



AEROSPACE RECOMMENDED PRACTICE	ARP5904™	REV. A
	Issued 2002-10 Reaffirmed 2019-06 Stabilized 2026-05	
	Superseding ARP5904	
Airborne Icing Tankers		

RATIONALE

The content of the main document is correct and applicable to the use of airborne tankers. It is unlikely to change in the future. Some of the information regarding existing tankers in Appendix A is no longer accurate.

STABILIZED NOTICE

This document has been declared “STABILIZED” by SAE AC-9C Aircraft Icing Technology Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

SAE Executive Standards Committee Rules provide that: “This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user.”

SAE reviews each technical report at least every five years at which time it may be revised, reaffirmed, stabilized, or cancelled. SAE invites your written comments and suggestions.

Copyright © 2026 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, or used for text and data mining, AI training, or similar technologies, without the prior written permission of SAE.

TO PLACE A DOCUMENT ORDER: Tel: 1-877-606-7323 (U.S. and Canada only)
Tel: 1-724-776-4970 (outside U.S. and Canada)
Fax: 724-776-0790
Email: CustomerService@sae.org
<http://www.sae.org>

SAE WEB ADDRESS:

Full document details: SAE ARP5904A

For more information on this standard, visit
<https://www.sae.org/standards/content/ARP5904A/>



Documents

Document Sharing Hub

TABLE OF CONTENTS

1. SCOPE	3
1.1 Purpose	3
1.2 Background.....	3
2. REFERENCES	4
2.1 Applicable Documents	4
2.1.1 SAE Publications	4
2.1.2 U.S. Government Publications.....	4
2.2 Applicable References.....	5
2.3 Definitions.....	5
2.4 Abbreviations and Symbols	6
3. AIRBORNE ICING TANKER.....	7
3.1 Airborne Platform.....	7
3.2 Water Delivery System	7
4. COMPLIANCE	8
4.1 Applications	8
4.2 Test Results	9
5. INSTRUMENTATION.....	11
5.1 Calibration.....	11
5.2 Water Droplet and Liquid Water Content Measurements	12
5.3 Airspeed, Temperature, and Humidity	12

TABLE OF CONTENTS (Continued)

5.4	Physical Icing Tanker System Parameters.....	13
5.5	Distance Measuring Equipment.....	13
5.6	Observer Input	13
6.	VISUAL DOCUMENTATION	14
6.1	Video/Motion Picture Imagery	14
6.2	Still Photographs.....	14
6.3	Visual Aids	14
6.4	Windows and Viewing Angles	14
6.5	Light Effects	15
6.5.1	Time of Day.....	15
6.5.2	Flash-Aided Exposures.....	15
7.	NOTES.....	15
7.1	Key Words	15
7.2	Intended Use.....	16
	APPENDIX A ICING TANKERS.....	17

1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) document establishes criteria and recommended practices for the use of airborne icing tankers to aid in design and certification of aircraft ice protection systems and components. Several icing tankers are described, along with their capabilities and suggested use. Sample data for these tanker spray systems are included, shown with 14 CFR Parts 25 and 29, Appendix C icing envelopes for continuous maximum and intermittent maximum icing conditions. (Note: In the remainder of this document, the phrase "Appendix C icing envelopes" will be used for brevity.) This ARP is intended as a guide toward standard practice and is subject to change to keep pace with experience and technical advances.

1.1 Purpose:

The purpose of this document is to support the objective of the "FAA Inflight Aircraft Icing Plan" of establishing acceptance criteria for icing tankers. To this purpose, the document surveys existing airborne icing tanker technology and provides guidance for the acceptance of icing tanker information for certification purposes. The document provides some, but not all, criteria that shall be considered when selecting and using an icing tanker for artificial inflight icing tests. Use of an airborne icing tanker to obtain certification information shall be negotiated with and approved by a certification office, and included in the certification plan for the aircraft.

1.2 Background:

The U.S. Federal Aviation Administration established an icing plan in 1997 to respond to a need for a comprehensive program to create an awareness of inflight icing issues and to establish documents to provide training and guidance for regulatory authorities, aircraft operators, research organizations, and aircraft manufacturers. The FAA published a 14-task plan, entitled the "FAA Inflight Aircraft Icing Plan," and identified groups of people within the U.S. Government and throughout the aircraft industry to address the action items contained in this plan. Task 11 of this plan called for the development of "validation criteria and data for simulation methods used to determine ice shapes on aircraft." It also indicated that this task was to include data on "wind tunnel[s], ice accretion computer codes, and icing tankers." The FAA suggested "a coordinated effort among research organizations, industry, and regulatory authorities" and individuals were asked to participate in this work. Task 11 was divided into three subtasks and the people that participated in Subtask A were tasked with addressing criteria for the use of tankers, tunnels, and codes. Three documents were developed by the members of the Task 11.A Working Group and these three documents are being published as SAE ARPs. While each document follows a format that is appropriate to the topic, the three documents provide guidance for the application of codes (ARP5903), tankers (ARP5904), and tunnels (ARP5905) to the icing certification or qualification process.

1.2 (Continued):

14 CFR 23.1419(b), 25.1419(b), 27.1419 (c), and 29.1419(c) state that to verify the ice protection analysis, check for icing anomalies, and demonstrate that the ice protection system and its components are effective, the aircraft or its components must be flight tested in measured natural icing conditions and, as found necessary, tested by one or more of the following means: (1) laboratory dry air and/or artificial icing tests, (2) flight dry air tests, and (3) flight tests of the airplane or its components in measured artificial icing conditions. These methods are used in combination to verify analyses, covering the applicable Appendix C icing envelopes. The degree of reliance on each of the methods varies with the applicant. Since it is difficult, often impossible, and sometimes dangerous to cover the entire Appendix C icing envelope in natural icing, icing simulation is generally employed. Properly conducted airborne icing tanker tests can be used to extend natural icing test results to the Appendix C icing envelopes and to verify analyses.

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 referencing document. 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, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AIR4906	Droplet Sizing Instrumentation Used in Icing Facilities
AIR5504	Aircraft Inflight Icing Terminology
ARP5905	Calibration and Acceptance of Icing Wind Tunnels
ARP5903	Droplet Impingement and Ice Accretion Computer Codes

2.1.2 U.S. Government Publications:

2.1.2.1 Advisory Circulars: Available from U.S. Department of Transportation, Subsequent Distribution Office, SVC-121.23, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, Maryland, 20785.

AC 20-73	"Aircraft Ice Protection," U.S. Department of Transportation, Federal Aviation Administration, April 21, 1971
AC 23.1419-2A	"Certification of Part 23 Airplanes for Flight in Icing Conditions," U.S. Department of Transportation, Federal Aviation Administration, August 19, 1998
AC 25.1419-1	"Certification of Transport Category Airplanes for Flight in Icing Conditions," U.S. Department of Transportation, Federal Aviation Administration, August 18, 1999

- 2.1.2.2 Code of Federal Regulations: Available from Superintendent of Documents, U.S. Government Printing Office, Mail: Stop SSOP, Washington, DC 20402-0001. Internet: bookstore.gpo.gov, telephone: (202) 512-1800, telefax: (202) 512-2250.

CFR 14 Part 23	Title 14 of the US Code of Federal Regulations, Part 23, Airworthiness Standards, Normal, Utility, Acrobatic, and Commuter Category Airplanes, paragraphs .1093 and .1419
CFR 14 Part 25	Title 14 of the US Code of Federal Regulations, Part 25, Airworthiness Standards, Transport Category Airplanes, paragraphs .1093 and .1419
CFR 14 Part 27	Title 14 of the US Code of Federal Regulations, Part 27, Airworthiness Standards, Normal Category Rotorcraft, paragraphs .1093 and .1419
CFR 14 Part 29	Title 14 of the US Code of Federal Regulations, Part 29, Airworthiness Standards, Transport Category Rotorcraft, paragraphs .1093 and .1419

- 2.1.2.3 Other Government Publications: Available through the National Technical Information Service (NTIS), Springfield, VA. However, there is a fee. Reports published since 1996 are available at the Federal Aviation Administration William J. Hughes Technical Center's Full-Text Technical Reports page: actlibrary.tc.faa.gov in Adobe Acrobat portable document format (PDF). (Unfortunately, this web site is currently down.)

DOT/FAA/CT-88/8-2 "Aircraft Icing Handbook," Volume 2, Chapter IV, Section 1.0, Test Methods and Facilities, U.S. Department of Transportation, Federal Aviation Administration, March 1991

"FAA Inflight Aircraft Icing Plan," United States Department of Transportation, Federal Aviation Administration, April 1997

2.2 Applicable References:

AIAA-93-0295 Ashenden, R. A., "The Air Force Flight Test Center Artificial Icing and Rain Testing Capability Upgrade Program," January 1993

2.3 Definitions:

APPENDIX C ICING ENVELOPES: The 14 CFR Parts 25 and 29, Appendix C icing envelopes for continuous maximum and intermittent maximum icing conditions.

ARTIFICIAL ICING: Icing that occurs in a cloud formed by artificial means, such as a spray rig in a tunnel or on a tanker.

COMPUTED (CALCULATED) ICE: Ice shapes that are generated from computational fluid dynamics (CFD) tools.

CONSERVATIVE ICE SHAPES: Ice shapes used in tunnel or flight testing that provide a conservative test relative to the objectives of the test, such as investigation of aerodynamic performance, handling qualities, or ice-shedding trajectories.

2.3 (Continued):

CONSERVATIVE ICING TEST (FOR AIRBORNE TANKERS): A test is said to be conservative when it can be established that the actual test conditions for a test of an aircraft or an aircraft component are more severe than the specified conditions for the test objective.

ICE SHAPES: The shape of ice formed on an aircraft surface or component. This shape may be calculated or based on actual accumulation during natural, tanker, or tunnel icing tests.

INTERCYCLE ICE: The ice accretion on a deiced surface that exists just prior to the actuation of the deice system.

NATURAL ICING: Icing that occurs during a flight in a cloud formed by natural processes in the atmosphere.

RESIDUAL ICE: The ice remaining on a deiced surface that exists immediately after actuation of the deice system.

RUNBACK ICE: Ice formed from the freezing or refreezing of water leaving electrothermally protected surfaces onto unprotected surfaces.

SIMULATED ICE: Ice shapes that are fabricated from wood, epoxy, or other material by any construction technique.

TARGET ICING CONDITIONS: The icing conditions at which it is desired to perform an icing test, whether or not the conditions can be met by the testing method used. The target icing conditions may be selected from the Appendix C icing envelopes or other certification or qualification criteria.

2.4 Abbreviations and Symbols:

AC – Advisory Circular
AFB – Air Force Base
AGL – Above ground level
AOA – Angle of attack
ARP – Aerospace Recommended Practices
CFD – Computational fluid dynamics
CFR – Code of Federal Regulations
CTEIP - Central Test and Evaluation Investment Program
DGPS – Differential Global Positioning System
FAA – Federal Aviation Administration
GMT – Greenwich Mean Time
GPS – Global positioning system
HISS- Helicopter Icing Spray System
IPS – Ice protection system
KIAS – Knots indicated air speed
kPa - kiloPascals
LWC – Liquid water content

2.4 (Continued):

MSL – Mean sea level
MVD – Median volume diameter
OAT – Outside air temperature
PMS – Particle measurement system
psi – Pounds per square inch
TAT – Total air temperature

3. AIRBORNE ICING TANKER:

3.1 Airborne Platform:

The icing tanker platform may be an airplane or helicopter. It should have adequate performance in speed, altitude, and endurance (fuel and water) relative to the icing test mission to be flown. The icing tanker platform shall have safe handling qualities with the water delivery system in place and activated.

Brief descriptions of currently operational inflight icing platforms are presented in Appendix A for information only.

3.2 Water Delivery System:

The icing tanker water delivery system shall provide a uniform spray pattern large enough to adequately cover the region of interest on the test aircraft. The entire surface (or a representative section of the surface) shall be covered by the spray without having to “sweep” the test section through the spray if simultaneous coverage of the entire section is essential to meet the particular test objective. In some cases, intentional sweeping of the spray is acceptable, such as in some tests of pneumatic boots and thermal deicing systems and of the effect of the delayed initiation of an ice protection system (based upon ice thickness, not upon time). For such tests, the surface may be iced using sweeps of or through the cloud to obtain a uniform ice coating prior to actuation of the ice protection device. For some tests and aircraft, successful results can be obtained from spray patterns as small as 0.9 to 1.3 m (3 to 4 ft) in diameter.

A sufficient quantity of water shall be available for test points, calibration, and for any time the spray is continued while the test aircraft is outside of the cloud (e.g., to visually record ice shapes or shed ice). The potential for blockage of the water delivery system nozzles should be considered when selecting the purity level of the water used. Therefore, water used for icing tests shall be relatively pure, but may contain a dye such as sea marker dye (see MIL-S-17980) to enhance visual observation of ice accretion, since no adverse effects of this dye have been observed. The icing tanker water spray system shall be capable of delivering a continuous volume of flow at a consistent droplet diameter such that the significant portion of the spray pattern can be defined to have droplet diameters (MVD) and liquid water content (LWC) that are consistent with the test objective. Typically, these parameters can be controlled by nozzle size, water delivery pressure, air atomization pressure (if air atomization is used), and distance of the test air vehicle behind the icing tanker. An appropriate distance behind the icing tanker shall be maintained to ensure that the droplets have become supercooled (near the freestream static temperature).

3.2 (Continued):

The nozzle system shall be protected from freezing. Ice forming in, on, or around the nozzles can change the spray pattern, MVD, and LWC and can cause a significant hazard to the test air vehicle if fragments of ice start shedding during the test.

The icing tanker with installed water delivery system shall direct the spray such that the test air vehicle (aircraft or helicopter) can fly without being subjected to unacceptable turbulence and buffeting from the icing tanker wake that would otherwise affect the outcome of the test. This will help alleviate any handling difficulties that prevent the test pilot from maintaining a stable enough position behind the icing tanker to obtain representative, or desired, icing exposure. Successful results have been obtained with significant vortex turbulence, which is generally outboard of the test air vehicle.

Exposure time can be adjusted for time out of the spray provided this latter time is brief and does not affect the accreted ice or the observed performance of the ice protection system; for example, provided no ice is shed or sublimated while out of the spray.

4. COMPLIANCE:

4.1 Applications:

Tanker icing tests are not used as a sole means of compliance, but may be used in various ways, including the verification of analysis or small-scale tunnel test results to the limits of the Appendix C icing envelopes of 14 CFR Part 25/29. Ice accretions developed by the tankers may also be used for fabrication of simulated ice shapes that may be used during flight tests to evaluate basic accretion effects and aircraft flying qualities. Use of an airborne icing tanker to obtain certification information shall be negotiated with and approved by an FAA certification office and included in the certification plan for the aircraft.

Tanker test missions may include, but are not limited to:

- a. Determination of impingement limits on wings, tailplanes, and other surfaces essentially exposed to the freestream flow.
- b. Building ice and recording ice shedding and ice shedding trajectories (most often through high-speed video), from parts of the test aircraft where that ice shedding could present a hazard to the test air vehicle.
- c. Determining or verifying ice shapes resulting from normal operation of the ice protection system. Shapes modeled shall be conservative shapes relative to the test objectives (for example, handling qualities, aerodynamic performance, and ice shedding trajectories). If a reliable analytical computer code is used to generate a computed ice shape on a given surface, the tanker is ordinarily used to verify the location and general features of the ice shape predicted analytically.

4.1 (Continued):

- d. Determining or verifying ice shapes for unprotected areas, particularly in complex 3-D areas that are difficult to predict by means of analytical computer codes (e.g., antennae, pods).
- e. Obtaining or verifying data used in analytical models to predict surface temperatures for thermal anti-ice systems throughout the Appendix C icing envelopes.
- f. Evaluating minor changes to anti-ice/deice systems previously approved by other means.
- g. Evaluating heated surfaces on components such as pitot tubes and windshields.

4.2 Test Results:

Icing tanker test results may be used for certification (with concurrence by the certification authorities), if it is established that either (1) the specified target icing conditions are met reasonably well or (2) the test is conservative relative to its objectives.

An example of a conservative test is the determination of impingement limits on a wing or tailplane surface exposed to freestream flow using test data with a droplet spectrum with an MVD larger than the target MVD. The objective of this test is to determine the impingement limits at specified target conditions in the Appendix C icing envelopes. While droplet size is known to be the most important variable for such a test, the specified target MVD for the icing conditions may be exceeded for a more conservative test. Since the spray cloud MVD is larger than the target MVD, and the impingement limits determined by the test will be at least as far aft as those for the specified point in the Appendix C icing envelopes, a conservative test is achieved.

Judgment must be exercised in determining whether larger droplets will create a conservative result. For example, an inlet that is characterized by flow streamlines with large concave curvature will accrete more ice in forward areas of the inlet if the droplets are large, leaving more aft areas of the inlet clear. However, smaller droplets more closely follow such streamlines, resulting in impingement in regions that would not be reached by larger droplets. Consequently, a test with a larger MVD is not considered conservative for such inlets. In addition, since particle trajectories are dependent upon the relative momentum of the particle, the velocity dependency precludes a distinct definition of conservatism for this objective. In general, larger droplets will constitute conservatism if the accretion area or runback ridge will increase with more ballistic trajectories, and smaller droplets will constitute conservatism if the flow undergoes sharp changes in slope and recirculation which have the potential to deposit droplets on otherwise flow-hidden surfaces (i.e., the accretion area increases). Therefore, if in doubt, a particle trajectory code should be utilized to compare droplet trajectories from a tanker spray to those that would be expected under natural icing conditions as described by the Appendix C icing envelopes.