AEROSPACE STANDARD

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Superseding AS5901D

Water Spray and High Humidity Endurance Test Methods for AMS1424 and AMS1428 Aircraft Deicing/Anti-Icing Fluids

RATIONALE

This document brings minor modifications of wording and some editorial changes. Throughout the document, the refining elements in relation to droplet diameter have been changed in 4.2.1, 5.2.1, and 5.4.1. In 5.1, standard measuring devices have been updated, Section 7 anti-icing performance has been added, and 6.6 becomes Section 8.

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1. SCOPE

1.1 Minimum Requirements

This document establishes the minimum requirements for an environmental test chamber and test procedures to carry out anti-icing performance tests according to the current materials specification for aircraft deicing/anti-icing fluids. The primary purpose for such a test method is to determine the anti-icing performance under controlled laboratory conditions of AMS1424 Type I and AMS1428 Type II, III, and IV fluids.

1.2 Hazardous Materials

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

1.3 Standard Units

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

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

AMS4037 Aluminum Alloy, Sheet and Plate, 4.4Cu - 1.5Mg - 0.60Mn (2024; -T3 Flat Sheet, -T351 Plate), Solution Heat Treated

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

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2.2 Related Publications

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

2.2.1 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 9001 Quality Management Systems - Requirements

3. SUMMARY OF TEST

3.1 Introduction

This test describes how to determine the laboratory anti-icing performance of AMS1424 Type I and AMS1428 Type II, III, and IV fluids. The test fluids to be evaluated are applied to a test plate exposed to two types of freezing conditions, and their anti-icing performance is evaluated by measuring the minimum exposure time before a specified degree of freezing occurs. A general description of the two types of anti-icing tests referred to in this standard is as follows.

3.2 Water Spray Endurance Test (WSET)

This test involves pouring the unchilled fluid onto an inclined test plate (10 degrees from horizontal) at -5.0 °C ± 0.5 °C (23 °F ± 1 °F) and applying a cooled water spray in air at -5.0 °C ± 0.5 °C (23 °F ± 1 °F). The water spray endurance is recorded as the time for ice formation to reach the failure zone defined as the area 25 mm below the upper edge of the test plate and 5 mm in from either side of the test plate or the formation of slush on 10% of the plate surface (see Figure 1) when water spray intensity corresponds to 5.0 g/dm^2.h ± 0.2 g/dm^2.h. It is a fundamental requirement of this test that the spray impinges onto the surface of the test plate as water droplets, which freeze on impact. This is verified by observation of the untreated or ice catch panels. Whatever the WSET endurance time of the fluid tested, the minimum duration of the test shall be at least 30 minutes in order to validate the average icing intensity measurement.

3.3 High Humidity Endurance Test (HHET)

This test involves pouring the unchilled fluid onto an inclined test plate (10 degrees from horizontal) at -5.0 °C ± 0.5 °C (23 °F ± 1 °F), when the air temperature is 0.0 °C ± 0.5 °C (32 °F ± 1 °F) and the relative humidity (RH) is more than 80%. The high humidity endurance is recorded as the time for ice formation to reach the failure zone defined as the area 25 mm below the upper edge of the test plate and 5 mm in from either side of the test plate (see Figure 1). Under these conditions, when the ice formation corresponds to 0.30 g/dm^2.h ± 0.05 g/dm^2.h, it is a fundamental requirement of this test that it be performed in the absence of any visible precipitation (such as mist, fog, or drizzle). Whatever the HHET endurance time of the fluid tested, the minimum duration of the test shall be at least 2 hours in order to validate the average icing intensity measurement.

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4. EQUIPMENT AND TEST PARAMETERS

4.1 General

A description of the minimum requirements for the environmental test chamber and associated test equipment, including chilling unit, test plate, ice catch panels, spray equipment, humidity generator, and data acquisition, is given below. Other spray and humidity control equipment, which meet the requirements of this standard, are acceptable.

4.2 Test Chamber

The test chamber used to perform both WSET and HHET shall have a minimum volume of 1 m^3 for each 2.25 dm^2 of test panel area or 8 m^3 for the minimum test plate dimensions (see 4.3). A window shall be installed and shall be double glazed or heated to prevent condensation to provide a clear view of the test plate. The tests can be real-time video-recorded to gain additional information and as a record of the test procedure and the duration of the tests. The chamber shall be fitted with a door or equivalent entry port to allow for fluid application, ice catch measurement, and inspection of the test chamber equipment.

The test chamber shall be capable of air temperature control in the range 0 to -5 °C (32 to 23 °F) with an accuracy of ±0.5 °C (±1 °F). The temperature sensing device shall be mounted at the exit side of the air recirculation system and shall be within 0.5 m of the side of the test plate, but outside the direct line of the spray nozzle when in use. When a high humidity condition is required, the humidity sensor shall be placed 5 cm above the surface of the test plate at the centerline of the upper edge of the test plate. Both the air temperature and humidity sensing devices shall be linked to a continuous recording data acquisition system as a means of checking the environmental control characteristics of the test chamber throughout the course of a test run. The air exchange rate in the chamber shall correspond to an average air velocity of 0.20 m/s ± 0.05 m/s when measured 5 cm above the surface of the test plate.

One test chamber can be used to perform both the WSET and HHET, provided that it meets the required specific environmental test parameters as described in 4.2.1 and 4.2.2.

4.2.1 Water Spray Endurance Test (WSET) Chamber

The spray equipment is used in the WSET to provide the water spray from a nozzle supplied with low flow water and atomized by compressed air or by spinning disc. This equipment is housed in the upper region (ceiling) of the test chamber above the test plate. The water shall conform to ASTM D1193, Type IV, and when used, the compressed air shall be clean and oil free. The spray equipment shall be adjusted in order to meet the following criteria:

a. Average droplet diameter of the water spray shall be 25 µm ± 7 µm, with at least 50% of the droplets in the range 15 to 35 µm, determined in accordance with one of the test methods described in 5.2.

b. The average intensity of the water spray produced during a test shall correspond to 5.0 $g/dm^2.h$ ± 0.2 $g/dm^2.h$.

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

d. The water spray shall impinge on the surface of the test plate in the form of water droplets, which freeze on impact when both air and test plate temperatures are at -5.0 °C ± 0.5 °C (23 °F ± 1 °F). The exact type and geometry of the spray system used to generate the water spray for the test is left to the discretion of the user, provided the foregoing parameters are met.

As a means of providing some background information, an example of a suitable spray system is described in 4.2.1.1. However, other equipment could be used to obtain the test requirements.

4.2.1.1 Example of Spray Equipment

The nozzle comprises two sections: outer and inner units for the respective passage of water and compressed air. An example of spray nozzle model and the critical dimensions are given in Figure 2. Typical input water and air pressure to achieve the required intensity are: water flow rate of 24 cm^3/min and air pressure 1.7 bar (25 psi). In this example, the nozzle is mounted 65 cm above the test plate and is capable of traversing a 1-m path parallel to the test plate face and some 60 cm behind the upper edge of the plate. The nozzle reciprocates at 18 passes per minute, and in this configuration provides even and reproducible coverage of the test plate at the specified rate. See Figure 3 for a schematic layout of this system.

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4.2.2 High Humidity Endurance Test (HHET) Chamber

The humidity can be produced using a saturated water vapor generator housed in the exit side of the air recirculation system and recorded using a calibrated humidity sensor. The humidity generator shall be capable of a minimum of 80% RH when the air temperature is at 0 °C (32 °F) in the absence of any visible precipitation such as mist, fog, or drizzle. There shall be no water droplets having a diameter greater than 4 µm, determined in accordance with one of the test methods described in 5.2. Under these conditions of RH and air temperature, and in the presence of horizontal air velocity of 0.20 m/s ± 0.05 m/s, the frost accumulation rate on the test plate, cooled to -5.0 °C ± 0.5 °C (23 °F ± 1 °F), shall be 0.30 g/dm^2.h ± 0.05 g/dm^2.h at the end of the test if the test lasts less than 10 hours and 0.3 g/dm^2.h ± 0.1 g/dm^2.h if the test lasts 10 hours or more.

4.2.2.1 Humidity Generator Equipment

Relative humidity shall be maintained at the minimum specified level using a saturated water vapor generator, or equivalent, connected to a humidity sensor of the capacitance, resistance, or conductivity type capable of covering the range 80 to 100% RH at 0 °C (32 °F).

4.3 Test Plate Requirement

The test plate is either the upper surface of the test plate chiller unit or removable 1.6 mm (0.0625 inch) thickness panels sited on the face of the chiller unit. Both the test plate and chiller unit are housed within the test chamber.

The test plate shall be 6061-T6 AMS4037 aluminum alloy with the test face having an average surface roughness of ≤0.5 µm Ra. This measurement shall be made widthwise across the upper section of each test plate using a surface roughness tester. The chiller unit face shall be inclined at 10.0 degrees ± 0.2 degree from the horizontal. The upper surface of the chiller unit shall be comprised of at least six panels (six test plates), each separated by a divider, which will protrude 5 mm above the surface of the test plates to obviate the possibility of cross contamination between fluids applied to adjacent panels. Each test plate shall measure 300.0-mm ± 0.5-mm long by 100.0-mm ± 0.5-mm wide (area = 3 dm^2) and may be clearly marked with the failure zone using a permanent pen as follows:

The area 25.0 mm ± 0.5 mm below the upper edge of the test plate and 5.0 mm ± 0.5 mm in from either side of the test plate (see Figure 1). Clear marks on the dividers and the chiller unit can also be used to determine the failure zone.

The chiller unit shall be coupled to a fluid cell capable of accepting a recirculation supply of heat transfer fluid such that the upper surface of the test plate can be exposed to a temperature of -5.0 °C ± 0.5 °C (23 °F ± 1 °F). The temperature sensing device shall be mounted in the recirculation fluid cell or in the return pipe taking the heat transfer fluid from the fluid cell to the heat exchanger. This temperature sensor shall be linked to a continuous electronic data acquisition system to check and record the test plate temperature throughout the course of a test run.

4.4 Temperature Control Equipment

Both the air and test plate temperatures shall be maintained at the required level using heat exchangers connected to on/off temperature control equipment comprising a solid state temperature sensor, such as a platinum resistance probe (100 Ω at 0 °C [32 °F]), coupled to a proportional temperature controller having a minimum resolution of 0.5 °C (1 °F).

4.5 Air Distribution System

The air distribution system shall be comprised of a fan to provide air recirculation through the main body of the test chamber and to the heat exchanger. Ducting for the passage of air to and from the heat exchanger shall have entry and exit ports positioned to provide good air recirculation throughout the test chamber. The heat exchanger shall be capable of cooling the air and maintaining it at the specified level. The air movement within the test chamber, measured during high humidity endurance testing, shall be as specified. Airflow shall be measured using a suitable anemometer or velometer within ±0.05 m/s.

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5. CALIBRATION OF TEST EQUIPMENT

5.1 Standard Measuring Devices

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 National Institute of Standards and Technology and/or the National Research Council Canada or any other recognized national standards organization.

5.2 Water Droplet Size and Distribution Range

5.2.1 Average Droplet Diameter Requirement for WSET

Water spray droplet size shall have an average diameter of 25 µm ± 7 µm, with at least 50% of the droplets in the range 15 to 35 µm.

Average droplet diameter shall be verified at least once every 6 months, or whenever a piece of equipment is repaired or replaced.

5.2.2 Droplet Limit Size for HHET

During the HHET, the water vapor must not contain any droplet greater in diameter than 4 µm.

5.3 Methods to Measure the Droplet Size

The following methods can be used to determine the droplet sizes referred to in 5.2.1 and 5.2.2.

5.3.1 Slide Impact Method

A sample of the water droplets from the precipitation is collected on an oil-coated microscope slide. Oil having a viscosity of 5000 mPa at 20 °C (68 °F), spread to a thickness of about 500 µm, will be suitable. The oil can be either a mineral oil or silicone oil. The droplet size is determined by direct observation under a microscope using an eyepiece with the graticule and appropriate magnification or from enlarged photographs of the slide with calibration rule.

5.3.2 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 distribution of the droplets. Some equipment is capable of achieving this in real time.

5.4 Icing Intensity Calibration and Measurement

5.4.1 Test Conditions

For both types of anti-icing performance tests, it is important to establish that even and reproducible ice formation occurs over the surface of the test plates. To carry out this evaluation, ice catch measurements must be performed under the appropriate test conditions for water spray and high humidity endurance tests. A summary of the test conditions follows in Table 1.

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Table 1 - Water spray and high humidity endurance tests conditions

Parameter	Test Requirement	
	WSET	**HHET**
Air Temperature	-5.0 °C ± 0.5 °C (23 °F ± 1 °F)	0.0 °C ± 0.5 °C (32 °F ± 1 °F)
Test Plate Temperature	-5.0 °C ± 0.5 °C (23 °F ± 1 °F)	
Relative Humidity	--	More than 80% RH
Horizontal Air Velocity	--	0.20 m/s ± 0.05 m/s
Test Plate Slope	10.0 degrees ± 0.2 degree from horizontal	
Test Plate Surface Roughness	≤0.5 µm	
Average Droplet Diameter	25 µm ± 7 µm	Not greater than 4 µm
Average Icing Intensity	5.0 g/dm^2.h ± 0.2 g/dm^2.h	0.30 g/dm^2.h ± 0.05 g/dm^2.h (test duration less than 10 hours) 0.3 g/dm^2.h ± 0.1 g.dm^2/h (test duration 10 hours or more)
Minimum Test Duration	30 minutes	2 hours

5.4.2 Icing Intensity Measurement

The ice catch for WSET and HHET shall be assessed using three 10 x 10 cm small ice catch panels (instead of one 10 x 30 cm test plate). This method is reliable, since the pre-weighed panels can be weighed upon completion of the test, and the difference between the recorded weights corresponds to the ice catch. The ice catch panels shall be AMS4037 aluminum alloy mill finish of 1.6-mm (0.0625-inch) thickness. Ice catch on each 10 x 10 cm section shall correspond to 5.0 g ± 0.2 g for each hour of the WSET and 0.30 g/h ± 0.05 g/h for each hour of the HHET for a duration less than 10 hours. When the HHET exceeds a 10-hour duration, the ice catch shall be 0.3 g/h ± 0.1 g/h. The icing intensity, expressed in terms of g/dm^2.h, corresponds to the average of the results obtained with all ice catch panels used during the test. Performing not less than two successive test runs shall check the degree of repeatability. The same performance limits must be achieved in each run. This calibration shall be run at least once every 6 months or whenever a piece of equipment is repaired or replaced.

NOTE: Other methods can be used to measure the icing intensity; however, the method described above is the only approved method as per AS5901. Therefore, other methods shall be used for screening tests only.

Here is an example of screening method: It consists of marking the 10 x 30 cm test panels with lines at the 10-cm and 20-cm points. On completion of the test, the ice is scraped from each third of the plate and weighed. The disadvantage with this method is the possibility of damaging the test panel's surface. Comparative tests have demonstrated that this method is clearly less accurate, but it can be used as an estimation of the icing intensity for fluids development purposes.

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6. TEST PROCEDURE

6.1 Test Plate Cleanliness

The test plates shall be free of all visible contamination, smears, or stains, including the area 25 mm below the upper edge of the test plate and 5 mm in from either side of the test plate (see Figure 1).

Washing and thoroughly drying shall remove any contamination. Between test runs using the same candidate fluid, water wash and drying will suffice. Particular care should be taken to ensure the test plate to divider interface is clean and dry in order to prevent the formation of ice seed crystals, which lead to premature failure indications.

6.2 Required Temperature

Ensure the test chamber and test plate support are at the required temperature (see Table 1).

6.3 Fluid Preparation

The candidate test fluid shall have been sheared, within the time limit, in accordance with the specification for the respective SAE Type fluid before the test is to commence (refer to AMS1424, 3.3.4, for Type I fluid and to AMS1428, 3.2.2.7, for Type II, III, and IV fluids). The candidate test fluid shall be at ambient temperature, in the range of 15 to 25 °C (59 to 77 °F). For each test panel to be coated with the fluid, prepare 115 mL or 120 g for each test run. If more fluid is required, the quantity of fluid actually used will be mentioned in the report qualification statement.

6.4 Test Description

Each test involves the use of three test plates (see 4.3) and nine ice catch panels (see 5.4.2). Pour the fluid onto each test plate in turn in the order shown in Figure 4. Start the timing device, and, after 5 minutes, turn on the water spray or humidity generator (an alternative option consists of covering the test plates with a protection shield, turning on the water spray or humidity generator, and, after 5 minutes, removing the protection shield). Observe the test panels, and, when the ice front touches the failure zone (or the formation of 10% slush of the plate's surface), record the time of this event. When the water spray or humidity generator is turned off, weigh the nine 10 x 10 cm ice catch panels and determine the average icing intensity as described in 5.4.2. If the ice catch is within the specified limits for the test being conducted, the time for the ice front to reach the failure zone is valid for that test. Repeat the test using the alternate layout for the test panels to be coated with the candidate test fluid. If the two successive runs indicate conformance to the ice catch criteria, the times for the ice fronts to reach the failure zone shall be recorded on the report. The formal anti-icing performance time (WSET or HHET) corresponds to the average time of the two test results, obtained with the tests performed, using the two different layouts of the test panels.

6.5 Reproducibility/Precision

The WSET and HHET are dynamic by nature, and small variations can be expected. The acceptable variation between the anti-icing performance time averages of two WSET or two HHET performed with the same candidate fluid is 20% of the average time for a Type I fluid and 10% for Type II, III, and IV fluids.

7. ANTI-ICING PERFORMANCE REQUIREMENTS

The anti-icing performance requirements are detailed in AMS1424, 3.5.2, for Type I and in AMS1428, 3.2.4, for Type II, III, and IV.

8. REPORT

The report shall state the name and address of the facility conducting the tests, together with a statement confirming the test facility is autonomous of the manufacturer or vendor of the fluid. The following information will also appear on the test document:

a. Date tests conducted

b. Manufacturer or vendor's name and address

c. Name or reference number of the fluid tested

d. Lot number of the fluid tested

e. Reception date of the fluid

f. Type of fluid (SAE Type I, SAE Type II, SAE Type III, or SAE Type IV)

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

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h. Printout showing the temperature of the test chamber and test plate; for the high humidity test, a printout showing the relative humidity percentage (% RH) for the duration of the tests

i. Summary of test results, ice catch results for each test performed, and anti-icing performance time for WSET and HHET with standard deviations

j. Statement that the fluid tested conforms to the requirements of the Aerospace Material Specification (AMS1424 or AMS1428) against which the candidate fluid was tested

k. The qualification date

l. The qualification period time duration

9. NOTES

9.1 Revision Indicator

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

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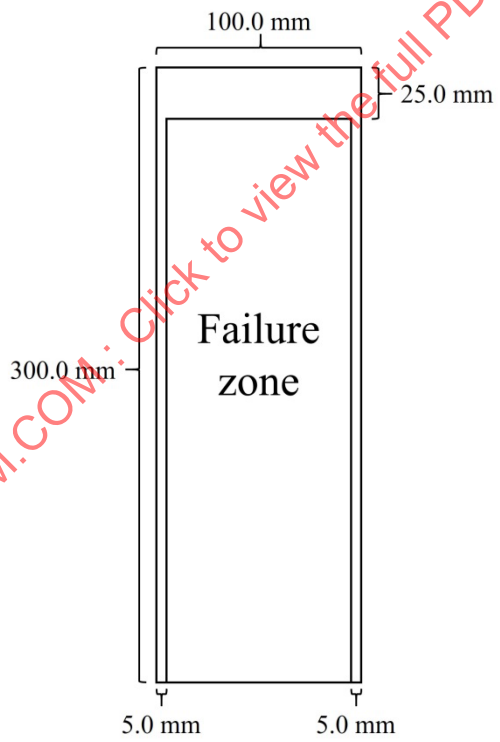

Figure 1 - Line markings on the test plate to delineate the failure zone (±0.5 mm)