



AEROSPACE INFORMATION REPORT

AIR6232™

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Aircraft Surface Coating Interaction with
Aircraft Deicing/Anti-Icing Fluids

RATIONALE

This SAE Aerospace Information Report (AIR) provides a description of screening methods for verifying whether aircraft surface coatings have adverse effects on aircraft deicing/anti-icing fluid performance as published in the holdover time guidelines. The surface coatings include thin film coatings, typically less than 1 mil (0.0254 mm) thick and sometimes called paint sealants or protectants, as well as bulk coatings that are typically greater than 2 mils (0.0508 mm) thick. Although recommended performance criteria have been outlined, ultimately, the interpretation of the test results outlined in this document will be left to the discretion of the aircraft operator.

AIR6232 has been reaffirmed to comply with the SAE Five-Year Review policy.

A reaffirmed status is given to technical reports that have been reviewed by the technical committee and deemed to be current with no need for immediate revision. No changes have been made to this document as a result of this review.

FOREWORD

Aircraft operators rely on the use of AMS1424 and/or AMS1428 deicing/anti-icing fluids during winter operations to provide a limited period of protection against frozen or freezing precipitation while the aircraft is on the ground. Methods of protection of aircraft surfaces with these fluids are described in ARP4737. The protection time can be estimated using fluid-specific holdover time guidelines that are published by the Federal Aviation Administration (FAA) and Transport Canada (TC). Holdover time values for deicing/anti-icing fluids are derived from standard endurance time testing procedures that are described in ARP5945 and ARP5485. The aerodynamic performance of deicing/anti-icing fluids is evaluated according to the procedure described in AS5900.

Recently, aircraft operators have expressed interest in the use of after-market coatings on aircraft surfaces for various purposes, including appearance enhancement, fuel savings, and ice shedding. The coatings may be designed to have hydrophilic or hydrophobic properties, and therefore, the interaction of these coatings with AMS1424 and/or AMS1428 deicing/anti-icing fluids and their associated holdover times is unclear. Since aircraft coatings may affect fluid wetting capability and resulting fluid thickness, they could affect a fluid's holdover time protection. Therefore, the interaction of aircraft surface coatings and aircraft deicing/anti-icing fluids should be evaluated with respect to holdover time performance and aerodynamic performance. In addition, test methods are available to help characterize the various aircraft surface coating properties, including durability, hardness, weathering, effect on aerodynamic drag, ice adhesion, ice accumulation, contact angle, and thermal conductivity. This AIR6232 provides test methods which can serve as screening indicators for compatibility and additional test methods which can be used to characterize the different coatings.

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1. SCOPE

This SAE Aerospace Information Report (AIR) provides descriptions of test methods for determining if an aircraft surface coating of any thickness has adverse effects on aircraft deicing/anti-icing fluids with respect to fluid holdover time performance and aerodynamic performance.

Although not the primary mandate of the G-12 Aircraft Ground Deicing Committee, this document also provides descriptions of suggested test methods for evaluating aircraft surface coatings with respect to durability, hardness, weathering, aerodynamic drag, ice adhesion, ice accumulation, contact angle, and thermal conductivity. These additional tests can provide informational data for characterizing the coatings and may be useful to operators when evaluating the coatings.

1.1 Purpose

To provide a reference method for evaluating the interaction of aircraft surface coatings with respect to aircraft deicing/anti-icing fluid holdover time performance and aerodynamic performance.

To provide additional informational test methods that can be used for characterizing the aircraft surface coatings.

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

AMS1424	Deicing/Anti-Icing Fluid, Aircraft, SAE Type I
AMS1428	Fluid, Aircraft Deicing/Anti-Icing, Non-Newtonian (Pseudoplastic), SAE Types II, III, and IV
AMS1650	Polish, Aircraft Metal
AMS3095	Paint: High Gloss for Airline Exterior System
AMS-C-83231A	Coatings, Polyurethane, Rain Erosion Resistant for Exterior Aircraft and Missile Plastic Parts
ARP4737	Aircraft Deicing/Anti-icing Methods
ARP5485	Endurance Time Tests for Aircraft Deicing/Anti-icing Fluids, SAE Type II, III, and IV
AS5900	Standard Test Method for Aerodynamic Acceptance for SAE AMS 1424 and SAE AMS 1428 Aircraft Deicing/Anti-icing Fluids
ARP5945	Endurance Time Tests for Aircraft Deicing/Anti-icing Fluids, SAE Type I
AIR6130	Cadmium Plate Cyclic Corrosion Test

2.1.2 FAA Publications

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

Official FAA Holdover Time Tables Winter 20XX-20XX. (New document published for each winter. Always use the latest issue; search for "FAA Holdover Time.")

FAA-Approved Deicing Program Updates, Winter 20XX-20XX. (New document published for each winter. Always use the latest issue; search for "FAA-Approved Deicing Program.")

2.1.3 Transport Canada Publications

Available from Transport Canada, Civil Aviation Directorate, Standards Branch, 330 Sparks Street, Ottawa, Ontario, K1A 0N5, Canada, Tel: 613-990-2309 or 1-866-995-9737, <http://www.tc.gc.ca/eng/civilaviation/standards/commerce-holdovertime-menu-1877.htm>.

Transport Canada Holdover Time Guidelines Winter 20XX-20XX. (New document published for each winter. Always use the latest issue).

Guidelines for Aircraft Ground Icing Operations. TP14052E, April 2005.

Aircraft Ground De/Anti-Icing Fluid Holdover Time and Endurance Time Testing Program for the 2001-02 Winter. TP13991E, December 2002.

2.1.4 Other Publications

Goldhammer, Mark I., and Plendl, Bruce R., "Surface Coatings and Drag Reduction," *AERO* magazine, The Boeing Company, edition Q1, 2013.

AIMS 09-00-002 Evaluation of Maintenance Materials, Airbus

AIP 94, 133109-1 Nonwetting of Impinging Droplets on Textured Surfaces

AIP 97, 234102 Frost Formation and Ice Adhesion on Superhydrophobic Surfaces

APS 106, 036102 Rapid Deceleration-Driven Wetting Transition during Pendant Drop Deposition on Superhydrophobic Surfaces

ASTM C518-10	Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus
ASTM D5930-01	Standard Test Method for Thermal Conductivity of Plastics by Means of a Transient Line-Source Technique
ASTM E1225-04	Standard Test Method for Thermal Conductivity of Solids by Means of the Guarded-Comparative-Longitudinal Heat Flow Technique
ASTM F483	Standard Practice for Total Immersion Corrosion Test for Aircraft Maintenance Chemicals
ASTM F484	Standard Test Method for Stress Cracking of Acrylic Plastics in Contact with Liquid or Semi-Liquid Compounds
ASTM F502	Standard Test Method for Effects of Cleaning and Chemical Maintenance Materials on Painted Aircraft Surfaces
ASTM F519-93	Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments

ASTM F1110	Standard Test Method for Sandwich Corrosion Test
D6-17487	Evaluation of Airplane Maintenance Materials, Boeing
ISO 8301	Thermal insulation - Determination of steady-state thermal resistance and related properties - Heat flow meter apparatus"
ISO 11507	Paints and varnishes - Exposure of coatings to artificial weathering - Exposure to fluorescent UV lamps and water
ISO 22007-2:2008	Plastics - Determination of thermal conductivity and thermal diffusivity - Part 2: Transient plane heat source (hot disc) method"
ISO 22007-3:2008	Plastics - Determination of thermal conductivity and thermal diffusivity - Part 3: Temperature wave analysis method"
ISO 22007-4:2008	Plastics - Determination of thermal conductivity and thermal diffusivity - Part 4: Laser flash method

2.2 Definitions and Abbreviations

ADVANCING CONTACT ANGLE: The advancing angle is the largest possible contact angle attained by the drop during volume addition before the motion of the contact line. Similarly, it is the maximum angle attained by the advancing front on an inclined surface before the motion of the contact line.

AERODYNAMIC ACCEPTANCE TEST: A performance test required under §3.2.5 of AMS1428 and defined in AS5900.

AIRCRAFT SURFACE COATING: A coating applied to an aircraft surface with properties that may be icephobic, hydrophobic, super-hydrophobic, or hydrophilic. This term as used in the document is not intended to refer to surface finishes that have been qualified by the original equipment manufacturer

BOUNDARY LAYER DISPLACEMENT THICKNESS (BLDT): The measured displacement of the air flow over a surface. The increase in BLDT over the flat plate surface caused by the fluid flow-off during the AS5900 aerodynamic acceptance is directly related to loss of lift during takeoff.

BUFFER: The difference between OAT and the freezing point of the fluids used.

CASSIE STATE: When the liquid of a drop does not fill the voids in the solid on which it sits and the voids remain filled with air, resulting in a hydrophobic condition, the opposite of Wenzel State.

CONTACT ANGLE: The angle, conventionally measured relative to the liquid-air and liquid-solid interfaces, quantifying the wettability of a solid surface by a liquid.

CONTACT ANGLE HYSTERESIS: The difference between the advancing and receding contact angles.

ENDURANCE TIME: Time that a fluid can endure defined and controlled temperature and precipitation conditions before visual failure. Endurance time tests are defined in ARP5485 and ARP5945.

FAA: United States Department of Transportation, Federal Aviation Administration.

HOLDOVER TIME (HOT): Starting from the time of initial application of an anti-icing fluid, the time that the fluid is expected to provide protection of an aircraft against freezing or frozen precipitation.

HOLDOVER TIME GUIDELINE: A table giving the holdover time for various precipitation conditions and temperatures, with cautions and notes, giving guidance to ground deicing/anti-icing crews and pilots. The "holdover time guideline" is also often referred to as the "holdover time table."

HYDROPHILIC SURFACE: A surface producing a contact angle of $\theta < 90$ degrees.

HYDROPHOBIC SURFACE: A surface producing a contact angle of $\theta > 90$ degrees.

ICEPHOBIC SURFACE: A surface producing a reduction in ice adhesion.

LOWEST ON-WING VISCOSITY (LOWV): Lowest viscosity of a fluid for which the applicable holdover time table can be used.

LOWEST OPERATIONAL USE TEMPERATURE (LOUT): The lowest temperature at which a Type I/II/III/IV fluid can be used on an aircraft, generally recognized as the higher of:

- a. the lowest temperature at which it meets the aerodynamics acceptance test (AS5900) for a given type of aircraft; or
- b. the freezing point of the fluid plus the freezing point buffer of 7 °C for Type II/III/IV fluids, or 10 °C for Type I fluids.

MAXIMUM ON-WING VISCOSITY (MOWV): Maximum viscosity of a fluid which is still aerodynamically acceptable.

OAT: Outside Air Temperature.

RECEDING CONTACT ANGLE: The receding angle is smallest possible angle which can be measured when liquid is removed from the drop. Similarly, it is the minimum angle attained by the receding front on an inclined surface before the motion of the contact line.

ROLL-OFF ANGLE: The tilt angle of a surface relative to horizontal at which the water drop starts to slide on the surface and varies between 0 and 90 degrees. Also called sliding angle.

SLIDING ANGLE: The tilt angle at which the water drop starts to slide on the surface and varies between 0 and 90 degrees. Also called roll-off angle.

STANDARD ALUMINUM TEST PLATE: Aluminum test plate surface used for endurance time testing of Type I and Type II/III/IV fluids in accordance with ARP5945 and ARP5485.

SUPER-HYDROPHOBIC SURFACE: A surface producing a static contact angle of $\theta > 150$ degrees and a roll-off angle of less than 10 degrees.

TREATED SURFACE: A surface that has been treated with an aircraft surface coating of any thickness.

UNTREATED SURFACE: A surface in its original condition from the airplane manufacturer, or a surface that has been painted with a coating qualified by the manufacturer for use on that surface, that has not been treated with an aircraft surface coating.

WENZEL STATE: When the liquid of a drop fills the voids in the solid on which it sits, the opposite of Cassie State.

3. COMPARATIVE FLUID ENDURANCE TIME TESTS

Tests should be conducted with AMS1424 Type I fluids and AMS1428 Type II/III/IV fluids to compare the endurance times of fluids applied to aluminum test plate surfaces treated with the aircraft surface coating to the endurance times of the same fluids applied to an untreated standard aluminum test plate (and as an optional test, a freshly painted aluminum test plate which serves as reference tool). If the coating being tested will typically be applied to painted surfaces, consideration should be given to conducting testing using painted, untreated and treated test plates.

Comparative endurance time testing should be conducted according to the procedures described in ARP5945 and ARP5485.

3.1 Fluid Selection

The aircraft operator or coating manufacturer should determine the fluid brands to be tested. The following are recommended criteria for selecting the fluids for the comparative endurance time testing:

- Minimum of two AMS1424 Type I fluids. Consideration should be given to testing both an ethylene-glycol and a propylene-glycol fluid diluted to a 10 °C freezing point buffer, and possibly also the standard mix. A non-glycol formulation may also be considered depending on the expected operations.
- Minimum of two AMS1428 Type II/III/IV fluids. Consideration should be given to testing both an ethylene-glycol and a propylene-glycol fluid at 100/0 fluid/water dilution (also referred to as undiluted or “neat”), and possibly also at 75/25 and 50/50 dilutions. A non-glycol formulation may also be considered depending on the expected operations. Fluid viscosity should be within the production range specified by the fluid manufacturer that meets on-wing viscosity limits.

3.2 Test Surfaces

The following is a description of the test surfaces that should be used for the comparative endurance time testing:

- Standard Aluminum Test Plate (Baseline Surface)
 - Material Aluminum alloy AMS4037 or AMS4041
 - Test plate dimensions 500 mm long x 300 mm wide x 3.2 mm thick
 - Angle 10.0 degrees ± 0.2 degree
 - Average surface roughness: $R_a \leq 0.5 \mu\text{m}$
- Treated Test Plate
 - Same material and construction as the “Standard Aluminum Test Plate” described above, however, treated using aircraft surface coating according to coating manufacturer specifications.
- Painted Test Plate (Optional)
 - Same material and construction as the “Standard Aluminum Test Plate” described above, however, painted using representative aircraft grade primer and paint according to AMS3095 specifications.

NOTE: In the case of outdoor natural snow testing with Type I fluid, the test surface is considered as the upper plate surface of the empty aluminum box described in ARP5945.

3.3 Precipitation Conditions for Holdover Time Evaluation

Comparative endurance time testing will evaluate the fluid performance on a treated test plate versus a standard aluminum test plate, and in some cases versus a painted test plate. Testing in each of the holdover time precipitation conditions described in ARP5945 and ARP5485 with each of the selected fluids is not practical in most cases. For that reason, Table 1 provides a suggested minimum set of precipitation conditions for comparative testing. All possible testing conditions have been included in Table 1 for planning purposes, with a minimum suggested set of precipitation conditions for comparative testing indicated by “X.” When selecting conditions, the objective is to try to obtain a broad range of temperatures and precipitation rates.

Natural snow tests have been specified with ranges of air temperature and icing intensity; as testing is conducted outdoors, conditions may vary depending on weather. In the event that natural snow testing is not possible, consideration can be given to conducting artificial snow testing.

A recommended set of frost tests has been included in Table 1 which may be modified in future revisions of this document to reflect new frost testing procedures being developed for inclusion in ARP5945 and ARP5485.