the contact between the test surface and the support.

6.1.2.5 Method B

The test plate support is set up in such a way that it can accommodate six test plates. The test plate support face shall be inclined from the horizontal as specified in [Table 2](#). The test plate is placed on the support such that the fluid can freely flow off all edges of the plate. The test stand should be designed to minimize the contact between the test surface and the support.

6.1.3 Ice-Catch Pans

The ice-catch pans, described in [Table 2](#) and [Figure 1](#) for Method A or [Table 2](#) for Method B, are used to evaluate the ice-catch.

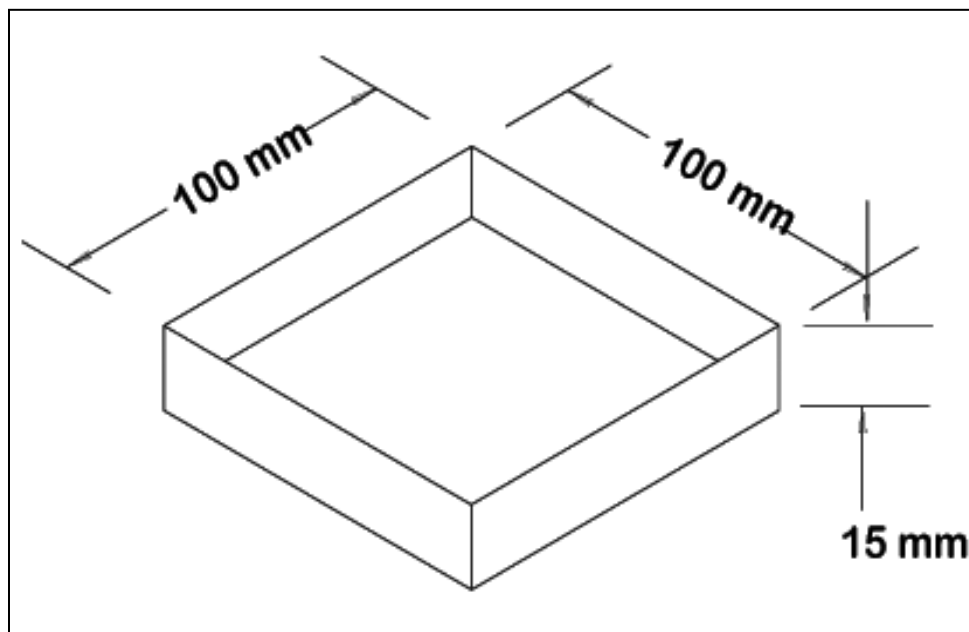


Figure 1 - Ice-catch pans

6.1.4 Spray Equipment

6.1.4.1 It is a fundamental requirement of this test that the spray impinges onto the surface of the test plate as supercooled water droplets that freeze on impact. This is verified by observation of an ice-catch plate.

6.1.4.2 The equipment used to provide the water spray comprises a low-flow nozzle supplied with water of quality and condition described in [4.5.6](#). This equipment is housed in the upper region of the test chamber above the test plate. 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 testing facility, provided the requirements of [Tables 2](#) and [3](#) are met.

6.1.5 Example of Spray Equipment

An example of a suitable spray system is as follows: the nozzle comprises two sections, outer and inner units for the respective passage of water and compressed air (see [Figure 2](#)). The nozzle reciprocates to provide even and reproducible coverage of the test plate at the specified water spray intensity.