SAE Aerospace
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AEROSPACE STANDARD

SAE AS5901

Issued 2003-02

Water Spray and High Humidity Endurance Test Methods for SAE AMS 1424 and SAE AMS 1428 Aircraft Deicing/Anti-icing Fluids

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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 endurance under controlled laboratory conditions of AMS 1424 Type I and AMS 1428 Type II, III and IV.

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 SI units are to be regarded as the standard.

2. REFERENCES:

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 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 1424	Deicing/Anti-icing Fluid, Aircraft SAE Type I
AMS 1428	Fluid, Aircraft Deicing/Anti-icing Material, Non-Newtonian (Pseudoplastic), SAE Types II,III and IV
AMS 4037	Aluminum Alloy Sheet and Plate, 4.4 Cu – 1.5 Mg 0.6 Mn (2024-T3 Flat Sheet, T351 Plate) Solution Heat Treated

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 1193	Reagent Water

2.3 ISO Publications:

Available from International Organization for Standardization, Case Postale 56, Rue de Varembe, CH-1211, Switzerland.

ISO 9001-2000 Quality Management Systems - Requirements

3. SUMMARY OF TEST:

3.1 Introduction:

This test describes how to determine the laboratory anti-icing performance of SAE Type I, Type II, Type III and Type 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 follow.

3.2 Water Spray Endurance Test:

This test involves pouring the unchilled fluid onto an inclined test plate at -5 °C ± 0.5 °C and applying a cooled water spray in air at -5 °C ± 0.5 °C. 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 (see Figure 1) when water spray intensity corresponds to 5 g/dm^2 ± 0.2 g/dm^2 per hour. This is equivalent to an average precipitation rate of 0.5 mm per hour. 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 plate.

3.3 High Humidity Endurance Test:

This test involves pouring the unchilled fluid onto an inclined test plate at -5 °C ± 0.5 °C, when the air temperature is 0 °C ± 0.5 °C and the Relative Humidity (RH) is 96% ± 2%. The high humidity endurance is recorded as the time for ice formation to reach the failure zone. 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 0.3 g/dm^2/hour, this is equivalent to a water accumulation rate (in the form of frost) of 0.03 mm per hour. It is a fundamental requirement of this test that the RH value is maintained to an accuracy of ±2% RH in the absence of any visible precipitation (such as mist, fog, or drizzle). The duration of the test shall be at least two hours for SAE Type I and Type III, at least four hours for SAE Type II and at least eight hours for Type IV.

4. EQUIPMENT AND TEST PARAMETERS:

4.1 General:

A description of the minimum requirements for the environmental test chamber and associated test equipment, including test plate chilling unit, test plate, 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 water spray endurance and high humidity endurance anti-icing tests 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 described in 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. It is recommended to videotape the tests using superimposed real time as a record of the test procedure and 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 with an accuracy of ±0.5 °C, the temperature sensing device shall be mounted at the exit side of the air recirculating 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. The air exchange rate in the chamber shall correspond to an average air velocity of 0.2 m/s ± 0.05 m/s when measured 5 cm above the surface of the test plate. Humidity control shall be capable of 96% RH ± 2% RH when the air temperature is at 0 °C 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 5.4.2. Under these conditions of RH and air temperature, and in the presence of horizontal air velocity of 0.2 m/s ± 0.05 m/s, the frost accumulation rate on the test plate (cooled to -5 °C ± 0.5 °C) shall be 0.3 g/dm^2/hour ± 0.05 g/dm^2/hour at the end of the test, if the test lasts less than 10 hours, and 0.3 g/dm^2/hour ± 0.1 g/dm^2/hour if the test lasts more than ten hours.

The humidity can be produced using a saturated water vapor generator housed in the exit side of the air recirculating system and controlled using a suitably calibrated humidity sensor linked to a control system. When a high humidity condition is required, the humidity sensor shall be placed 5 cm above the surface of the test plate at the center line of the upper edge of the test plate. Both the air temperature and humidity sensing devices shall be linked to a continuous pen recorder or electronic data acquisition system as a means of checking the environmental control characteristics of the test chamber throughout the course of a test run.

4.3 Test Plate:

The test plate is either the upper surface of the test plate chiller unit or removable 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 AMS 4037 aluminum alloy with the test face polished to an average surface roughness of 0.1 to 0.2 µm Ra. The chiller unit face shall be inclined at 10° ± 0.2° from the horizontal. The upper surface of the test plate shall comprise of at least six panels, 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 fluid applied to adjacent panels. Each plate shall measure 30 cm x 10 cm (area = 3 dm^2) and shall be clearly marked with the failure zone using a permanent pen as follows:

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).

The lower surface of the test plate shall be coupled to a fluid cell capable of accepting a recirculating supply of heat transfer fluid such that the upper surface of the test plate can be exposed to a temperature of -5 °C ± 0.5 °C. The temperature sensing device shall be mounted in the recirculating 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 pen recorder or electronic data acquisition system to check and record the test plate temperature throughout the course of a test run.

4.4 Spray Equipment:

4.4.1 General Requirements: The spray equipment is used in the water spray endurance test 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 of the test chamber above the test plate. The water shall conform to ASTM D 1193, 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:

Average droplet diameter of the water spray shall be 20 µm, with 50% of the droplets in the range 15 to 35 µm.

The average intensity of the water spray produced during a test shall correspond to 5 g/dm^2 ± 0.2 g/dm^2 per hour.

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

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 °C.

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.

4.4.1 (Continued):

As a means of providing some background information, an example of a suitable spray system is as follows:

4.4.2 Example of Spray Equipment: The nozzle comprises two sections, outer and inner units for the respective passage of water and compressed air. 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 per minute, air pressure 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.

4.4.3 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 solid state temperature sensor such as a platinum resistance probe (100 ohms at 0 °C), coupled to a proportional temperature controller having a minimum resolution of 0.5 °C.

4.5 Humidity Control Equipment:

Relative humidity shall be maintained at the specified level using a saturated water vapor generator, or equivalent, connected to on/off humidity control equipment comprising humidity sensor of the capacitance, resistance or conductivity type capable of covering the range 90 to 100% RH at 0 °C; this in turn coupled to a controller capable of regulating the saturated water vapor generator heater supply (and therefore the amount of water vapor introduced into the air stream).

4.6 Air Distribution System:

Shall comprise 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. Air flow shall be measured using a suitable anemometer or velometer.

5. CALIBRATION OF TEST EQUIPMENT:

5.1 Standard Measuring Devices:

All temperature sensors, humidity sensors, electronic balance, anemometer, and timing device shall be maintained in a known state of calibration in accordance with recognized international standards such as ISO 9001-2000.

5.2 Surface Roughness of Test Plate:

The average surface roughness of the aluminum alloy test plate shall be 0.1 to 0.2 µm Ra. This measurement shall be made width-wise across the upper section of each test plate using a surface measuring instrument.

5.3 Average Air Velocity:

It is a requirement of the high humidity test that the average air velocity in the test chamber, when measured 5 cm above the centerline at the upper edge of the test plate be 0.2 m/s ± 0.05 m/s.

5.4 Water Droplet Size:

5.4.1 Average Diameter of Droplet: Water spray droplet size shall have an average diameter of 20 µm ± 2 µm, with 50% of the droplets in the range 15 to 35 µm.

5.4.2 Limit Size of Droplet: During the high humidity test the water vapor must not contain any droplet greater in diameter than 4 µm.

5.4.3 Methods to Determine the Droplet Size: The following methods can be used to determine the droplet sizes referred to in 5.4.1 and 5.4.2.

a. Slide Impact Method: 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 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 appropriate graticle, or from enlarged photographs of the slide.

b. 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 towards the surface of the test plate. Analyzing the diffraction patterns, which will give the size and the distribution of the droplets, does this. Some equipment is capable of achieving this in real time.

5.4.4 Ice Catch Calibration: For both types of anti-icing 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 endurance and high humidity endurance. A summary of the test conditions follows in Table 1 and Table 2:

TABLE 1 - Water Spray Endurance

Air Temperature	-5 °C ± 0.5 °C
Test Plate Temperature	-5 °C ± 0.5 °C
Test Plate Slope	10° ± 0.2° from horizontal
Water Spray Intensity	5 g/dm^2 ± 0.2 g/dm^2 per hour
Test Duration	30 minutes minimum

TABLE 2 - High Humidity Endurance

Air Temperature	0 °C ± 0.5 °C
Test Plate Temperature	-5 °C ± 0.5 °C
Test Plate Slope	10° ± 0.2° from horizontal
Relative Humidity	96% ± 2%
Horizontal Air Velocity	0.2 m/s ± 0.05 m/s
Test Duration	Type I: 2 hours minimum Type II, III, IV: 4 hours minimum
Frost Accumulation	0.3 g/dm^2/hour ± 0.05 g/dm^2/hour

5.4.4 (Continued):

There are two ways to assess the ice catch.

Use three panels, each 10 cm x 10 cm in place of each 10 cm x 30 cm test plate, this is the preferred method since the preweighed panel can be weighed on completion of test and the difference in the recorded weights is the ice catch.

Mark the 10 cm x 30 cm test panels with lines at the 10 and 20 cm points, on completion of test, scrape the ice from each third in turn and weigh it. The disadvantage with this method is the possibility of damaging the polished surface of the test panel.

In either case the ice catch on each 10 cm x 10 cm section shall correspond to 5.0 g ± 0.2 g for each hour of the water spray test and 0.3 g/hour ± 0.05 g/hour in the high humidity 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 six months or whenever a piece of equipment is repaired or replaced.

6. TEST PROCEDURE:

6.1 Test Plate Cleanliness:

The test plates shall be free of all visible contamination, smears, or stains, except for 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 dry will suffice. Particular care should be taken to ensure the test plate to divider interface is clean and dry in order to obviate 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.

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. The candidate test fluid shall be at ambient temperature, in the range of 15 to 25 °C. 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:

Pour the fluid onto each test plate in turn in the order shown in Figure 4. Start the timing device, after five minutes, turn on the water spray or humidity generator, observe the panels and, when the ice front touches the failure zone, record the time of this event. When the water spray or humidity generator is turned off, weigh the ice catch on each 10 cm x 10 cm section of the uncoated panels. 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.

6.5 Reproducibility/Precision:

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

6.6 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. Type of fluid (SAE Type I, SAE Type II, SAE Type III or SAE Type IV)
f. 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.
g. Print out showing the temperature of the test chamber, and test plate; and for the high humidity test a print out showing the RH for the duration of the tests.
h. Summary of test results and ice catch results for each test performed.
i. Statement that the fluid tested either conforms to, or does not conform to the requirements of the specification against which the candidate fluid was tested.

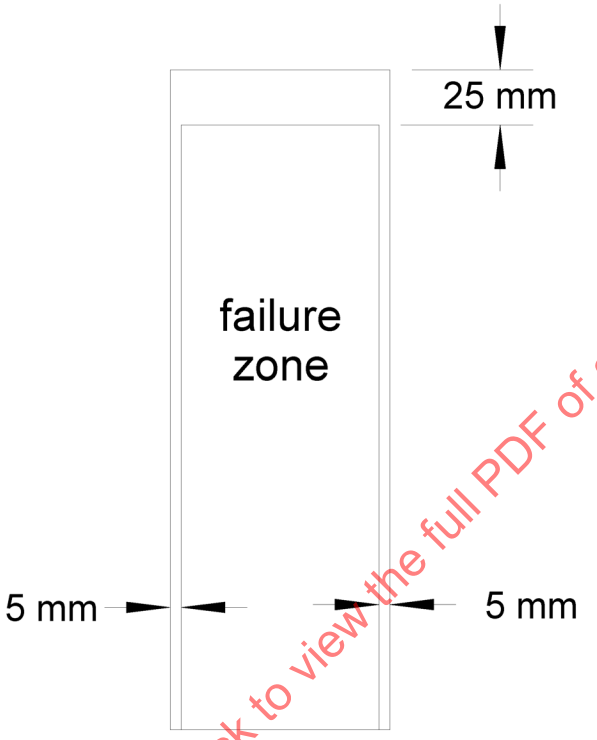

FIGURE 1 - Line Markings on the Test Plate to Delineate the Failure Zone