U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: Certification of Part 23 Airplanes for Flight in Icing Conditions	**Date: 7/21/04** **Initiated By: ACE-100**	**AC No: 23.1419-2C** **Change:**

1. PURPOSE. This Advisory Circular (AC) sets forth an acceptable means, but not the only means, of demonstrating compliance with the ice protection requirements in Title 14 of the Code of Federal Regulations (14 CFR) part 23. The Federal Aviation Administration (FAA) will consider other methods of demonstrating compliance that an applicant may elect to present. This material is neither mandatory nor regulatory in nature and does not constitute a regulation.

2. CANCELLATION. AC 23.1419-2B, Certification of Part 23 Airplanes for Flight in Icing Conditions, dated September 26, 2002, is canceled. In addition, all policy related to the certification of ice protection systems on part 23 airplanes, issued prior to this AC is cancelled.

3. APPLICABILITY. The guidance provided here applies to the approval of airplane ice protection systems for operating in the icing environment defined by part 25, Appendix C. The guidance should be applied to new Type Certificates (TCs), Supplemental Type Certificates (STCs), and amendments to existing TCs for airplanes under part 3 of the Civil Aviation Regulations (CAR) and part 23, for which approval under the provisions of § 23.1419 is desired.

S/

Dorenda D. Baker
Manager, Small Airplane Directorate
Aircraft Certification Service

CONTENTS

TABLES

4. RELATED REGULATIONS AND DOCUMENTS.

a. Regulations. By their adoption in amendment 23-14, which shows their requirements are directly related, §§ 23.929, 23.1309, and 23.1419 are applicable to a part 23 airplane icing certification program regardless of the certification basis for the basic airplane; however, for those airplanes certificated in accordance with part 3 of the CAR and part 23 through amendment 23-13, the application of these sections may be limited to the equipment being used for ice protection. Some systems that were previously approved on the airplane may need to be modified to improve their reliability when those systems are utilized as part of that airplane's icing approval.

(1) With the adoption of amendment 23-43, § 23.1419 was revised to do the following: to specify that the performance, controllability, maneuverability, and stability must not be less than that required by subpart B of part 23; add the requirement for flight testing in measured, natural icing conditions; provide specific test requirements; clarify the requirements for information that must be provided to the pilot, and allow approval of equivalent components that have been previously tested and approved, and that have demonstrated satisfactory service if the installations are similar.

(2) Prior to the adoption of amendment 23-43, some part 23 airplanes were certificated for flight in icing using § 25.1419.

(3) In addition to the previously mentioned requirements (§§ 23.929, 23.1309, and 23.1419), the following sections should be applied depending upon the ice protection system design and the original certification basis of the airplane. Many of the following requirements in Table 1 are also applicable, even without approval for flight in icing conditions. Further guidance on establishing a certification basis for flight in icing approval can be found in Appendix B.

TABLE 1. FLIGHT IN ICING REQUIREMENTS

Date of Airplane Type Certification Application	**CAR/Title 14 CFR Status**	**Icing Certification Requirements**
Prior to February 1, 1965	Part 3 of the CAR, (May 15, 1956, as amended through amendment 3-8)	Sections 3.85(a) and (c), 3.85a(a) and (c), 3.382, 3.383, 3.446, 3.575, (including note following (b)), 3.652, 3.652-1, 3.665, 3.666, 3.681, 3.682, 3.685, 3.686, 3.687, 3.690, 3.691, 3.692, 3.712, 3.725, 3.758, 3.770, 3.772, 3.777, 3.778, and 3.779

TABLE 1. FLIGHT IN ICING REQUIREMENTS (Continued)

Date of Airplane Type Certification Application	**CAR/Title 14 CFR Status**	**Icing Certification Requirements**
On or after February 1, 1965	Recodification	Sections 23.65, 23.75, 23.77, 23.773, 23.775, 23.1301, 23.1351, 23.1357, 23.1437, 23.1541, 23.1559(b), 23.1583(h), 23.1585, and 23.1419 (boot requirement before amendment 23-14)
On or after July 29, 1965	Amendment 23-1	Add § 23.1325 to the above part 23 requirements.
On or after February 5, 1970	Amendment 23-8	Add § 23.1529 to the above part 23 requirements.
On or after December 20, 1973	Amendment 23-14	Add §§ 23.853(d), 23.929 and 23.903(c) to the above part 23 requirements, significant revision to § 23.1419.
On September 1, 1977	Amendment 23-20	Add §§ 23.1327 and 23.1547 to the above part 23 requirements.
On or after December 1, 1978	Amendment 23-23	Add §§ 23.863, and 23.1416 (in lieu of the boot requirement of § 23.1419 before amendment 23-14) to the above part 23 requirements.
On or after February 17, 1987	Amendment 23-34	For commuter category airplanes, add §§ 23.67(e)(2), 23.67(e)(3), 23.997(e), and 23.1199(b) to the above part 23 requirements.
On or after February 4, 1991	Amendment 23-42	Add §§ 23.1323(e) and 23.1325(g) to the above part 23 requirements.

TABLE 1. FLIGHT IN ICING REQUIREMENTS (Continued)

Date of Airplane Type Certification Application	CAR/Title 14 CFR Status	Icing Certification Requirements
On or after May 10, 1993	Amendment 23-43	Add §§ 23.905(e), 23.1093(a)(6), and 23.1307(c) to the above part 23 requirements; significant revision to § 23.1419, added Subpart B sections and natural icing flight test requirement.
On or after September 7, 1993	Amendment 23-45	Add §§ 23.773(b), 23.775(f), 23.775(g), and 23.1525 to the above part 23 requirements.
On or after March 11, 1996	Amendment 23-49	Add § 23.1326 to the above part 23 requirements.

b. Advisory Circulars. Copies of current editions of the following publications may be downloaded from the FAA's Regulatory and Guidance Library (RGL) www.airweb.faa.gov/AC or obtained from the U.S. Department of Transportation, Subsequent Distribution Office, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785:

AC 20-73 “Aircraft Ice Protection,” April 21, 1971.

AC 20-115B “Radio Technical Commission for Aeronautic, Inc. Document RTCA/DO-178B,” January 11, 1993.

AC 20-117 “Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing,” December 3, 1982.

AC 20-147 “Turbojet, Turboprop, and Turbofan Engine Induction System Icing and Ice Ingestion,” February 2, 2004.

AC 21-16D “RTCA Document DO-160D,” July 21, 1978.

AC 21-40 “Application Guide for Obtaining a Supplemental Type Certification,” May 6, 1998.

AC 21.101-1 Establishing the Certification Basis of Changed Aeronautical Products,” April 28, 20003.

AC 23-16A	“Powerplant Guide for Certification of Part 23 Airplanes and Airships,” February 3, 2004.
AC 23-17A	“Systems and Equipment Guide for Certification of Part 23 Airplanes,” June 27, 2002.
AC 23.143-1	“Ice Contaminated Tailplane Stall (ICTS),” December 20, 2001.
AC 23.629-1A	“Means of Compliance with Section 23.629, Flutter,” October 23, 1985.
AC 23.1309-1C	“Equipment, Systems, and Installations in Part 23 Airplanes,” March 23, March 12, 1999.
AC 91-74	“Pilot Guide Flight in Icing Conditions,” December 12, 2002.

Copies of the current AC may be purchased from the Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954. Make check or money order payable to the Superintendent of Documents:

AC 23-8B	“Flight Test Guide for Certification of Part 23 Airplanes,” August 14, 2003.

5. RELATED READING MATERIAL.

a. FAA Orders.

FAA Order 8110.4B, “Type Certification,” April 24, 2000.

b. FAA Technical Reports. The following FAA technical reports can be obtained from the National Technical Information Service in Springfield, Virginia 22161:

(1) FAA Technical Report DOT/FAA/CT-88/8, "Aircraft Icing Handbook" (March 1991), includes reference material on ground and airborne icing facilities, simulation procedures, and analytical techniques. This document represents all types and classes of aircraft and is intended as a working tool for the designer and analyst of ice protection systems.

(2) FAA Technical Report ADS-4, "Engineering Summary of Airframe Icing Technical Data," and Report No., FAA-RD-77-76, "Engineering Summary of Powerplant Icing Technical Data," provide technical information on airframe and engine icing conditions, and methods of detecting, preventing, and removing ice accretion on airframes and engines in flight. Although most of the information contained in ADS-4 and FAA-RD-77-76 reports is still valid, some is outdated, and more usable information is now available through recent research and experience, and is included in the Aircraft Icing Handbook.

(3) FAA Technical Report DOT/FAA/AR-01/91, "A History and Interpretation of Aircraft Icing Intensity Definitions and FAA Rules for Operating in Icing Conditions" (November 2001), provides a good reference for understanding icing operational rules.

(4) FAA Technical Report DOT/FAA/AR-02/68, "Effect of Residual and Intercycle Ice Accretions on Airfoil Performance" (May 2002), details icing tunnel testing to determine intercycle and residual ice on a 23012 airfoil, and wind tunnel testing of uniform sandpaper and intercycle ice shapes.

(5) FAA Technical Report DOT/FAA/CT-TN86/11, “Fluid Ice Protection Systems.”

c. Technical Standard Order (TSO): A copy of the current edition of the following publication may be obtained from the Federal Aviation Administration, Aircraft Certification Service, Aircraft Engineering Division, Technical Programs and Continued Airworthiness Branch—AIR-120, 800 Independence Avenue, SW, Washington, DC 20591 or from the FAA website at www.faa.gov:

TSO-C16	“Air-Speed Tubes (Electrically Heated),” September 1, 1948.
TSO-C54	“Stall Warning Instruments,” October 15, 1961.

d. SAE Documents. The Society of Automotive Engineers (SAE), Inc. Aerospace Recommended Practice (ARP) and Aerospace Information Report (AIR) documents are available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or from their website at www.sae.org:

ARP4761	“Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment,” December 1, 1996.
AIR4367	“Aircraft Ice Detectors and Icing Rate Measuring Instruments, “April 1, 1995.
AIR5504	“Aircraft Inflight Icing Terminology,” September 17, 2002.
AIR1168/4	“Ice, Rain, Fog, and Frost Protection,” July 1, 1989.
ARP4087	“Wing Inspection Lights – Design Criteria,” April 1, 1996.
AS393	“Airspeed Tubes Electrically Heated,” August 14, 2002.
AS403	“Stall Warning Instruments,” July 15, 1958.

The SAE and a working group for Task 11A of the FAA Inflight Aircraft Icing Plan have developed the following documents:

ARP5903	“Droplet Impingement and Ice Accretion Computer Codes, October 16, 2003.
ARP5904	“Airborne Icing Tankers,” October 21, 2002.
ARP5905	“Calibration and Acceptance of Icing Wind Tunnels,” September 18, 2003.

e. Miscellaneous Documents.

(1) British Specification (BS) 2G-135, “Specification for Electrically-Heated Pitot and Pitotstatic Pressure Heads”

(2) American Society for Testing and Materials (ASTM) G76-95, “Standard Test Method for Conducting Erosion Tests by Solid Particle Impingement Using Gas Jets”

6. BACKGROUND.

a. Prior to 1945, airplanes were certificated under part 4 of the CAR. Section 04.5814 required that if deicer boots were installed, they would have a positive means of deflation. There were no other references to an ice protection system in part 4. When separate regulations (part 3 of the CAR) were written for normal category airplanes, this requirement for positive means of deflating deicer boots was incorporated without change in § 03.541. In 1949, § 03.541 was renumbered as § 3.712.

b. Ice protection was not addressed again until part 3 of the CAR was revised in 1962 by amendment 3-7. This amendment added §§ 3.772 and 3.778, which required that information be provided to the crew specifying the types of operation and the meteorological conditions to which the airplane is limited by the equipment installed. This section gave icing as a specific example of the meteorological conditions to be delineated. This change required a list of all installed equipment affecting the airplane operation limitations. The list also identified this equipment by its operational function. This list of equipment later became known as the “Kind of Equipment List (KOEL).”

c. In 1964, part 3 of the CAR was recodified into part 23. After recodification, § 3.712 became § 23.1419, and §§ 3.772 and 3.778(h) became §§ 23.1559 and 23.1583(h). In 1965, § 23.1325 was revised by amendment 23-1 to take into account the effect of icing conditions on static pressure dependent instruments. This requirement applies to all airplanes regardless of whether or not they have an ice protection system approved under § 23.1419. In the latter part of 1968, the FAA instituted an extensive review of the airworthiness standards of part 23. As a result of this review, the FAA issued amendment 23-14 (November 1973), which made several substantive changes in the interest of safety to part 23. This amendment introduced a new § 23.929, which required engine installation ice protection and completely revised § 23.1419 to establish standards for ice protection systems. It also introduced a new § 23.1309, which established reliability and noninterference requirements for installed equipment and systems.

These three sections are directly related, as defined in § 21.101, to the certification of an ice protection system because of the increased reliance on this system when operating the airplane in an icing environment.

d. Specific standards for pneumatic deicer boots, which were contained in the former § 23.1419, were inadvertently omitted in amendment 23-14. The FAA, realizing that a specific standard for pneumatic deicer boot systems was needed, issued amendment 23-23 in 1978, which added § 23.1416, pneumatic deicer boot system. As currently configured, certification requirements are limited to those icing conditions produced by supercooled clouds as defined by part 25, Appendix C, and do not require design or proof of capability to operate in freezing rain and drizzle, snow, or mixed conditions.

e. In 1987, with the creation of the commuter category, airplanes that had weight, altitude, and temperature limitations for takeoff, en route, climb, and landing distance were being certificated. Required climb performance for commuter category airplanes is defined in § 23.67(c) and § 23.77(c).

f. With the adoption of amendment 23-41 (effective November 26, 1990), § 23.1309 retained the existing reliability requirements adopted by amendment 23-14 for airplane equipment, systems, and installations that are not complex and do not perform critical functions. For those cases where the applicant finds it necessary or desirable to include complex systems and/or systems that perform critical functions, amendment 23-41, § 23.1309, provides additional requirements for identifying and certificating such equipment, systems, and installations. This amendment permitted the approval of more advanced systems having the capability to perform critical functions.

g. In 1991, with the adoption of amendment 23-42 (effective February 4, 1991), § 23.1323(e) was added to require a heated pitot tube, or an equivalent means of preventing malfunction due to icing, and to clarify the requirement that a heated pitot tube be part of the system approval for flight in icing conditions. Also, § 23.1325(g) was added to allow airplanes that are prohibited from flight in Instrument Meteorological Conditions (IMC) to be certificated without an alternate static air source.

h. In 1993, with the adoption of amendment 23-43 (effective May 10, 1993), § 23.905(e) was added to require that ice shed from the airplane not damage a pusher propeller. Section 23.1093(a)(6) specified ice protection requirements for fuel injection system designs with and without metering components on which impact ice may accumulate. Also, § 23.1307(c) was added to require the airplane type design to include all of the equipment necessary for operation in accordance with the limitations required by § 23.1559. Section 23.1419 was revised to do the following: to specify that the performance, controllability, maneuverability, and stability must not be less than that required by subpart B of part 23; add the requirement for flight testing in measured, natural icing conditions, provide other specific test requirements, and to clarify requirements for certification by similarity.

i. In 1993, with the adoption of amendment 23-45 (effective September 7, 1993), the following sections were added: (1) section 23.773(b) to provide requirements for the pilot compartment view to address the environment expected in all the operations requested for certification; (2) section 23.775(f) to clarify the criteria for determining the cleared windshield area that is necessary to assure safe operation in icing conditions; (3) section 23.775(g) to require that a probable single failure of a transparency heating system may not adversely affect the integrity of the airplane cabin or danger of fire; and (4) section 23.1525 was revised to require the establishment and inclusion of kinds of operations authorized in the Airplane Flight Manual (AFM) as specified by § 23.1583(h).

j. In 1996, with the adoption of amendment 23-49 (effective March 11, 1996), § 23.1325(g) was revised by exempting airplanes that are prohibited from flight in icing conditions from the requirements of § 23.1325(b)(3). Also, § 23.1326 was added to require the installation of a pitot tube heat indicating system on those airplanes required to be equipped with a heated pitot tube. Airplanes that are approved for instrument flight, or for flight in icing conditions, would be required to be equipped with a heated pitot tube and a heated pitot tube indicator. See AC 23-17A for guidance on compliance to § 23.1326. Section 23.1323(e) was recodified to § 23.1323(d).

7. PLANNING.

a. Flight in Icing Approval. The applicant should submit a certification plan at the start of the design and development efforts. Refer to FAA Order 8110.4B. The certification plan should describe all of the applicant's efforts intended to lead to certification. This plan should identify, by item to be certificated, the certification methods that the applicant intends to use. It should provide for a certification checklist. Regarding § 23.1419, it should clearly identify analyses and tests, or references to similarity of designs that the applicant intends for certification of the ice protection system. These methods of showing compliance should be agreed upon between the applicant and the FAA early in the type certification program. Detailed guidance for STCs or amended TCs on part 23 airplanes approved for flight in icing can be found in Appendix C of this AC. It is imperative that the applicant obtains FAA concurrence prior to conducting certification tests. The certification plan should include the following basic information:

(1) Airplane and systems descriptions, including dimensions, operating envelope and limitations, and other data that may be relevant to certification for flight in icing conditions;

(2) Ice protection systems description;

(3) Compliance checklist that addresses each applicable section of part 23 and the proposed methods of compliance (to be agreed upon between the applicant and the FAA early in the certification program);

(4) Analyses or tests performed to date;

(5) Analyses or tests planned;

(6) Projected schedules of design, analyses, testing, and reporting.

b. Installations without Flight in Icing Approval. There may be times when applicants may want to certificate an ice protection system installation but do not want to obtain flight in icing approval. In the past these systems have been called "non-hazard" installations. This means that the aircraft is prohibited from flight in icing conditions but there is some ice protection to facilitate an exit from an inadvertent icing encounter. Guidance for the approval of these types of ice protection systems can be found in Appendix D of this AC.

c. Replacement Parts for Airframe Ice Protection Systems. The requirements leading to approval of replacement airframe deicing systems or airframe thermal deicing or anti-icing systems are detailed in Appendix E.

8. DESIGN OBJECTIVES. The applicant must demonstrate by analyses and tests that the airplane is capable of safely operating throughout the icing envelope of part 25, Appendix C. The envelope can be reduced for airplanes certificated for operation where systems or performance limitations (e.g., altitude), not related to ice protection, exist. Appendix F lists various influence items that should be examined for their effect on safety when operating in icing conditions.

9. ANALYSES AND GROUND TESTING. The applicant normally prepares analyses to substantiate decisions involving application of selected ice protection equipment and to substantiate decisions to leave normally protected areas and components unprotected. Such analyses should clearly state the basic protection required, the assumptions made, and delineate the methods of analysis used. All analyses should be validated either by tests or by methods agreed to by the FAA. This substantiation should include a discussion of the assumptions made in the analyses and the design provisions included to compensate for these assumptions. Analyses are normally used for the following:

a. Areas and Components to be Protected. The applicant should examine those areas listed below to determine the degree of protection required:

(1) Leading edges of wings, winglets, and wing struts; horizontal and vertical stabilizers; and other lifting surfaces;

(2) Leading edges of control surface balance areas if not shielded;

(3) Engine induction system and any portion of the airframe from which accumulated ice could be ingested

(4) Accessory cooling air intakes that face the airstream and/or could otherwise become restricted due to ice accretion;

(5) Antennas and masts;

(6) Fuel tank vents;

(7) External tanks, including fuel tip tanks;

(8) Propellers;

(9) External hinges, tracks, door handles, and entry steps;

(10) Instrument transducers including pitot tube (and mast), static ports, angle-of-attack sensors, and stall warning transducers;

(11) Forward fuselage nose cone and radome;

(12) Windshields;

(13) Landing gear;

(14) Retractable forward landing lights;

(15) Ram air turbines;

(16) Ice detection lights if required; and

(17) Any other external protuberance.

An applicant may find that protection is not required for one or more of these areas and components. If so, the applicant should include supporting data and rationale in the analysis for allowing them to go unprotected. The applicant should demonstrate that allowing them to go unprotected does not adversely affect the handling or performance of the airplane.

b. Ice Accretion Analyses.

(1) Impingement Limit Analyses. The applicant should prepare a droplet trajectory and impingement analysis of the wing, horizontal and vertical stabilizers, propellers, and any other leading edges that may require protection. This analysis should consider the various airplane operational configurations and associated angles of attack. This analysis is needed to establish the upper and lower aft droplet impingement limits that can then be used to establish the aft ice formation limit and the extent of the protection surface coverage needed. The largest droplet size within part 25, Appendix C will determine the maximum impingement limits. More specific information can be found in AC 20-73, "Aircraft Ice Protection."

(2) Critical Ice Accretions. The critical ice accretions for which operational characteristics are to be evaluated should be determined for each flight phase as discussed in paragraph 12.b. of this AC. The parameters to be considered are the flight conditions (e.g., airplane configuration, airspeed, angle of attack, altitude) and the icing conditions of part 25, Appendix C (temperature, liquid water content, mean effective drop diameter). The applicant should substantiate the critical mean effective drop diameter, Liquid Water Content (LWC), and temperature that result in the formation of an ice accretion that is critical to the airplane's operational characteristics. For deicing systems, intercycle and residual ice accretions need to be considered.

(3) The 45-Minute Hold Condition. The 45-minute hold criterion should be evaluated when determining critical ice shapes for which the operational characteristics of the overall airplane are to be analyzed. The airplane's tolerance to continuous ice accumulation on the unprotected surfaces should be evaluated in accordance with the information contained in AC 20-73. The applicant should determine the effect of the 45-minute hold in continuous maximum icing conditions.

(a) A mean effective droplet diameter of 22 microns and a liquid water content of 0.5 gm/m^3 with no horizontal extent correction are normally used for this analysis; however, the applicant should substantiate the specific values used, including temperature, which represent the critical conditions for the airplane's performance and handling qualities. The analysis should consider that the airplane would remain in an icing cloud based on a rectangular course with leg lengths not exceeding the cloud horizontal extent and all turns being made within the icing cloud. Critical flight conditions should be considered such as weight and speed for critical angle of attack, and airspeed and altitude for maximum water catch.

(b) The applicant may elect to use more severe liquid water contents that are more representative of expected holding altitudes. The critical ice shapes derived from this analysis should be compared to critical shapes derived from other analyses (climb, cruise, and descent) to establish the most critical simulated ice shapes to be used during dry air flight tests.

c. Flutter Analysis. AC 23.629-1A, “Means of Compliance With Section 23.629, Flutter,” provides guidance for showing compliance with § 23.629. The flutter analyses should reflect any mass accumulations on unprotected and protected surfaces from exposure to part 25, Appendix C icing conditions, including any accretions that could develop on control surfaces. The 45-minute hold should also be considered. Ice accretions due to failure of the ice protection system should also be addressed.

d. Power Sources.

(1) Electrical Load Analysis. The applicants should evaluate the power sources in their ice protection system design. Electrical, bleed air, and pneumatic sources are normally used. A load analysis or test should be conducted on each power source to determine that the power source is adequate to supply the ice protection system, plus all other essential loads throughout the airplane flight envelope under conditions requiring operation of the ice protection system.

(2) Effect on Essential Systems. The effect of an ice protection system component failure on power availability to other essential loads should be evaluated, and any resultant hazard should be prevented on multi-engine designs and minimized on single-engine designs. The applicant should show that there is no hazard to the airplane in the event of any power source failure during flight in icing conditions. Two separate power sources (installed so that the failure of one source does not affect the ability of the remaining source to provide system power) are adequate if the single source can carry all the essential loads.

(a) Two-Engine Airplanes require two sources in accordance with § 23.1309(c). If a single source system is planned, additional reliability evaluation of the power source under system loads and environmental conditions may be required. All power sources that affect engine or engine ice protection systems for multi-engine airplanes must comply with the engine isolation requirements of § 23.903(c).

(b) Single-Engine Airplanes. Section 23.1309(a) requires that the ice protection system be designed to minimize hazards to the airplane in the event of a probable malfunction or failure. Failure condition classifications of “major”, “hazardous” or “catastrophic” are considered hazards. Complete loss of the airframe ice protection system has been considered at least “major” on past certification programs. Since experience has shown that the failure of generators currently in service is probable, for example, systems that utilize a generator, such as an alternator, would require two sources of electrical power. This is also consistent with past project specific guidance on interpretation of § 23.1309, which stated that the level of safety in a single engine airplane is established by engine reliability and the ice protection system should not compromise it.

e. Failure Analysis. AC 23.1309-1C provides guidance and information for an acceptable means, but not the only means, for showing compliance with the requirements of § 23.1309(a) and (b) (amendment 23-49) for equipment, systems, and installations in 14 CFR, part 23 airplanes. The regulatory requirements are in § 23.1309. Substantiation of the hazard classification of ice protection system failure conditions is typically accomplished through analyses and/or testing. It has been standard industry practice to assign a probability of encountering icing conditions of “one” for an airplane certificated for flight in icing.

(1) During the analyses, each identifiable failure within the system should be examined for its effect on the airplane and its occupants. Examples of failures that need to be examined include:

(a) (a) Those that allow ice to accumulate beyond design levels; or

(b) Those that allow asymmetric ice accumulation.

(c) System failures such as loss of pneumatic boot vacuum or overheat of a thermal system

(2) A probable malfunction or failure is any single malfunction or failure that is expected to occur during the life of any single airplane of a specific type. This may be determined on the basis of past service experience with similar components in comparable airplane applications. This definition should be extended to multiple malfunctions or failure when:

(a) The first malfunction or failure would not be detected during normal operation of the system, including periodic checks established at intervals that are consistent with the degree of hazard involved; or

(b) The first malfunction would inevitably lead to other malfunctions or failures. A procedure requiring a pilot to exit icing conditions would not be acceptable after any failure condition that would become catastrophic within the average exposure time it takes to exit icing conditions.

f. Similarity Analyses.

(1) In the case of certification based on similarities to other type certificated airplanes previously approved for flight in icing conditions, the applicant should specify the reference airplane model and the component to which the reference applies. Specific similarities should be shown for physical, functional, thermodynamic, pneumatic, aerodynamic, and environmental areas. Analyses should be conducted to show that the component installation and operation is equivalent to the previously approved installation.

(2) Similarity requires an evaluation of both the system and installation differences that may adversely affect the system performance. An assessment of a new installation should consider differences affecting the aircraft and the system. Similarity may be used as the basis for certification without the need for additional tests provided:

(a) Only minimal differences exist between the previously certificated system and installation, and the system and installation to be certificated; and

(b) The previously certificated system and installation have no unresolved icing related service history problems.

(3) FAA Order 8110.4B should be consulted regarding the use of previously approved FAA data.

If there is uncertainty about the effects of the differences, additional tests or analyses, or both, should be conducted as necessary and appropriate to resolve the open issues.

g. Induction Air System Protection. The induction air system for airplanes is certificated for ice protection in accordance with § 23.1093. These requirements are for all airplanes even those not certificated for flight in icing conditions. Thus ice protection systems installed on previously type certificated airplanes to protect the engine induction air system should be adequate and need not be re-examined, unless the inlet is being modified, the original certification basis is inadequate, or an in-flight AFM limitation was used to comply with the falling and blowing snow regulation. When natural icing flight tests are conducted to show compliance to 23.1419, engine operation, engine ice protection system procedures, and engine inlet ice accretion should be evaluated if flight tests in natural icing conditions were not previously accomplished on the engine/inlet configuration.

h. Pitot Probe Ice Protection. Compliance to the TSO qualification standard for electrically heated pitot probes (TSO-C16) is not sufficient by itself in demonstrating compliance to the installation requirements of § 23.1309(b)(1) and § 23.1419. Section 23.1309(b)(1) requires that the system must perform its intended function under any foreseeable operating condition. Section 23.1419 requires that an airplane certificated for flight in icing must be able to safely operate in part 25, Appendix C icing conditions. It is unlikely that the conditions of part 25, Appendix C that are critical to the air data system equipment will be encountered during flight tests. Consequently certification programs should supplement the icing flight tests with an icing tunnel test and/or airborne icing tanker test data, as necessary, or reference testing that has been accomplished by the pitot probe manufacturer. In-service experience during severe atmospheric conditions has shown that pitot tubes qualified to the older standards have resulted in airspeed fluctuations and even loss of indicated airspeed. As these components should perform as intended in all expected atmospheric environments, it is reasonable to require that they be qualified to the Continuous and intermittent maximum icing conditions defined in part 25, Appendix C. Additionally, more recent standards indicate that these components should be qualified for operation in atmospheric conditions beyond the environment described by part 25, Appendix C, specifically during ice crystal and mixed phase icing conditions.

(1) Conditions Within the Part 25, Appendix C Icing Envelope. TSO C16, Air-speed tubes (electrically heated) require compliance to the performance specifications of SAE Aeronautical Standard AS393. This standard and AS393A (out-of-date), are non-current. SAE AS393A includes a test to demonstrate deicing and anti-icing capability, but only temperature and airspeed are specified. Liquid water content is not specified but it influences heat requirements. Although functioning of pitot probes are evaluated in natural icing conditions during certification test programs, there is no requirement to flight test at the part 25, Appendix C icing limits because the low probability of finding those conditions imposes a burden. The airframe manufacturer is responsible for showing the pitot heat is adequate throughout the part 25, Appendix C icing envelope. If not obtained in flight test, analysis or icing tunnel test data should be submitted.

(2) Conditions Outside of the Part 25, Appendix C Icing Envelope. Although part 25, Appendix C only considers the liquid water content of icing conditions, recent cloud characterization research has indicated that approximately 40 percent of icing condition events consist of liquid water drops and ice crystals (mixed-phase icing conditions). Also ice crystal atmospheric conditions are encountered during aircraft operations. The ice crystal environment may be more critical than liquid water for thermal systems since more energy is required to melt the ice crystals. Recently, some aircraft manufacturers and foreign certification authorities have required pitot and pitot-static probes to be tested in ice crystal and mixed phase icing conditions along with supercooled liquid water conditions. As a result, some pitot tube manufacturers now use the icing environment of British Specification (BS) 2G.135 “Specification for Electrically-Heated Pitot and Pitot-Static Pressure Heads,” as modified by the maximum rate that the icing tunnel facility can produce ice crystal, in addition to the requirements of the TSO. Even though the part 23 and part 25 regulations only address liquid water and testing in the mixed phase or ice crystal conditions are not required for FAA approval, it is good design practice to assure the pitot heat is sufficient for the ice crystal and mixed phase conditions of BS 2G.135.

i. Stall Warning Ice Protection. Compliance to the TSO qualification standard for stall warning instruments (TSO-C54) is not sufficient by itself in demonstrating compliance to the installation requirements of § 23.1309(b)(1) and § 23.1419.

(1) Conditions Within the Part 25, Appendix C Icing Envelope. TSO-C54, “Stall Warning Instruments”, requires compliance to the performance specifications of SAE Aeronautical Standard AS403A with some exceptions and additions. This standard is non-current. As in AS393A, the requirements include a test to demonstrate deicing and anti-icing capability, but only temperature and airspeed are specified. The precipitation test conditions of AS403A include moderate icing conditions for Type II instruments. However, "moderate" is not defined. The same comments from 9i(1) apply. The airframe manufacturer is responsible for showing that stall warning heat is adequate throughout the part 25, Appendix C icing envelope.

(2) Conditions Outside of the Part 25, Appendix C Icing Envelope. The same comments from paragraph 9i(2) above apply to stall warning ice protection systems.

j. Ice Detector. Besides the pilot's appraisal of icing conditions (i.e., defined by temperature and visible moisture or visual detection of ice accretions on wiper blades, window frames or propeller spinner, etc.), some airplanes use In-Flight Ice Detection Systems (IIDS). IIDS may either directly detect the presence of ice on an airplane reference surface or detect that the airplane is in icing conditions. There are basically two classes of IIDS:

(1) Advisory In-flight Ice Detection System. An advisory IIDS provides information to advise the flightcrew of the presence of ice accretion or icing conditions. The flight crew has primary responsibility for detecting icing conditions or ice accretions, using the means defined in the AFM, and activating the Ice Protection Systems (IPSs). An advisory IIDS can automatically activate the IPS. However, the AFM must state the flight crew has primary responsibility for detecting icing conditions or ice accretions.

(2) Primary In-flight Ice Detection System. A Primary IIDS (PIIDS) is considered the sole means used to determine when the IPS must be activated. The IPS may be automatically activated by the PIIDS or the PIIDS may provide a flight deck signal that will direct the crew to manually activate the IPS. Installation of an ice detection system is considered a safety enhancement since the icing conditions may be identified or confirmed at an early stage and appropriate actions can be initiated in a timely manner. However, recent investigations indicate that previously certificated ice detection systems may not detect airframe and engine icing in some part 25, Appendix C conditions. It has also been demonstrated in an icing wind tunnel that atmospheric moisture may fail to freeze on ice detector probes even though ice may be accreting on other airplane surfaces. With the continuing development of ice detection systems and due to recent in-service incidents, the FAA has determined there is a need to define specific criteria to certify ice detection systems that are used as the sole means of determining when the ice protection systems are activated.

(a) Applicable regulations. When certificating a PIIDS, compliance with §§ 23.929, 23.1093, 23.1301, 23.1309 and 23.1419 should be substantiated with the ice accretions that form prior to activation of the ice protection system and ice accretion during the system response time (e.g., for a thermal ice protection system, the time to heat the surface and remove the ice).

(b) System Safety Assessment. A PIIDS and associated components considered separately and in relation to other systems, shall be designed so that failure conditions classification and effects must be in compliance with § 23.1309. In particular, reliability of the PIIDS hardware and software should be established using means for showing compliance provided by AC 23.1309-1C.

1. The probability of encountering part 25, Appendix C icing conditions is considered to be 1.

2. An undetected failure of the PIIDS should be considered as catastrophic unless a lower failure condition classification is substantiated and agreed to by the FAA.

3. Information concerning unsafe PIIDS operating conditions must be provided to the flight crew. For example, loss of PIIDS capability should be annunciated.

(c) System Operation. To be compliant with § 23.1301 a PIIDS must be capable of detecting the presence of icing conditions or actual ice accretion under all atmospheric conditions defined in part 25, Appendix C, or the airplane must be capable of safely operating without restriction in the icing conditions that are not detected by the PIIDS. Certification data must be provided that substantiates that the PIIDS complies with applicable 14 CFR, part 23 requirements and the specific tests identified in this appendix. Compliance should be demonstrated by analysis that is verified using flight test data gathered and measured in natural icing conditions, and, as found necessary, by icing wind tunnel or tanker tests.

(d) Freezing Fraction Consideration. Certain icing conditions defined by part 25, Appendix C may result in failure of the liquid water to freeze on ice detector probes even though ice may be accreting on other airplane surfaces. In these cases the ice detector accretion may be insufficient to trigger the ice detection signal, or the response time for the detector to detect icing conditions may be extended such that significant ice can accrete on protected airplane or propulsion components. This phenomenon occurs when the freezing fraction is well below one. A specific assessment of this phenomenon should be accomplished for the PIIDS. Icing wind tunnel evaluations used to evaluate these conditions should include the use of actual size leading edge models of the airfoils used on the airplane. Additionally the evaluation should include engine inlets, vanes and blades to assure that these conditions will not adversely affect the propulsion system unless specific AFM provisions are provided that assure engine ice protection independent of the PIIDS detection of icing conditions.

(e) Location of the Sensors. Performance of the PIIDS is affected by the physical installation and can only be verified after installation. The ice detecting devices should be installed at locations that assure safe flight by detection of icing prior to a hazardous build up of ice on the airframe or propulsion components. Proper location of ice detectors may require various computational fluid dynamic analyses and icing wind tunnel tests to assure that the ice detector is capable of adequately sampling the icing environment. It should be shown by analysis and/or flight test that the detection system sensors are located properly for all flight phases and airplane configurations and all combinations of icing conditions parameters as defined in part 25, Appendix C (liquid water content, mean effective drop diameter, temperature, altitude and horizontal extent). Additionally, the airframe manufacturer should show that ice accretions occurring forward of the sensor, such as on the radome, do not interfere with the airflow ice sensing, and that shed ice will not damage the detectors. Also other probes forward of the ice detector should not interfere with the proper functioning of the detector.

(f) Annunciation. The PIIDS display(s) flight deck lights and crew alerting messages must be located so that they are within the seated flight crew's seat forward vision scan area while performing their normal duties.

(g) Icing Conditions Outside of Part 25, Appendix C. Ice detectors typically have limitations with certain atmospheric phenomena, e.g. ice crystal conditions, outside of part 25, Appendix C, which the airframe manufacturer must understand and not rely on the PIIDS to detect these conditions. There have been cases (an anomaly that has affected some engine models) where atmospheric ice crystals ingested in the initial fan stages of jet engines have melted, and re-accreted on subsequent low pressure compressor stages or initial stages to the high pressure compressor resulting in engine core ice. Subsequent shedding of this type of ice accretion has resulted in at least one unrecoverable engine surge. Therefore, airframe manufacturers must be aware of the potential limitations of engines during ice crystal conditions without reliance on the ice detection system. Current policy considers this potential condition in § 23.1093(b)(1)(ii) which requires demonstration of adequate engine performance in ice crystal conditions during falling or blowing snow. 14 CFR part 23 and part 33 regulations and compliance methods intend to provide unrestricted engine operation throughout the atmospheric environmental envelope.

k. Fluid (Freezing Point Depressant) Systems. Freezing point depressant fluid systems have been successfully certificated on part 23 airplanes. However, the system is not as common as other ice protection systems and that prompted the FAA in 1986 to publish information on certification of these systems in DOT/FAA/CT-TN86/11. Certification highlights from this publication are repeated below.

(1) Analyses. The two critical analyses required are the fluid flow rate required and an evaluation of the operational angles of attack, which will dictate chordwise coverage.

(2) Fluid Capacity. The fluid capacity does not have to exceed the maximum endurance of the airplane but the minimum should be as follows in Table 2.

TABLE 2. FLUID CAPACITY

Airplane Type	Minimum Fluid Capacity is the greater of:
Turbojet powered airplanes Turbopropeller airplanes with maximum operating altitude above 30,000 feet	90 minutes or 15 percent of the maximum endurance based on the flow rate required in continuous maximum icing conditions
Turbopropeller airplanes with maximum operating altitude 30,000 feet and below Reciprocating engine powered airplanes	150 minutes or 20 percent of the maximum endurance based on the flow rate required in continuous maximum icing conditions

(3) Fluid Quantity.

(a) There should be a fluid quantity indicator to allow the crew to determine how much longer the fluid will last. The fluid quantity indicator should be evaluated to determine that it is plainly visible to the pilot and that the indicator provided can be effectively read.

(b) If it is desired that the airplane be dispatched with less than full fluid in the reservoir, the AFM should contain a chart or table to allow the crew to determine the minimum fluid level. The AFM limitations should state a minimum dispatch fluid level of 90 minutes based on the flow rate required in continuous maximum icing conditions.

(4) Fluid Characteristics.

(a) The freezing point depressant fluids used become a gel at very cold temperatures and the temperature extremes to which the airplane will be operated should be considered when evaluating the reservoir, pump and plumbing installations.

(b) An accessible shutoff should be provided in systems using flammable fluids. The alcohol used on propeller systems is flammable and should be addressed. The common fluid used in freezing point depressant systems in the U.S., AL5, has been shown to have low flammability properties.

(c) The effect of fluid ingestion into engines, Auxiliary Power Units (APUs), and accessories should be evaluated.

(d) The effect of fluid compatibility with electrical contacts and with composite materials should be evaluated.

(e) There should be sufficient AFM and maintenance manual warnings on handling fluids. AL5 is 85 percent mono-ethylene glycol, which is considered extremely toxic.

(f) Another freezing point depressant fluid, TKS80, is available. Icing tunnel tests of TKS80 and AL5 fluids have shown that they perform differently. The fluid reservoir should be placarded to permit only the fluid(s) that have been tested during certification.

(g) To avoid confusion, the fluid filler tank cap should be distinguishable from other caps such as fuel and a placard stating approved fluid should be located near the filler cap.

(h) There should be adequate drainage in the areas that hold or can receive spillage from leaks.

(5) **Windshield Visibility.** The effect of the fluid on windshield visibility should be evaluated to show compliance to § 23.775(f) if either the windshield or propellers are protected with a freezing point depressant system. On many of the approved installations the windshield system is turned off just prior to landing.

10. FLIGHT TEST PLANNING. When operating any airplane in an icing environment, degradation in performance and flying qualities may be expected. The primary purposes for flight testing an airplane equipped for flight in icing conditions is to evaluate such degradation, determining that the flying qualities remain adequate, and that performance levels are acceptable for this flight environment. For airplanes with a certification basis of 23-43 or higher, § 23.1419 requires that an airplane comply with the performance, stability, controllability and maneuverability regulations of part 23, Subpart B.

a. The flight tests and analyses of flight tests should:

(1) Evaluate normal operation of the airplane with the ice protection system installed in non-icing flight.

(2) Evaluate operation of the airplane with anticipated in-flight accumulations of ice.

(3) Verify the analyses conducted to show adequacy of the ice protection system throughout the icing envelope of part 25, Appendix C.

(4) Develop procedures and limitations for the use of the ice protection system in normal, abnormal, and emergency conditions.

b. Flight tests are generally conducted in three stages:

(1) Initial Dry Air Tests With Ice Protection Equipment Installed And Operating. Initial dry air tests are usually the first steps conducted to extend the basic airplane certification to evaluate the airplane with the ice protection system installed and operating. The initial dry air tests are conducted to verify that the ice protection system does not affect the flying qualities of the basic airplane in clear air.

(2) Dry Air Tests With Predicted Simulated Ice Shapes Installed. Dry air tests with predicted, simulated critical ice shapes installed are usually the second step for certification for flight in icing. Airplane performance and handling characteristics are evaluated with these simulated ice shapes. Often, it is more economical to verify specific analyses by ground tests such as icing tunnel tests where the design variables can be controlled to some extent.

(3) Flight Tests in Icing Conditions. Flight tests in icing conditions, including artificial icing tests such as flight behind an airborne icing tanker aircraft, are normally employed to demonstrate that the ice protection system performs under flight conditions as the analysis or ground test indicated. These demonstrations should be made at various points (targeting critical points) in the icing envelope of part 25, Appendix C, to verify the airplane's ability to safely operate throughout that icing envelope.

11. FLIGHT TESTS. The following sections cover the major flight tests and/or analyses normally performed to substantiate the flight aspects of an ice protection system:

a. Initial Dry Air Tests with Ice Protection Equipment Installed. Depending upon the detailed design of the ice protection system, some preliminary ground tests of the equipment may be warranted to verify the basic function of each item. Quantitative data on such items as temperatures of thermal devices, fluid flow rates and flow patterns on liquid devices, or operating pressures of pneumatic components may be obtained as necessary to verify the system designs. The airplane should be shown to comply with the certification requirements when all ice protection system components are installed and functioning. This can normally be accomplished by performing tests at those conditions found to be most critical to basic airplane aerodynamics, ice protection system design, and powerplant functions. Section 23.1419 requires that the adequacy of the airplane's ice protection system be established based on operational needs. Tests must be conducted to demonstrate that the airplane is capable of operating safely in continuous maximum and intermittent maximum icing conditions as described in part 25, Appendix C. Several commonly used ice protection system components are discussed below to illustrate typical flight test practices. Other types of equipment should be evaluated as their specific design dictates.

(1) Pneumatic Leading Edge Boots.

(a) Operation. Boot inflation rate and inflated boot shape are important parameters in ice accretion removal. Tests should demonstrate a rapid rise and decrease in operating pressures for effective ice removal. This pressure rise time, as well as the maximum operating pressure for each boot, should be evaluated throughout the altitude band of part 25, Appendix C—Mean Sea Level (MSL) to 22,000 feet above MSL—unless performance constraints or aircraft limitations unrelated to the ice protection system in the AFM restrict the airplane to a lesser altitude range.

(b) Minimum Operating Temperature. Boots should be operated in flight at the minimum envelope temperature (-22 degrees Fahrenheit (F) of part 25, Appendix C, to demonstrate adequate inflation/deflation and throughout the entire flight envelope. Boots should be operated near the proposed AFM operating temperature limit, if below -22 degrees F, to demonstrate that no damage occurs. The appropriate speed and temperature (if any) limitation on activation of boots should be included in the AFM.

(c) Effect of Inflated Boots. The operation of the boots (inflation) should have no hazardous affect on airplane performance and handling qualities. An example of an unacceptable hazardous effect is that some boot inflation sequencing schemes result in abnormal pitch attitude changes. If there are anomalous pitch changes in any configuration, appropriate information or limitation should be in the AFM. This can be shown by inflating the boots at several speeds in the flight envelope from stall speed to $(V_{NE} + V_D)/2$ or $(V_{MO} + V_D)/2$ and observing the reaction of the airplane. This test can be hazardous and should be approached in a build-up manner by inflating the boots at incremental airspeeds starting from the middle of the flight envelope.

(d) Cockpit Annunciations. Section 23.1309(b)(3) states that warning information must be provided to alert the crew to unsafe system operating conditions, and to enable them to take appropriate corrective action. Systems, controls, and associated monitoring and warning means must be designed to minimize crew errors, which could create additional hazards. Section 23.1416(c) requires "that means to indicate to the flight crew that the pneumatic deicer boots system is receiving adequate pressure and is functioning normally must be provided." Stall speed can increase dramatically with inflated boots and failures in the vacuum system need to be addressed. If the indicating lights for the pneumatic deicing system (boots) illuminate at a lower pressure than required for proper boot operation, misleading information is furnished to the flight crew, which can, in turn, lead to an unsafe operation. This could mislead the crew to believe the boots are operating normally when, in fact, the boots might not be inflating sufficiently to shed ice.

(e) Water Contamination. Consideration should be given to the potential for accumulation of liquid water inside the pneumatic deicing boots, which could freeze within the system and prevent proper operation. The pneumatic and boot arrangement should be examined for low points, which may collect water, and consideration should be given to the installation of water drainage points. Periodic inspection and drainage procedure instructions should be provided in the appropriate manual. Similarly, placement of the pressure sensor(s) should be evaluated to prevent misleading boot inflation indications. An evaluation of the effectiveness of water/air separators and/or drainage holes should be accomplished by flying through precipitation followed by a demonstration of system operation at freezing altitudes.

(2) Electric Propeller Boots.

(a) Dry Air Function Flight Test.

1. System Function. When flying in dry air, the systems should be monitored to confirm proper function. It is suggested that system current, brush block voltage (between each input brush and the ground brush), and system duty-cycles be monitored to assure that proper power is applied to the deicers.

2. Temperature Measurements. If not furnished by the manufacturer, surface temperature measurements may be made during dry air tests. These surface temperature measurements are useful for correlating analytically predicted dry air temperatures with measured temperatures or as a general indicator that the system is functioning and that each deicer is heating.

3. Vibration. The system operation should be checked throughout the full certificated Revolutions Per Minute (RPM) and propeller cyclic pitch range expected during icing flights. Any significant vibrations should be investigated.

(b) Maximum Temperature. Consideration should be given to the maximum temperatures that a composite propeller blade may be subjected to when the deicers are energized. It may be useful to monitor deicer bond-side temperatures. When performing this evaluation, the most critical conditions should be investigated. For example, this may occur on the ground (propellers non-rotating) on a hot day with the system inadvertently energized. Service difficulty reports have indicated propeller damage during de-ice/anti-ice system activation during maintenance without the engines running.

(c) Precipitation. The system should be monitored to confirm proper function in precipitation. There have been designs that allowed water to reach the electrical brush blocks and prevent their operation.

(3) Electric Windshield Anti-Ice.

(a) Thermal Analysis Validation. Dry air flight tests should be conducted in support of the systems design, as required. Inner and outer windshield surface temperature evaluations of the protected area may be needed to support thermal analyses. Thermal analysis should substantiate that the surface temperature is sufficient to maintain anti-icing capability without causing structural damage to the windshield. In the case of add-on plates, temperatures of the basic airplane windshield, inside and out, may also be needed, particularly with pressurized airplanes.

(b) Cockpit Visibility. An evaluation of the visibility, including distortion effects through the protected area, should be made in both day and night operations to show compliance to § 23.775(f).

(c) Size of Protected Area. The size and location of the protected area should be reviewed for adequate visibility, especially for approach and landing conditions. Crosswinds and runway light visibility during instrument landings need to be considered.

(d) Failure Analysis. A probable single failure of a transparency heating system should not adversely affect the integrity of the airplane cabin or create a potential danger of fire.

(4) Pitot-Static and Static Pressure Sources. If the air data system configuration of either the pitot or the static source(s) differs from that of the basic airplane, then airspeed and altimeter system calibrations should be evaluated for compliance with the certification requirements. A component surface temperature evaluation may be necessary to verify thermal analyses. Section 23.1325(b) requires that static pressure port design or location should be such that the correlation between air pressure in the static pressure system and true ambient atmospheric static pressure is not altered when the airplane encounters icing conditions. Section 23.1325(b)(3) allows an anti-icing means or an alternate source of static pressure may be used in showing compliance with the requirement.

(5) Stall Warning and Angle-of-Attack Sensors. Ice could form on these sensors if these devices are not protected. When the icing approval requires installation of new or modified sensors, that sensor's function should be evaluated for compliance with the certification requirements. These sensors may not require heat for ice protection if substantiated by analyses. A surface temperature evaluation may be necessary to verify thermal analyses. Consideration should be given to ice formations on the airframe in the vicinity of the sensor mounting location that may affect the sensor's operation.

(6) Pitot Tube. Section 23.1323 requires a heated pitot tube or an equivalent means of preventing malfunction due to icing. Section 23.1326 requires a pitot tube heat indicating system if a flight instrument pitot heating system is installed to meet ice protection requirements.

(7) Fluid (Freezing Point Depressant) Systems.

(a) Fluid Coverage. Dry air testing should include evaluation of fluid flow paths to determine that adequate and uniform fluid distribution over the protected surfaces is achieved. Colored fluid or colored water with camera documentation may be used. A range of angles of attack should be evaluated with both high and low volume rates. Inlets or openings where fluid ingestion will have a detrimental effect should be evaluated.

(b) Aircraft Performance. Dry air testing should also include performance testing with the system operating since drag increases have been documented on previous certification programs.

(c) Temperature. The system should be functionally tested at the minimum part 25, Appendix C ambient temperatures.

(d) Windshield. The fluid anti-ice/deice systems may be used to protect propellers and windshields, as well as leading edges of airfoils. The fluid for windshield fluid systems, and for propeller fluid systems forward of the windshield, should be tested to demonstrate that it does not become opaque at low temperature.

(e) Cockpit Annunciations. Means of indicating fluid flow rates, quantity remaining, and so forth, should be evaluated to determine that the indicators are plainly visible to the pilot and that the indications provided can be effectively read.

(8) Compressor Bleed Air Systems. The effect of any bleed air extraction on engine and airplane performance should be examined and shown in the AFM performance data. The surface heat distribution analysis should be verified for varying flight conditions including climb, cruise, hold, and descent. A temperature evaluation may be necessary to verify the thermal analyses. If a minimum engine speed is required for ice protection system operation, the ability to descend should be evaluated. If compressor bleed air is used for anti-icing an engine cowl that is made of composite material, a thermal analysis/survey should be conducted to assure there is no engine cowl delamination or other structural failure.

(9) Ice Inspection Light(s). Ice inspection lights may be necessary if operations are dependent upon observing ice accumulations at night (§ 23.1419(d)). Ice inspection lights should be evaluated both in and out of clouds during night flight to determine that adequate illumination of the component of interest is available without excessive glare, reflections or other distractions to the flight crew. These tests may be conveniently accomplished both in and out of clouds during dry air tests. Use of a hand-held flashlight for ice detection is not acceptable. As described in § 23.1419(d), “The Airplane Flight Manual or other approved manual material must describe the means of determining ice formation and must contain information for the safe operation of the airplane in icing conditions.”

b. Dry Air Tests with Simulated Ice Shapes.

(1) Why Do Simulated Ice Shape Flight Testing? The installation of simulated ice shapes allows airplane performance and handling characteristics to be evaluated in stable dry air conditions with the critical ice shape being held constant (no change of ice accretion due to erosion, shedding, and so forth, that can occur with natural ice shapes). Dry air flight tests with simulated ice shapes installed also result in a considerable reduction in the amount of flight testing that would otherwise be required to accumulate the test ice shapes, and then evaluate their effects on airplane performance and handling characteristics in stable air.

(2) Flight Test Safety. Dry air tests with simulated ice shapes can be hazardous if not approached safely; therefore, the dry air flight test evaluation should be performed using a build-up technique, considering increases in spanwise coverage and dimensions of simulated ice shapes prior to full span ice shape tests.

(3) Simulated Ice Shapes.

(a) Critical Ice Accretions. Consideration should be given to the type of ice protection systems (for example: mechanical, fluid, thermal, or hybrid), and the most adverse ice conditions (shape or shapes, texture, location, and thickness) for the relevant aerodynamic characteristics for the following, as appropriate: delayed system turn on, intercycle ice, failure conditions, runback ice, and residual ice. Consideration should also be given to unprotected areas. See paragraph 12c for more information. The validity of the ice shape predictions from analytical computations simulated icing flight tests or icing tunnel tests should be confirmed by flight tests in natural icing. These predictive methods should be conservative and should address the conditions associated with the icing envelope of part 25, Appendix C, that are critical to the airplane's performance and handling qualities in critical phases of the airplane's operational envelope, including climb, cruise, descent, holding pattern, approach, and landing. Ice shapes critical for performance may not be necessarily critical for handling qualities.

(b) Ice Detection Systems. For aircraft that have an ice detection system, consideration must be given to delays in ice detection and annunciation. These delays may include slow ice detector response at temperatures near freezing (low freezing fraction as discussed in AC 20-73) and the number of probe heat cycles utilized for annunciation or automatic ice protection activation.

(4) Flight Test Objectives.

(a) Performance. The effect of the ice shapes on stall speeds and airplane climb performance should be determined. Stall warning margins and maneuvering capability should also be evaluated. Operating speeds, stall warning speeds, and AFM performance information should be adjusted, if necessary, to provide acceptable performance capability and stall warning margins. The computation of the effects of ice on AFM performance should include reductions in engine power or thrust resulting from the applicable operating mode of the ice protection system.

(b) Handling Qualities. Handling characteristics are expected to degrade in icing conditions and should be investigated to determine that the “airplane is capable of operating safely.” For certification basis before amendment 23-43, subpart B requirements are used as guidelines. For certification basis at amendment 23-43 and higher, several subpart B requirements also apply in icing conditions. This is addressed in paragraph 12a. The results of these tests may be used in preparing specific AFM operating procedures and limitations for flight in icing conditions.

(c) Air Data Calibrations. If ice accretion is predicted to alter the position error of the production air data system (e.g. radome ice accretion), the position error would need to be determined using air data calibration flight tests (i.e. tower fly-by, trailing cone, speed course) with the critical, simulated ice shapes determined by analysis.

c. Flight Tests in Icing Conditions. Flight tests in measured natural icing and the use of simulated icing tools such as airborne icing tankers and icing wind tunnels are normally employed to demonstrate that the ice protection system performs under flight conditions as the analysis or other tests indicate. They are also used to confirm the analyses used in developing the various components (for example, ice detectors) and ice shapes and, in the case of natural icing tests, to confirm the conclusions reached in flight tests conducted with simulated ice shapes. Testing should be accomplished at various points in the icing envelope of part 25, Appendix C, to verify the airplane's ability to safely operate throughout that icing envelope.

(1) Instrumentation. Sufficient instrumentation should be planned to allow documentation of important airplane, system and component parameters, and icing conditions encountered. The following parameters should be considered:

(a) Altitude, airspeed, and engine power.

(b) Temperatures. Static air temperature, engine component temperatures (for example, oil, heat exchanger fluids, cylinder head), electrical generation equipment temperatures, surface temperatures, interlaminate temperatures, and any other key temperatures that could be affected by ice protection equipment, by ice accumulation or other key temperatures that are necessary for validation of analyses

(c) Liquid water content can be measured using a hot-wire based instrument, calibrated drum, or other equivalent and acceptable means.

(d) Median volumetric droplet diameter can be approximately determined by using a drop snatcher to expose a gelatin oil or soot slide and then measuring the resultant impact craters, or by use of more sophisticated equipment such as a laser based droplet measuring and recording instrument.

(e) Cameras and dimensional reference aids to assist in determining ice accretion thickness and ice accretion coverage.

(2) Artificial Icing.

(a) Why Do Artificial Icing Tests? Testing in artificial icing environments such as icing tunnels or behind airborne icing tankers represents one way to predict the ice protection capabilities of individual elements of the ice protection equipment. Due to the usually small dimensions of the artificial icing environment, testing is usually limited to sections of lifting surfaces, to components having small exposed surfaces such as heated pitot tubes, antennas, air inlets including engine induction air inlets, empennage, and other surfaces having small leading edge radii and windshields. Small components are more sensitive to the higher accumulation rates associated with high liquid water content and large droplet size. These conditions are easily simulated and not frequently encountered in natural icing flight tests.

(b) Airborne Icing Tankers. An artificial icing exposure may be obtained by the use of onboard spray nozzles forward of the component under examination or by flying the test airplane in the cloud generated by an airborne icing tanker. Recommended procedures for airborne icing tanker testing, including instrumentation requirements, are in SAE ARP 5904, “Airborne Icing Tankers.”

(c) Icing Tunnels. Icing tunnel tests have been accepted for definition of pre-activation, intercycle, residual, and runback ice on protected surfaces with the following considerations:

1. Scaling. A full-scale test article is preferable due to uncertainties in ice accretion scaling. To date the FAA has not accepted data on scaled models because of the uncertainties involved in the scaling laws.

2. Conformity. The test article must be conformed. Although parts of the ice protection system may be simulated, critical system parameters must be conformed. An example would be deicing boot steady state pressure, and pressure rise time and decay time.

3. Tolerances. Ice protection system tolerances on the production airplane, such as boot operating pressure, must be accounted for.

4. Operational Consideration. Proposed ice protection system operation (activation procedures, ice detection system delay, and deicing boot cycle times) must be accounted for in the test matrix.

5. Spray Times. If the facility cannot produce the required LWC, spray times can be adjusted to provide the equivalent water catch for part 25, Appendix C cloud lengths. If large ice shapes are expected, test ambient temperature may have to be adjusted to provide an equivalent freezing fraction. Temperatures can change the ice adhesion/shed characteristics and this should be taken into account when adjusting test parameters. The test matrix should include longer times in continuous maximum conditions to evaluate the stability and cyclic nature of intercycle and residual ice. Certain unique design features, such as stall strips mounted on deicing boots, may not readily shed ice and spray times up to 45 minutes need to be evaluated.

6. Test Section. An outboard wing section is usually tested since it is typically more critical for aerodynamic degradations due to the reduced scale relative to the wing root (on wings incorporating significant taper ratios). It will also have higher water collection efficiency and may operate at a lower angle of attack, thereby promoting greater aft impingement of droplets on the suction surface. For thermal systems, the outboard sections also represent the extremities of the bleed air system where temperature and pressure losses are the greatest, which can be critical for runback accretions. The distribution of icing cloud parameters along the test span should be taken into account.

(3) Natural Icing.

(a) Why Do Flight Tests In Natural Icing Conditions? Section 23.1419(b) requires flight test in measured natural icing conditions. Flight tests in natural icing conditions are necessary to demonstrate the acceptability of the airplane and ice protection system for flight in icing conditions. AC 20-73 provides additional information that would be useful when establishing a natural icing flight test program.

(b) What Icing Conditions Should Be Tested?

1. Continuous maximum Icing Conditions. At least one exposure to icing conditions within the part 25, Appendix C, continuous maximum envelope should be obtained. The exposure should be sufficiently stabilized to obtain valid data. It is often difficult to obtain temperature stabilization in brief exposures. Additional exposures may be required to allow extrapolation to the envelope critical conditions by analysis. Test data obtained during these exposures may be used to validate the analytical methods used and the results of any preceding simulated icing tests.

2. Intermittent Maximum Icing Conditions. Past experience has shown that flight testing in natural intermittent maximum icing conditions may be hazardous due to accompanying severe turbulence and possible hail encounters that may extensively damage the test airplane. When design analyses show that the critical ice protection design points (that is, heat loads, critical shapes, accumulation, and accumulation rates, and so forth) are adequate under these conditions, and sufficient ground or flight test data exists to verify the analysis, then hazardous flight testing should be avoided.

(c) Documentation of Ice Accretions. During natural icing flight tests, ice accumulation on unprotected and protected areas should be observed and documented. Remotely located cameras either on the test airplane or on a chase airplane has been used to document ice accumulations on areas that cannot be seen from the test airplane's flight deck or cabin. Visual devices such as rods and/or paint stripes may be used to aid in visual dimensional analysis of ice accretions. Care should be taken since some measuring devices may accrete ice and alter analysis of accretions on a surface of importance. The edges of paint stripes can be efficient ice collectors if not smoothed and must be accounted for. The location of all external instrumentation installed for icing flight tests, including cameras and visual devices, should be analyzed to verify that ice-shedding hazards are not introduced.

(d) How Much Ice Should Be Allowed to Accrete?

1. Normal Ice Protection System Operation. Sufficient data should be taken to allow correlation with dry air tests using simulated ice shapes. This should be accomplished with a target accretion thickness equivalent to the 45-minute dry air ice shapes on an unprotected part of the wing. Handling qualities and performance should be subjectively reviewed and determined to be in general correlation with those found in dry air testing. Refer to paragraph 12.a. for performance, stability, control and maneuverability requirements.

2. **Delayed Ice Protection System Activation.** In addition, flying qualities and performance should be qualitatively evaluated with the ice accumulations existing just prior to operation of deice (as opposed to anti-ice) components. The ice protection systems are to be activated by the flight crew in accordance with approved AFM procedures when icing conditions exist; however, for anti-ice components, tests should be conducted that simulate inadvertent icing encounters in which the pilot may not recognize that the airplane is about to enter an icing condition and the anti-ice component may not be activated until actual ice build-up is noticed.

How Long is the Delayed Activation? A delayed ice accumulation event of 30 seconds to two minutes has been used in these tests to simulate the flight crew's failure to recognize an icing condition. For engine ice protection systems, which for aft fuselage mounted engines can include the inboard wing ice protection system, a delay of two minutes is utilized to validate the ice shedding analyses and § 33.77 ice slab test results. For the delayed ice accumulation time event, consideration should be given to the icing conditions, the icing recognition means available, recommended crew procedures, and ice protection system performance of the particular aircraft. The tests to be accomplished are summarized in Table 4 of paragraph 12c of this AC.

(e) What Should Be Evaluated During Natural Icing Tests? All systems and components of the basic airplane should continue to function as intended when operating in an icing environment. Some considerations are:

1. **Engine and equipment operation** such as generator cooling under maximum load should be monitored during icing tests and be found acceptable for this operation.

2. **Engine alternate induction air** sources should remain functional in an icing environment.

3. **Fuel system venting** should not be affected by ice accumulation.

4. **Retractable landing gear** should be available for landing following an icing encounter. Gear retraction should not result in an unsafe indication because of ice accretion.

5. **Ice shedding** from components including antennas should cause no more than cosmetic damage to other parts of the airplane, including aft-mounted engines and propellers.

6. **Stall Warning and Maneuver Margin.** With ice accretions on the airplane, acceptable stall warning (aerodynamic or artificial) and stall protection, if a stall protection system is installed, should be provided to validate the results of the dry air ice shape testing. The stall warning should meet the requirements of § 23.307(a), (b), and (c). The type of stall warning in icing conditions should be the same as in no icing conditions. Biasing of the

stall warning and stall protection system, if installed, may be required to achieve acceptable margins to stall. The maneuver margin requirements § 23.207(d) should be demonstrated in icing conditions.

NOTE 1

This test and any handling qualities tests in natural icing should be accomplished in daytime visual meteorological conditions for safety.

__7__. **Ice detection cues or ice detection system operation** that the pilot relies on for timely operation of ice protection equipment should be evaluated in all anticipated flight attitudes.

__8__. **Ice inspection lights** should be evaluated in natural icing night conditions to verify that they illuminate ice build-up areas, are adequate under the conditions encountered, and do not introduce objectionable glare.

__9__. **Flight Control Systems.** Primary and secondary flight control surfaces should remain operational after exposure to icing conditions. Evaluations should confirm that aerodynamic balance surfaces are not subject to icing throughout the airplane's operating envelope (weight, Center Of Gravity (CG), and speed), or that any ice accumulation on these surfaces does not interfere with or limit actuation of the control for these surfaces including retraction of flaps for a safe go around from the landing configuration.

__10__. **Air Data Systems.** Ice accretions forward of pitot probes and static sources, such as accretions on radomes or other probes, should be evaluated to determine the effect, if any, on the position error of the aircraft's production air data system.

__11__. **Autopilot.** All autopilot modes should be evaluated in natural icing conditions to validate the dry air ice shape test results. All autopilot modes should function properly in icing conditions. Airframe leading edge ice accretions could affect control power and control hinge moments resulting in incorrect autopilot gains. These evaluations should also show that autopilot actuators function properly and do not freeze up. The autopilot should be engaged for an extended period of time in natural icing conditions to check for unusual trimming and potential for ice to accrete in control surface gaps "control surface ice bridging."

__12__. **Pilot Workload.** The workload in icing conditions should be evaluated when showing compliance to § 23.1523. Ice detection, ice protection system operation and monitoring, and autopilot operation and monitoring (including periodic disconnects), as a minimum should be evaluated.

12. PERFORMANCE AND HANDLING QUALITIES. Airplane performance and handling qualities are degraded by ice accumulations in various ways depending upon type, shape, size, and location of these accumulations. If numerous unprotected areas exist, the weight and center of gravity effects of the ice formations should also be evaluated.

a. Flight Tests

(1) Section 23.1419 at Amendment 23-43 or Later. In accordance with § 23.1419(a), "capable of operating safely" means that airplane performance, controllability, maneuverability, and stability may be degraded from the non-iced airplane but must not be less than the requirements in part 23, subpart B. Guidance for each subpart B regulation, as related to icing, is in Appendix G. Unless noted otherwise, the guidance is applicable to all airplane categories for which compliance to § 23.1419 is being shown.

(a) Configurations and Flight Conditions. The handling qualities test matrix for ice shapes can be reduced from the basic (no ice) matrix, with concurrence from the administrator, to configurations and flight conditions that were deemed critical based on the no ice testing (basic aircraft certification). It is not required to test flight conditions at altitudes above the part 25, Appendix C icing envelopes.

(b) Harmonization. The FAA and the European Aviation Safety Agency (EASA) are harmonizing the performance and handling qualities of part 25. This harmonization project will standardize the performance and handling qualities requirements, and provide additional guidance material for certification of part 25/large aeroplanes to safely operate in the icing conditions of part 25/CS-25, Appendix C. Much of this performance and handling qualities guidance has been adopted for part 23 airplanes and is presented in Appendix G. There have been some modifications for part 23 applications. For example performance criteria had to reflect different categories of airplanes (commuter category, normal category below 6,000 lb. maximum weight, and normal category above 6,000 lb. maximum weight). Also, stall speed tolerance criteria in some cases were modified to reflect lower stall speeds of part 23 airplanes compared to transport airplanes.

(c) Stall Speed. Section 23.1419, amendment 23-43, requires "…airplane performance…must not be less than that required in part 23, subpart B." The stall speed requirements of § 23.49 are included in subpart B performance. For single engine aircraft that do not meet the emergency landing requirements of § 23.562(d), the stall speed at maximum weight must not exceed 61 knots. Recent flight testing of deicing boot-equipped aircraft with simulated intercycle/residual ice has shown stall lift coefficient losses of 17 percent to 23 percent with flaps extended. These lift losses were experienced on an airplane equipped with a stick pusher and on an airplane whose stall was defined by aerodynamic wing stall. This can represent a significant performance penalty for new aircraft if they had to be designed to meet the 61-knot stall speed requirement with ice on protected surfaces. Recently certificated single engine part 23 airplanes would most likely not meet this requirement since their no-ice stall speed in landing configuration is at or near 61 knots. Calculations on recently certificated single engine airplanes show that useful load in icing would have to be reduced by 40 percent in order to meet the 61-knot stall speed requirement with no major redesign.

In the notice of proposed rulemaking published in the "Federal Register" on October 3, 1990 (55 FR 40598), for the proposed rule that was to become amendment 23-43, the FAA stated the background for imposing subpart B requirements on part 23 airplanes versus part 25 transport airplanes: "The justification given was that normal and transport category airplanes must operate in about the same icing environment, but the normal category airplane is more likely to remain in icing conditions for longer periods of time because it may not have the performance capability to exit the icing environment as readily as transport category airplanes." Normal category airplane airfoils, being smaller than those of transport airplanes, are much more efficient collectors of ice, and their percentage drag increase in icing conditions are larger than transport airplanes. The requirement to meet subpart B performance was added to guarantee there would be a given level of excess power that could be used to exit icing conditions. An increase in stall speed in icing would not prevent an airplane from meeting the subpart B performance requirements if it was accounted for in analyses and testing.

For single-engine airplanes that do not meet the 61-knot stall speed requirement with critical ice accretions, the applicant should consider the following compensating features to propose an exemption to the stall speed requirement of § 23.1419(a), amendment 23-43. The exemption with the following compensating features would not adversely affect safety since it is safer to make a forced landing at higher speed than it is to inadvertently stall the airplane. There have been many fatal accidents in icing conditions attributed to the latter.

1. The airplane with no ice accretions meets the 61-knot stall speed requirement of § 23.49(c);

2. The airplane with critical ice accretions as defined in paragraph 12b of this AC complies with stall warning requirements of § 23.207.

(aa) For aircraft with artificial stall warning systems, paragraph 12a(1)2, may require a bias in the stall warning schedules to maintain adequate stall warning margins.

(bb) For aircraft without artificial stall warning systems, 12a(1)2, may require one to be installed to meet minimum stall warning margin requirements. Meeting § 23.207(d) may require an increase in operational speeds in icing to preclude nuisance stall warnings.

3. The AFM performance data in icing conditions reflects the higher stall and operating speeds.

4. Most importantly, the airplane with critical ice accretions has acceptable stall characteristics and is safely controllable with normal piloting skill as required by §§ 23.201 and 23.203.

5. The tire requirements of § 23.733 and brake requirements of § 23.735 are met with the higher stall and operating speeds.

6. The ground handling requirements of §§ 23.231, 23.233 and 23.235 and nose/tail wheel steering system of § 23.745, if applicable, are met with the higher landing speeds.

7. All other airplane system or testing requirements that could be affected by higher operating speeds, such as autopilot and flight director gains are evaluated.

8. Each seat/restraint system would have to include a safety belt and shoulder harness with a metal to metal latching device (this would address STCs on older airplanes that do not include § 23.785 in their certification basis).

9. The airplane certification basis would have to include § 23.1091 at amendment 23-51 and § 23.1093 at amendment 23-51 to provide the latest regulations for engine operation in icing conditions.

10. The airplane certification basis would have to include § 23.995 at amendment 23-29. This regulation was promulgated as a result of a National Transportation Safety Board (NTSB) recommendation and a 1983 study, which indicated at least half of off field forced landings were a result of fuel mismanagement.

The above approach represents only the minimum consideration, other issues may have to be considered depending on the aircraft design. In the petition for exemption, the applicant needs to state why it would be in the public interest and include the weight penalty in icing conditions as a result of complying with the 61-knot stall speed regulation.

(2) Section 23.1419 at Amendment 23-14. The definition of "capable of operating safely" is not defined in the regulation. The tests and pass/fail criteria of paragraph 12a(1) should be used as a guide to develop a test program that demonstrates the airplane is capable of operating safely in the part 25, Appendix C, icing envelope. The regulations italicized in Appendix G are not typically addressed in showing compliance to § 23.1419 at amendment 23-14.

b. Ice Accretions.

(1) Airframe Ice Accretions.

(a) Definition of Ice Accretions. The most critical ice accretions in terms of handling characteristics and/or performance for each flight phase should be determined. The parameters to be considered are the flight conditions (e.g., airplane configuration, airspeed, angle of attack. altitude) and the icing conditions of part 25, Appendix C (temperature, liquid water content, mean effective drop diameter). Table 3 summarizes the ice accretions for each flight phase for normal ice protection system operation.

TABLE 3. ICE ACCRETION DEFINITIONS

Ice Accretion	Normal, Utility and Acrobatic Categories	Commuter Category
Takeoff	None if the AFM prohibits takeoff with ice, snow and frost on the wing and control surfaces. Otherwise, "polished" frost, as permitted by the parts 91 and 135 operating rules should be defined by the applicant and simulated for flight test evaluation if not prohibited for takeoff in the AFM.	Ice accretion occurring between liftoff and 400 feet above the takeoff surface, assuming accretion starts at liftoff in the "takeoff maximum icing" conditions, on: • unprotected surfaces; and • the protected surfaces appropriate to normal IPS operation; or • the protected surfaces if IPS operation is prohibited for takeoff. (It should be assumed no flight crew action to activate the ice protection will occur until at least 400 feet above the ground level, or higher if specified in the AFM.) "Takeoff maximum icing" conditions defined as: • cloud liquid water content of 0.35 g/m^3; • cloud droplets Mean Effective Diameter (MED) of 20 microns; and • ambient air temperature at ground level of minus nine degrees Centigrade (C) Also includes simulated "polished" frost, as permitted by the parts 91 and 135 operating rules, as defined by the applicant, if not prohibited for takeoff in the AFM.

TABLE 3. ICE ACCRETION DEFINITIONS (Continued)

<table>
<tr><th>Ice Accretion</th><th>Normal, Utility and Acrobatic Categories</th><th>Commuter Category</th></tr>
<tr><td>Final Takeoff</td><td>Not applicable.</td><td>Same as “takeoff” ice except ice accretion occurs between liftoff and 1,500 feet above the takeoff surface.</td></tr>
<tr><td>Enroute</td><td colspan="2">Ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, during the en route phase, in part 25, Appendix C, continuous or intermittent maximum icing conditions. At the applicant’s option, “holding” ice may be used in showing compliance with requirements that specify “en route” ice.</td></tr>
<tr><td>Holding</td><td colspan="2">Ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, during a 45-minute hold in part 25, Appendix C, continuous maximum icing conditions.</td></tr>
<tr><td>Pre-Activation</td><td colspan="2">The ice accretion prior to normal system operation is the ice accretion formed on the unprotected and normally protected surfaces prior to activation and effective operation of any ice protection system in continuous maximum atmospheric icing conditions. Ice detection procedures, ice detector system design and performance, and boot activation procedures should be considered.</td></tr>
<tr><td>Critical</td><td colspan="2">The ice accretion, applicable to the phase of flight that has the most adverse effect on performance and flying qualities. For protected surfaces, intercycle ice, residual ice, and runback ice should be accounted for. In order to reduce the number of ice accretions to be considered when demonstrating compliance:

(1) The more critical of takeoff ice and final takeoff ice may be used throughout the takeoff phase.

(2) Holding ice may be used for the en route, holding, approach, landing, and go-around flight phases.

(3) Holding ice may also be used for the takeoff phase provided it is shown to be more conservative than takeoff ice and final takeoff ice.

(4) The ice accretion that has the most adverse effect on handling characteristics may be used for climb performance tests provided any difference in climb performance is conservatively taken into account.</td></tr>
</table>

(b) Shape and Texture of Simulated Ice. The shape and texture of the simulated ice should be established and substantiated by agreed methods. Common practices include:

1. Use of computer codes;

2. Flight in measured natural icing conditions;

3. Icing wind tunnel tests; and

4. Flight in a controlled artificial icing cloud (e.g. airborne icing tanker).

(c) Ice Adhesion Inhibitors. For the determination or validation of intercycle and residual ice shapes and roughness on deicing boots, the application of any ice adhesion inhibitor such as ICEX is not permitted for natural icing flight tests, artificial icing flight tests or icing tunnel tests. This is because the use of ICEX cannot be controlled in operations and the effectiveness in operations degrades over time. (Intercycle ice is the ice accretion that exists on a deicing system surface just prior to an actuation of the deicing system; residual ice is the accretion remaining immediately after an actuation.) Other products that enhance appearance or life should also not be applied. Deicing boots can be cleaned at the start of a natural icing or artificial icing test program per recommended maintenance procedures.

(2) Propeller Icing. To date, climb performance analyses and climb flight testing with ice shapes have not taken into account propeller efficiency losses due to ice accretion on the propeller blades. Deicing boot manufacturers analyses show that residual ice does exist with propeller deicing systems and their analyses do not account for ice runback. The outer part of the blade, which normally is not protected, theoretically has sufficient centrifugal force to shed ice. Stop frame video of recent flight testing of a part 23 aircraft in Super-Cooled Large Droplet (SLD) conditions have shown ice accretions on the full span of the propeller blades. Although this condition was outside of part 25, Appendix C icing conditions, there is a possibility that this may occur within some portions of part 25, Appendix C. Airplane performance during natural icing flight testing should be qualitatively compared with performance during ice shape flight tests. On reciprocating and turboprop powered airplanes, if there is degradation in performance compared to the ice shape results, propeller efficiency losses due to propeller ice accretions should be investigated.

(3) Failure Ice Accretions. Flight tests with failure ice shapes representing failures not shown to be extremely improbable should be conducted to validate hazard classifications and to develop procedures for safe operation following a failure. For example, this testing may show that landing flap settings may have to be reduced following failure of the empennage ice protection system.

(a) Failure ice accretion is defined as:

1. "Holding" ice as defined in Table 3 for unprotected surfaces; and

2. For protected surfaces, one-half the accretion specified for unprotected surfaces (22.5 minutes) unless another value is agreed to by the responsible aircraft certification office.

(b) If the failure is annunciated, the applicant may propose an ice accretion based on a realistic exit scenario in lieu of the 22.5 minutes ice accretion. This failure scenario should account for the time it takes:

1. for the system to annunciate the failure (e.g., one deicing boot cycle);

2. for the pilot to decide on a course of action and notify Air Traffic Control (e.g., two minutes); and

3. to exit the icing conditions.

(c) The time to exit should include a 180-degree standard rate turn and transiting a 17.4-nautical mile, part 25, Appendix C continuous maximum cloud. Besides the design standard 17.4 nautical mile horizontal cloud extent, a cloud extent of 46-nautical miles (adjusted for liquid water content per part 25, Appendix C), which is expected for 10 percent of icing encounters, should also be considered in the safety analysis. The exit scenario shall include the possibility that the airplane may have to climb 4,000 feet out of icing if it results in a longer time than traversing the part 25, Appendix C cloud.

c. Natural Icing Flight Tests. Whether the performance and handling qualities flight testing has been performed with simulated ice shapes or in natural icing conditions, additional limited flight testing described in this section should be conducted in natural icing conditions. Where flight testing with simulated ice shapes is the primary means for showing compliance**,** the objective of the tests described in this section is to corroborate the handling characteristics and performance results obtained in flight testing with simulated ice shapes. It is acceptable for some ice to be shed during the testing due to air loads or wing flexure, etc., or during transit to a higher altitude or test area for safety reasons. However, an attempt should be made to accomplish the test maneuvers as soon as possible after exiting the icing cloud to minimize the atmospheric influences on ice shedding. During any of the maneuvers specified in Table 4, the performance and behavior of the airplane should be consistent with that obtained with simulated ice shapes. There should be no unusual control responses or uncommanded airplane motions. Additionally, during the level turns and bank-to-bank rolls, there should be no buffeting or stall warning.

TABLE 4. NATURAL ICING PERFORMANCE AND HANDLING QUALITIES TESTS

Configuration	Ice Accretion	Trim Speed	Maneuver
Flaps up, gear up	Equivalent to 45-minute hold at critical conditions.	Minimum Holding	• Level, 40-degree banked turns; • Bank-to-bank rapid rolls, 30 degrees – 30 degrees; • Climb or level performance evaluation; • Autopilot tests • Straight stall.
Landing flaps, gear down	1.25 inches on unprotected part of wing tip	V_{REF}	• Level, 40-degree banked turns; • Bank-to-bank rapid rolls, 30 degrees – 30 degrees; • Climb or level performance evaluation; • Straight stall.
Flaps up, gear up	Defined pre-activation ice	Optional	• Level, 40-degree banked turns; • Bank-to-bank rapid rolls, 30 degrees – 30 degrees; • Climb or level performance evaluation; • Autopilot tests • Straight stall.

d. Tolerances. The same airplane and system production tolerances used in the non-icing tests should be used when evaluating performance and handling qualities with ice accretions. Ice protection system production tolerances should be addressed during flight testing in natural icing conditions. Examples are provided in Table 5. Stall speed and warning system tolerance are critical when establishing tolerances for production acceptance flights.

TABLE 5. FLIGHT TEST TOLERANCES

Test	Tolerances
Stall speed	• Elevator to minimum trailing edge up if stall defined by aft control stop • Stick pusher, if equipped, set for minimum angle of attack • Flap travels should be set to minimum allowable settings
Stall warning	• Set for maximum angle of attack.
Stall characteristics	• Elevator to maximum trailing edge up. • Stick pusher, if equipped, set for maximum angle of attack
Maneuver margin	• Stall warning set for minimum angle of attack.
Natural icing flight tests	• Pneumatic boots set for minimum pressure • Electrothermal systems set at minimum current

e. Ice Contaminated Tailplane Stall (ICTS). ICTS occurs due to airflow separation on the lower surface of the tailplane that is caused by the angle-of-attack of the horizontal tailplane being increased above the reduced stall angle-of-attack that can result when even small quantities of ice have formed on the tailplane leading edge. The increase in tailplane angle-of-attack can result from airplane configuration (for example, increased flap extension increasing the downwash angle or trim required for the CG position) and/or flight conditions (for example, high approach speed resulting in an increased flap downwash angle and reduced angle-of-attack, gusts, maneuvering or engine power changes). ICTS is characterized by a reduction or loss, sometimes sudden, of pitch control or stability while operating in, or recently departing from, icing conditions. For airplanes with longitudinal control systems that are not powered (reversible control systems), the pressure differential between the upper and lower surfaces of the stalled tailplane may result in a high elevator hinge moment, forcing the elevator trailing edge down. This elevator hinge moment reversal can be of sufficient magnitude to draw the control column forward with a level of force that is beyond the combined efforts of the flightcrew to overcome. On some airplanes, ICTS has been caused by a lateral flow component coming from the vertical stabilizer, as may occur in sideslip conditions or due to a gust with a lateral component. An evaluation should be made to determine if this unsafe flight condition is likely to occur. Susceptible airplanes are those having a near zero or negative stall margin with contamination. Flight test procedures for determining susceptibility to ICTS are included in AC 23.143-1, "Ice Contaminated Tailplane Stall (ICTS)".

(1) Maximum landing flaps may be limited to the "takeoff/approach" configuration due to ICTS characteristics, either with normal operation of the ice protection systems or with a failed horizontal tail system. This is true regardless of the certification basis. Literal interpretation of § 23.1419, amendment 23-43 means that the aircraft would have to comply with the 61-knot stall speed in icing at the takeoff/approach flap setting if the flap setting was limited to preclude ICTS with normal ice protection system operation. The FAA would also consider the exemption approach described above for the 61-knot rule to address higher stall speeds for those aircraft that limit flaps to takeoff/approach setting with ice accretions to preclude ICTS.

(2) If sandpaper ice results in ICTS susceptibility and limited flap deflection for landing, the AFM procedure for limiting flap should be based on visible moisture and temperature rather than airframe ice accretions if the flight crew cannot see the tail.

(3) For pre-activation ice, when the activation of the ice protection system does not require the flight crew to wait for a specified ice accumulation, the pushover maneuver can be accomplished to 0.5g rather than 0g.

(4) For failure ice accretions, when the failure is annunciated to the flight crew and the procedures are to exit icing conditions, the pushover maneuver can be accomplished to 0.5g rather than 0g.

f. Pneumatic Deicer Boots. Many AFMs specify a minimum ice accumulation thickness prior to activation of the deicer boot system. This practice has been in existence due to the belief that a bridge of ice could form if the boots are operated prematurely. Flight testing and icing tunnel testing of several “modern” boot designs have not shown evidence of “ice bridging”, and no degradation in ice shedding performance, when the boots were activated at the first sign of ice accretion. Although the ice may not shed completely with one cycle of the boots, this residual ice will be removed during subsequent boot cycles. Tunnel testing is documented in FAA Technical Report DOT/FAA/AR-02/68, "Effect of Residual and Intercycle Ice Accretions on Airfoil Performance" (May 2002), and recommends that activating the deicing boots “early and often” are given more consideration as a means of limiting the size of intercycle and residual ice accretions. “Modern” boots are defined as high operating pressure (nominal greater than 15 Pounds Per Square Inch Gauge (PSIG)) and fast inflation and deflation times. Both one-inch diameter tube designs operating at a nominal 18 PSIG, and 1.75-inch diameter tube designs operating at a nominal 15 PSIG, have been evaluated. The recommended AFM procedure for boot operation should be to operate the boots in an appropriate continuous mode at the first sign of ice and not to wait for a specific amount of ice to accumulate. The boots should be operated until icing conditions are exited and ice no longer adheres to the airframe.

(1) For applicants that choose to recommend a measurable ice accumulation prior to activation of the boots, flight tests in simulated or natural icing conditions should be accomplished to verify that the crew could detect and recognize the specified ice accumulation thickness. The following test criteria have been accepted for previous flight test programs:

(a) The pilot or a crewmember should be provided a means to detect from his crew position, under both day and night operation, the accumulation level the applicant has specified for activation of the boot system for proper ice removal.

(b) The applicant should show that an ice accumulation margin exists that allows for errors in crew recognition of the ice accumulation level.

(2) In addition, for applicants that choose to recommend a measurable ice accumulation prior to boot activation, this pre-activation ice accretion must be considered when determining critical ice accretions for performance, stability, control, and stall testing.

NOTE 2

Usually, selection of the deicing boots to operate causes one cycle of inflation and deflation of all boots, but not necessarily at the same time. Some systems are designed such that all the boots do not complete the cycle if the deicing boots are selected off during the middle of one cycle. For these systems, there should be an AFM warning to the flight crew to select the ice protection on for at least one complete cycle of the deicing boots. This note is equally applicable to any deicing system.

(3) For deicing systems that do not have a timer to cycle the system automatically once activated, the additional task of manually cycling deicing systems on pilot workload should be evaluated. A recent part 23 applicant found that definition of airframe deicing boot intercycle and residual ice steered them toward one-minute boot cycles and the workload evaluation dictated an automatic timer for the boots.

g. Emergency and Abnormal Operating Conditions. Flight investigations should be conducted to verify that, after pilot recognition of emergency and abnormal operating conditions, the airplane handling qualities have not deteriorated to the extent that the AFM procedures for the condition are ineffective. These demonstrations should be conducted with anticipated residual ice accumulation on normally protected surfaces. The tests in Table 6 represent a sample matrix for a part 23 airplane with failure ice shapes defined in paragraph 12b(3).

TABLE 6. FAILURE ICE ACCRETION FLIGHT TESTS

Ice Shape Configuration	Configuration and Trim Speed	Maneuver
One wing zone failure	Flaps up and minimum holding	• Level, 40-degree banked turns; • Bank-to-bank rapid rolls, 30 degrees – 30 degrees; • Deceleration to stall warning (natural acceptable), recover after one second.
Empennage zone failure	Full landing flaps and V_{REF}	• ICTS evaluation; • Sideslips
Total wing and empennage zone failure		• ICTS evaluation • Level, 40-degree banked turns; • Bank-to-bank rapid rolls, 30 degrees – 30 degrees; • Deceleration to stall warning (natural acceptable), recover after one second. • Approach and go-around demonstration
Pilot's windshield ice protection failure	Full landing flaps and V_{REF}	• Approach and landing demonstration

h. Roll Control in Supercooled Large Droplet Conditions. The following guidance, with some modifications, is contained in a July 23, 1997 Policy Memorandum issued by the Transport Directorate and coordinated with the Standards Office. This policy memorandum was applicable to certain part 25 and part 23 airplanes. The FAA and EASA are currently harmonizing rulemaking and guidance for flight in icing conditions that exceed part 25, Appendix C. This policy in this paragraph is interim and will be replaced when the harmonized regulations and guidance are issued for part 23 airplanes. In October 1994, an accident involving a transport category airplane occurred in which severe icing conditions were reported in the area. During extensive testing, the accident profile was replicated by ice shapes developed from testing in an icing cloud having droplets in the size range of freezing drizzle at a temperature near freezing. This condition created a ridge of ice aft of the deicing boots and forward of the ailerons, which resulted in uncommanded motion of the ailerons and rapid roll of the aircraft. The NTSB recommended that the FAA develop a test procedure to identify the unsafe aileron hinge moment characteristics. The procedure described herein is the procedure used during an FAA program to screen certain airplanes for susceptibility to aileron control anomalies. The FAA has identified the susceptibility to loss of control following exposure to supercooled large droplets as an unsafe condition that may exist on other aircraft. The FAA is particularly concerned with airplanes that are equipped with non-powered roll control systems, since non-powered roll flight controls do not have the physical advantage of hydraulic or electrical power to assist the pilot in overcoming the large control forces that may exist from differential pressure resulting from flow separation over the roll control surfaces. Therefore, airplanes certified for flight in icing equipped with non-powered roll control systems and without fully evaporative wing anti-ice systems should be evaluated for susceptibility to roll upset in the event the airplane is exposed to certain freezing drizzle conditions. The following paragraphs provide an acceptable means of compliance with the evaluation.

(1) Tests and analyses should show that the airplane characteristics meet the criteria specified in paragraph (2) following a 20-minute icing encounter characterized by:

(a) Supercooled droplets having maximum diameters of approximately 400 microns;

(b) A Liquid Water Content (LWC) of approximately 0.6 grams per cubic meter;

NOTE 3

For this condition, the LWC strongly affects the rate at which the ice feature develops. A higher LWC results in more rapid formation of the ice feature, while a lower LWC results in a slower formation of the ice feature. The LWC should be adequate to produce an ice feature during the exposure interval that will start to shed on its own accord and then reform.

(c) A median volumetric diameter of approximately 170 microns,

NOTE 4

The cloud physics instrumentation, calibration, and data processing methodologies should be presented for acceptance by the FAA.

(d) Temperatures near freezing such that runback conditions exist at the stagnation line; and

NOTE 5

For this test, temperature is a critical factor. Not only is the temperature critical to the development of the ice shape and dimension, static air temperature excursions above freezing, although short in duration, can reverse the ice accretion process.

(e) Operation at holding speeds and holding configurations.

(2) When manually flying the airplane:

(a) The pilot roll force to counter any uncommanded roll control surface deflection should not exceed 50 pounds with two hands available for control; and

(b) The airplane should not exhibit a hazardous degradation of flying qualities. Rapid control force onset, and unsteady and oscillatory forces must be considered carefully as these dynamic conditions may be hazardous even though the peak force may be less than the static limit.

(3) The tests and analyses described in paragraph (1) should consider the effects of asymmetric shedding of the ice.

(4) There should be a means for the flightcrew to determine when the airplane has entered into a supercooled large droplet environment, to enable the crew to take appropriate action.

(5) There should be appropriate crew information provided in the AFM that describes the limitations and procedures to be observed while exiting the supercooled large droplet environment. The FAA has found that the limitations and procedures specified in Appendix H are an acceptable means of providing this information.

(6) One means of compliance with paragraphs (1), (2), and (3) is to perform a high speed taxi test to evaluate control wheel force characteristics that may result from flow separation over the roll control surfaces induced by an simulated ice shape as described below. The testing should include the following:

(a) Install a one-inch high, quarter-round molding, flat side forward, located on the upper surface of the wing, at the chord position aft of the active portion of the boots and forward of the non-powered roll control surfaces (i.e., ailerons and/or inflight spoilers) that produce the most adverse lateral wheel force.

(b) Locate this shape in front of the roll control surfaces on one wing only. As a minimum, the shape should cover the entire span of the roll control surface.

(c) Plan and configure the airplane for flight. Perform high-speed taxi tests with the flaps retracted and at various angles of attack. The maximum angle of attack should be obtained at the highest takeoff weight such that the airplane does not become airborne.

(d) Measure the forces required to maintain the wings level.

(e) Extrapolate the maximum forces obtained from the high-speed taxi tests to the maximum speeds expected while in holding conditions. In most cases the maximum forces will occur at the maximum angle of attack achieved during the high-speed taxi tests.

(f) The extrapolated forces should not exceed 50 pounds with two hands available for control.

(g) Inflight spoilers may be mechanically locked out while the airplane is on the ground. Therefore, airplanes equipped with non-powered inflight spoilers may need tunnel or flight testing to evaluate the effect on airplane control and handling characteristics.

13. ICE SHEDDING. Ice shed from forward airplane structure could result in damage or erode engine or powerplant components, as well as lifting, stabilizing, and flight control surface leading edges. Fan and compressor blades, impeller vanes, inlet screens and ducts, as well as propellers, are examples of powerplant components subject to damage from shedding ice. For pusher propellers that are very close to the fuselage and well back from the airplane's nose, ice shed from the forward fuselage and from the wings may cause significant propeller damage. Control surfaces such as elevators, ailerons, flaps, and spoilers are also subject to damage, especially those that are thin metallic, non-metallic, or composite constructed surfaces. Trajectory and impingement analysis may not adequately predict such damage. Unpredicted ice shedding paths from forward areas such as radomes and forward wings (canards) have been found to negate the results of this analysis. For this reason, flight tests should be conducted to supplement trajectory and impingement analysis. If flight tests are not conducted, a damage analysis should consider the worst-case ice shed event. Video or motion pictures are excellent for documenting ice shedding trajectories and impingements, while still photography may be used to document the extent of damage. Any damage should be evaluated for acceptability. In flight testing the airplane should be exposed to an icing condition of magnitude and duration sufficient to create the expected worst-case ice accretion, including the 45-minute hold. Flight test evaluation should also account for critical, predicted trajectories in terms of normal operational angle of attack and sideslip.

14. PLACARDING AND AFM. This AC provides guidance on airplanes for which the certification basis requires an AFM. Guidance for AFMs in this AC also applies to AFM supplements.

a. Placarding. Any placarding necessary for the safe operation of the airplane in an icing environment must be provided in accordance with § 23.1541. Examples of such placards are:

(1) Kinds of operation approved (for example, "Flight in Icing Conditions Approved if Ice Protection Equipment is Installed and Operational”).

(2) Equipment limits (for example, "Operation of Windshield Anti-Ice May Cause Compass Deviation in Excess of 10 degrees)”.

(3) Speed restrictions (for example, "Maximum Speed for Boot Operation—175 Knots Indicated Airspeed (KIAS) inches)”.

(4) Fluid filler—inlets for fluid freezing point depressants should bear a placard showing approved fluid type and quantity.

b. AFM. The AFM should provide the pilot with the information needed to operate the ice protection system and operate in icing conditions. Information should include:

(1) Operating Limitations Section. Suggested areas to be addressed are as follows:

(a) Limitations on operating time for ice protection equipment if these limitations are based on fluid anti-ice/deice systems capacities and flow rates.

(b) Speed limitations (if any).

(c) Environmental limitations for equipment operations as applicable (for example, minimum temperature for boot operation, maximum altitude for boot operation, and maximum outside air temperature for operation of thermal ice protection systems).

(d) A list of all equipment required for flight in icing conditions. Section 23.1583(h) (CAR § 3.778) requires that this list be included in the KOEL.

(e) Minimum engine speed if the engine ice protection system does not function properly below this speed.

(f) A list of required placards.

(g) For commuter category airplanes, the balked landing climb weight, approach climb weight, and landing weight limitations for flight in icing should be presented. The variation in weight limitations may be presented in the performance section of the manual and included as limitations by specific reference in the limitations section of the AFM.

(h) Minimum and maximum (as appropriate) airspeed that should be maintained during operations in icing conditions.

(i) Configuration limitations, if any (for example, a reduced flap setting for approach and landing, and flaps up for holding).

(j) For exceedance icing conditions that may result from environmental conditions outside the icing envelope established as the basis of the approval defined in part 25, Appendix C, information should be provided as follows (see Appendix H for an example):

1. A means to identify an icing condition that exceeds the limits of the ice protection system for which the airplane is certificated.

2. Recommended procedures and configurations when exiting the exceedance icing conditions.

3. Procedures to follow during and after flight in these conditions in the event of degraded performance or handling characteristics. Information should include recommended use of flight controls, configuration of high lift devices, drag devices, automatic flight guidance system, engine power/propeller settings (as appropriate), and ice-protection system operation.

Exceedance icing conditions may be primarily water content related for thermal ice protection systems, primarily droplet diameter related for mechanical ice protection systems or some combination thereof.

(k) Autopilot operation should be prohibited if any of the following conditions in icing flight are experienced:

1. Severe icing;

2. Unusual control force or control deflection, or unusually large control forces to move flight controls when the autopilot is disconnected periodically; or

3. Indications of frequent autopilot retrimming during straight and level flight.

(2) Operating Procedures Section.

(a) Section 23.1585(a) requires the pilot be provided with the necessary procedures for safe operation. This should include any preflight action necessary to minimize the potential of enroute emergencies associated with the ice protection system. The system components should be described with sufficient clarity and depth that the pilot can understand their function. Unless flight crew actions are accepted as normal airmanship, the appropriate procedures should be included in the FAA-approved AFM, AFM revision, or AFM supplement. These procedures should include proper pilot response to cockpit warnings, a means to diagnose system failures, and the use of the system(s) in a safe manner.

(b) Procedures should be provided to optimize operation of the airplane during penetration of icing conditions, including all flight regimes. The AFM should include procedures that advise upon which conditions the ice protection equipment should be activated.

(c) Emergency or abnormal procedures, including procedures to be followed when ice protection systems fail and/or warning or monitor alerts occur, should be provided.

(d) For fluid anti-ice/deice systems, information and method(s) for determining the remaining flight operation time should be provided.

(e) For airplanes that cannot supply adequate power for all systems at low engine speeds, load-shedding instructions should be provided to the pilot for approach and landing in icing conditions.

(f) For aircraft equipped with an autopilot, the autopilot should be disconnected periodically to check for unusual control force or deflection, and to move the flight controls to check for evidence of ice accreting in control surface gaps or frozen actuators.

(3) Performance Information Section. A brief statement that supercooled cloud test environment and freezing rain, freezing drizzle, or mixed conditions (as appropriate) have not been tested. These icing environmental conditions outside the icing envelope of part 25, Appendix C, may exceed the capabilities of the ice protection system, and it may result in a serious degradation of performance or handling characteristics.

(a) Normal, Utility, and Acrobatic Category Airplanes. For these airplanes, general performance information should be provided to give the pilot knowledge of allowances necessary while operating in ice or with residual ice on the airframe. The following items are only examples that provide some guidelines and are not requirements. These guidelines may be revised for specific airplanes as appropriate:

1. An accumulation of ___ inch of ice on the leading edges can cause a loss in rate of climb up to ___ Feet Per Minute (FPM), a cruise speed reduction of up to __ KIAS, as well as a significant buffet and stall speed increase (up to ____ knots). Even after cycling the deicing boots, the ice accumulation remaining on the boots and unprotected areas of the airplane can cause large performance losses. With residual ice from the initial ____ inch accumulation, losses up to ___ FPM in climb, ___ KIAS in cruise, and a stall speed increase of ____ knots can result. With ____ inch of residual accumulation, these losses can double.

2. Airspeed—MAINTAIN BETWEEN ___ KIAS AND ___ KIAS with ____ inch or more of ice accumulation for appropriate configuration.

3. Prior to a landing approach cycle the wing and stabilizer deice boots to shed any accumulated ice. Maintain extra airspeed on approach to compensate for the increased stall speed associated with ice on unprotected areas. Use caution when cycling the boots during an approach, since boot inflation with no ice accumulation may cause mild pitching and increase stall speeds by ___ knots. It may also decrease stall warning margin by the same amount; and it may cause or increase rolling tendency during stall.

4. Holding in icing conditions for longer than 45 minutes may reduce margins and could result in inadequate handling and control characteristics.

5. Maintain engine speeds of __ RPM higher to assure proper operation of the ice protection system.

(b) Commuter Category Airplanes. Data should be provided so that the balked landing climb limited weight and approach climb limited landing weight could be determined. These data should include the effect of drag due to residual ice on protected and unprotected surfaces, power extraction associated with ice protection system operation, and any changes in operating speeds due to icing. Also, the effect on landing distance due to revised approach speeds, and/or landing configurations, should be shown.

(4) For airplanes with a certification basis at amendment 23-14 or higher, the AFM should contain a statement similar to "This airplane is approved for flight in icing conditions as defined in part 25, Appendix C." For these airplanes, there should not be references to operational terms such as "light" or "moderate" ice or "known icing."

(5) The AFM should reference the maintenance manual for ice protection surface cleaning procedures if the flight crew can be expected to perform this function.

c. Prior to AFM Requirement. If the airplane was certificated prior to the effective date of the requirement for an AFM, then the combination of manuals, markings, and placards should adequately address the placard and AFM subjects previously discussed in this AC.

15. INSTRUCTIONS FOR CONTINUED AIRWORTHINESS.

a. Pneumatic Deicing Boots. Boot manufacturers have developed repair procedures for pinholes, cuts and tears. The repair process for these types of damage is critical because proper operation of the boots could be affected. If leaks or pinholes are not periodically repaired, the entire system could become inoperable if water, drawn in by the vacuum that holds the boots deflated, subsequently refreezes and blocks a pneumatic line. The performance of deicing boots is dependent on the height and speed of deicing boot inflation and of the composition of the surface ply and its ice adhesion characteristics. Repairs should not pinch off tubes and thereby reduce inflation height. With these concerns in mind, the following guidance represents a minimum that should be addressed for repair procedures:

(1) Testing. The following tests should be accomplished:

(a) Boot Cycle Testing. The integrity of the repair should be evaluated via boot cycling at the maximum normal system operating pressure. Cycling should continue until the repair or boot fails. The normal deflation time may be shortened to speed up the test. For example, a 174-second deflation cycle can be reduced to 18 seconds while maintaining the six-second inflation time. Any material applied to the whole surface of the boot should also be evaluated in this test.

(b) Cold Temperature Cycling. The testing in (1)(a) should be repeated at a temperature of zero degrees F or colder.

(c) Hot Temperature. The boots may be exposed to hot temperatures, especially after on the ground on a hot, sunny day. The combination of high temperature and fluid exposure may cause deterioration and should be evaluated, see paragraph (e).

(d) Proof and Burst Pressure Testing. This testing should be accomplished to show compliance to § 23.1438(b). When conducting the proof pressure test at 1.5 times maximum operating pressure, the repaired deicing boot should hold that pressure for 60 seconds and the repair should not fail. After the proof pressure test, the system should be inflated at maximum operating pressure, isolated, and the pressure drop verified not to exceed three Pounds Per Square Inch (PSI) in one minute.

(e) Fluids Susceptibility. The repair should be exposed to various fluids for at least 24 hours in combination with a high temperature (160 degrees F) and the boots cycled at nominal pressure for at least 24 hours. Fluids to be evaluated include: fuels, oil, hydraulic fluids, glycol/water mixture, deicing boot age reduction, surface treatments and ice adhesion products, and ground deicing fluids. One method of accomplishing this test is to soak a rag with the fluid, place on the deicing boot over the repair, seal to prevent evaporation, and place in an oven at 160 degrees F for 24 hours. Following this exposure the boot is removed, and cycled for 24 hours. The deicing boot should inflate and hold air, and the repairs should remain in place and not leak air.

(f) Sand and Rain Erosion. Sand and rain erosion testing should be accomplished to show that the repair does not erode at a greater rate than the boot. A typical sand erosion test is ASTM G-76-95. A typical rain erosion test is conducted on a whirling arm rig that exposes the boot to a rainfall rate of one inch per hour at 300 to 500 Mile Per Hour (MPH) (depending on the airplane maximum speed), using one to two Millimeter (mm) diameter drops.

(g) The inflation height over the repaired area should be measured and compared against other unrepaired portions of the boot at temperatures covering the part 25, Appendix C envelope.

(h) Ice Shedding. Ice shedding performance in the area of the repair, and of the whole boot if any material is applied to the whole boot, should be evaluated throughout the part 25, Appendix C continuous maximum and intermittent maximum icing conditions. It is particularly important to cover the range of temperatures and liquid water contents of part 25, Appendix C and the expected operational airspeeds. Simulated icing tests, such as an icing tunnel, may be used.

(2) Materials Properties. Any material applied to the boots should be compatible with the deicing boot material. Use of brittle repair materials is not recommended. If the boot is completely resurfaced with a material, that material should be electrically conductive to allow bleeding of static charge from the deicing boot.

(3) Repair Process Limitations. The repair process should contain limitations and quality control procedures such as:

(a) Size of repairs. The maximum allowed repair size should be established and tested. Another consideration is the effect of the repair failure on the airplane.

(b) Location and depth of repairs. Can structural elements such as tube fabric or stitches be damaged or can the wrong internal layers, such as tube fabric, be bonded together? It is recommended that boot manufacturers limits be used.

(c) Density of repairs. The maximum density of repairs (number per area) should be tested. It is recommended that boot manufacturers limits be used.

(d) Application of solvents and other chemicals. The application of solvents and other chemicals used in the repair process that can disbond the boot should be controlled so that they cannot penetrate internal layers of the boot.

(e) Applicability of the repair procedure. Broken stitches represent a structural failure of the boot and should not be repaired. There should also be guidelines as to when severely worn boots should be replaced.

b. Electrothermal Propeller and Engine Inlet Deicing Boots. Boot manufacturers historically have not developed repair procedures for electrothermal deicing boots because the thermal mass characteristics of the repaired location will change and affect ice shedding. The following guidance is a minimum that should be addressed for electrothermal boot repairs:

(1) Testing. The following tests should be accomplished:

(a) Fluids Susceptibility. The repair should be exposed to various fluids and the boots operated. Fluids to be evaluated include: fuels, oil, hydraulic fluids, glycol/water mixture, deicing boot age, appearance and ice adhesion products, and ground deicing fluids.

(b) Sand and Rain Erosion. Sand and rain erosion testing should be accomplished to show that the repair does not erode at a greater rate than the boot.

(c) Thermal Characteristics. The thermal conductivity of the repair should be evaluated to insure that it does not provide a "cold spot" on the deicing boot, resulting from either a higher thermal mass or lower thermal conductivity of the repair material.

(d) Ice Shedding. Ice shedding performance in the area of the repair, and of the whole boot if any material is applied to the whole boot, should be evaluated throughout the part 25, Appendix C, continuous maximum and intermittent maximum icing conditions. Simulated icing tests, such as an icing tanker, may be used.

(e) Vibration. The airplane should be tested in icing conditions to verify the repair on one blade does not directly or indirectly (due to ice shedding) cause unacceptable propeller vibration.

(2) Materials Properties. Any material applied to the boots should be compatible with the deicing boot material. Use of brittle repair materials is not recommended. The material should be electrically non-conductive and should have similar thermal conductivity of the deicing boot material. The effect of the chemicals on the electrical wires or foil should be evaluated.

(3) Repair Process Limitations. The repair process should contain limitations and quality control procedures such as:

(a) Size of repairs. The maximum allowed repair size should be established and tested. Another consideration is the effect of the repair failure on the airplane.

(b) Location and depth of repairs. Can heating elements such as wires or etched foil be damaged or can the resistance of the wire or foil be altered by the repair procedure?

(c) Density of repairs. The maximum density of repairs (number per area) should be tested.

(d) Application of chemicals. Can the application of too much chemicals penetrate the boot and cause internal debonding of the boot?

(e) Applicability of the repair procedure. Can the repair be accomplished on severely worn boots?

APPENDIX A. DEFINITIONS

1. DEFINITION OF TERMS. For the purposes of this AC, the following definitions should be used.

a. Anti-Ice. The prevention of ice formation or accumulation on a protection surface, either by evaporating the impinging water or by allowing it to run back and off the surface or freeze on non-critical areas.

b Part 25, Appendix C Icing Conditions. Part 25 Appendix C certification icing condition standard for approving ice protection provisions on aircraft. The conditions are specified in terms of altitude, temperature, LWC, representative droplet size (MED), and cloud horizontal extent.

NOTE 6

In part 25, Appendix C, the term "mean effective diameter" refers to what is now called the "Median Volume Diameter (MVD)," determined using rotating multi-cylinders and assuming a Langmuir distribution.

c. Artificial Ice. Real ice, but formed by artificial means, such as a spray rig in a tunnel or on a tanker.

d. Critical Ice. The aircraft surface ice shape formed within required icing conditions that results in the most adverse effects for specific flight safety requirements. For an aircraft surface, the critical ice shape may differ for different flight safety requirements, e.g., stall speed, climb, aircraft controllability, control surface movement, control forces, air data system performance, dynamic pressure probes for control force "feel" adjustment, ingestion and structural damage from shed ice, engine thrust, engine control, and aeroelastic stability.

e. Deice or Deicing. The periodic shedding or removal of ice accumulations from a surface, by destroying the bond between the ice and the protection surface.

f. Freezing Drizzle. Drizzle is precipitation on the ground or aloft in the form of liquid water drops that have diameters less than 0.5 mm and greater than 0.05 mm (100 µm to 500 µm). Freezing drizzle is drizzle that exists at air temperatures less than 0 degrees C (supercooled), remains in liquid form, and freezes upon contact with objects on the surface or airborne.

g. Freezing Precipitation. Any form of liquid precipitation that freezes upon impact with the ground or exposed objects, that is, freezing rain or freezing drizzle.

h. Freezing Rain. Rain is precipitation on the ground or aloft in the form of liquid water drops which have diameters greater than 0.5 mm. Freezing rain is rain that exists at air temperatures less than zero degrees C (supercooled), remains in liquid form, and freezes upon contact with objects on the surface or airborne.

i. Ice Crystals. Any one of a number of macroscopic, crystalline forms in which ice appears.

j. Icing Conditions. The presence of atmospheric moisture and temperature conducive to airplane icing.

k. Intercycle Ice. Ice that accumulates on a deiced surface that exists just prior to the actuation of the deice system.

l. LWC. The total mass of water contained in liquid drops within a unit volume or mass of air, usually given in units of grams of water per cubic meter (g/m3) or kilogram of dry air (g/kg).

m. MED. The calculated drop diameter that divides the total liquid water content present in the drop size distribution in half, i.e., half the water volume will be in larger drops and half the volume in smaller drops. The value is calculated, based on an assumed droplet size distribution, (e.g. Langmuir distribution) which is how it differs from median volume diameter.

n. MVD. The drop diameter that divides the total liquid water content present in the drop distribution in half, i.e., half the water volume will be in larger drops and half the volume in smaller drops. The value is obtained by actual drop size measurements.

o. Mixed Phase Icing Conditions. A homogeneous mixture of supercooled water drops and ice crystals existing within the same cloud environment.

p. Monitored Surface. The surface of concern regarding the ice hazard, (e.g., the leading edge of a wing). Ice accretion on the monitored surface may be measured directly or correlated to ice accretion on a reference surface.

q. Pre-Activation Ice. Protected surface ice accretion prior to the full effectiveness of the ice protection system.

r. Protected Surface. A surface containing ice protection, typically located at the surface's leading edge.

s. Protection Surface. Active surface of an ice protection system, for example, the surface of a deicing boot or thermal ice protection system.

t. Reference Surface. The observed (directly or indirectly) surface used as a reference for the presence of ice on the monitored surface. The presence of ice on the reference surface must occur prior to – or coincidentally with – the presence of ice on the monitored surface. Examples of reference surfaces include windshield wiper blades or bolts, windshield posts, ice evidence probes, propeller spinner ice, and the surface of ice detectors. The reference surface may also be the monitored surface.

u. Residual Ice. Ice that remains on a protected surface immediately following the actuation of a deicing system.

v. Reversible Flight Controls. The flight deck controls are connected to the pitch, roll, or yaw control surfaces by direct mechanical linkages, cables, or push-pull rods such that pilot effort produces motion or force about the hinge line. Conversely, force or motion originating at the control surface (through aerodynamic loads, static imbalance, or trim tab inputs, for example) is transmitted back to flight deck controls.

(1) Aerodynamically Boosted Flight Controls: Reversible flight control systems that employ a movable tab on the trailing edge of the main control surface linked to the pilot's controls or to the structure in such a way as to produce aerodynamic forces that move, or help to move, the surface. Among the various forms are flying tabs, geared or servo tabs, and spring tabs.

(2) Power-Assisted Flight Controls: Reversible flight control systems in which some means is provided, usually a hydraulic actuator, to apply force to a control surface in addition to that supplied by the pilot to enable large surface deflections to be obtained at high speeds.

w. Runback Ice. Ice formed from the freezing or refreezing of water leaving an area on an aircraft surface that is above freezing and flowing downwind to an area that is sufficiently cooled for freezing to take place. This ice type is frequently a byproduct of partially evaporative (running wet) ice protection systems.

x. Simulated Ice. Ice shapes that are fabricated from wood, epoxy, or other materials by any construction technique.

y. Supercooled Large Drops (SLD). Supercooled liquid water that includes freezing rain or freezing drizzle.

z. Supercooled Water. Liquid water at a temperature below the freezing point of zero degrees C.

2. DEFINITION OF ACRONYMS.

AC	Advisory Circular
ACO	Aircraft Certification Office
AFM	Airplane Flight Manual
AIR	Aerospace Information Report
APU	Auxiliary Power Unit
ARP	Aerospace Recommended Practice
AS	Aerospace Standard
C	Centigrade
CAR	Civil Air Regulations
CFR	Code of Federal Regulations

CG	Center of Gravity
CS	Certification Specification (EASA)
F	Fahrenheit
FAA	Federal Aviation Administration
FPM	Feet Per Minute
EASA	European Aviation Safety Agency
EFIS	Electronic Flight Information Systems
ICTS	Ice Contaminated Tailplane Stall
IIDS	In-Flight Ice Detection System
IMC	Instrument Meteorological Conditions
IPS	Ice Protection System
KCAS	Knots Calibrated Airspeed
KIAS	Knots Indicated Airspeed
KOEL	Kind of Equipment List
LWC	Liquid Water Content
MDI	Magnetic Direction Indicator
MED	Mean Effective Diameter
M_{FC}	Maximum Mach number for stability characteristics
MMEL	Master Minimum Equipment List
MOC	Means Of Compliance
MSL	Mean Sea Level
MVD	Median Volume Diameter
NTSB	National Transportation Safety Board
OAT	Outside Air Temperature
PIIDS	Primary In-Flight Ice Detection System
PMA	Parts Manufacturing Approval
POH	Pilot's Operating Handbook
PSI	Pounds Per Square Inch
PSIG	Pounds Per Square Inch Gauge
RGL	Regulatory and Guidance Library
RPM	Revolutions Per Minute
SAE	Society of Automotive Engineers
SLD	Supercooled Large Drops
STC	Supplemental Type Certificate
TC	Type Certificate
TCDS	Type Certificate Data Sheet
TSO	Technical Standard Order
V_{MC}	Minimum Control Airspeed
V_{MO}	Maximum Operating Airspeed
M_{MO}	Maximum Operating Mach Number
V_{NE}	Never Exceed Airspeed
V_{REF}	Reference Landing Approach Airspeed

APPENDIX B. GUIDELINES FOR DETERMINING CERTIFICATION BASIS ON FLIGHT IN ICING APPROVAL STCS AND AMENDED TCS

1. My CAR 3 aircraft has ice protection systems installed and is not placarded against flight into known icing. Am I approved for flight in icing conditions?

These CAR 3 airplanes are permitted to fly in icing conditions if:

- the ice protection systems are installed per type design data of the same model in the Type Certificate Data Sheet (TCDS);
- the POH, AFM, or AFM supplement associated with the ice protection systems do not prohibit it;
- the equipment listed in the KOEL are installed and functioning; and
- the airplane complies with the equipment requirements of § 91.527 or § 135.227, if applicable.

2. What if I have a CAR 3 airplane that is permitted to fly in icing conditions but I replace the ice protection system with another system?

It depends on what is meant by another system. If it is replacement parts, such as replacing pneumatic deicing boots with those from another manufacturer, the certification basis can remain unchanged; see Appendix E for more information. If it is another type of system, for example replacing a pneumatic deicing system with a freezing point depressant system or electrothermal system, compliance to § 23.1419, amendment 23-14 must be shown. Section 23.1419, amendment 23-43 would not be required since a modification to an ice protection system is considered "not significant" under the Changed Product Rule.

3. As a follow-up to the last question, suppose I change my mind and want to re-install my ice protection systems. Will my aircraft be approved for flight in icing?

Yes, as long as the systems are installed per type design data and the POH, AFM, or AFM supplement associated with the ice protection systems do not prohibit flight in icing conditions (or "flight into known icing"). Retroactive removal of flight into known icing approval can only be accomplished by the airworthiness directive process.

4. I have a CAR 3 airplane that has no ice protection system installed and the type design data does not contain flight in icing approval. What is the certification basis if I add ice protection systems?

Under the Changed Product Rule, adding approval for flight in icing conditions is considered a significant change (AC 21.101-1) and compliance should be shown to the latest amendment. In addition, § 91.527 or § 135.227, if applicable, has a minimum requirement of equipment. The applicable regulations for an icing certification are:

23.603	23.1093	23.1301	23.1327	23.1501	23.1581
23.773	23.1095	23.1309	23.1351	23.1525	23.1583
23.775	23.1097	23.1323	23.1357	23.1529	
23.905	23.1099	23.1325	23.1416	23.1547	
23.929	23.1101	23.1326	23.1419	23.1559	

It is recognized that compliance to § 23.1419(a), which requires that the airplane meet Subpart B performance in icing conditions, may be impractical for some CAR 3 airplanes. The Changed Product Rule allows the applicant to elect compliance to amendment 23-14 for that particular paragraph of § 23.1419. In this case the performance regulations are used as guidelines as discussed in paragraph 12a(2) of this AC.

5. My airplane has some ice protection systems installed but is not certified for flight in icing. A later model of my airplane, which is on the same TCDS, is certified for flight in icing in accordance with § 23.1419. The later model does have a different engine installed with higher horsepower and a different ice protection system. Can I install the exact same ice protection systems as the later model, install a new engine with at least the same horsepower, and be certified for flight in icing?

Yes, and similarity may be used to show compliance to the applicable regulations. However, there may be some testing required. The current method of compliance to § 23.1419 includes tests (susceptibility to ice contaminated tailplane stall, for example) that may not have been accomplished during certification of the later model.

APPENDIX C. GUIDELINES FOR SUPPLEMENTAL TYPE CERTIFICATES (STC) AND AMENDED TYPE CERTIFICATES ON AIRPLANES

1. APPLICATION.

a. As stated in the "APPLICABILITY" section, the guidance in this AC applies to any STC or amended TC on an airplane for which the applicant wants approval under the provisions of § 23.1419. Increase in gross weight, changes in engine power, and propeller changes could affect approval in icing and these areas would have to be evaluated using AC 23.1419-2C as the method of compliance. An applicant wishing to use an alternate MOC needs to consult the Standards Office. Whether the certification basis for the STC or amended TC includes 14 CFR, § 23.1419 at amendment 23-14 or 23-43 is irrelevant as far as the tests that should be accomplished. The difference in the certification basis does not change the tests that must be accomplished, only their pass/fail criteria.

b. Compliance to icing regulations has been either an afterthought or totally disregarded on many modification programs on aircraft certified for flight in icing conditions. In some cases, the rationale used was that since the ice protection systems were not modified, icing regulations do not need to be addressed. This may be an incorrect assumption. Icing regulations may need to be addressed for any modification that could affect the following in icing conditions:

(1) Aircraft performance

(2) Flying qualities,

(3) Engine operation

(4) Essential system operation.

c. If it is desired to retain flight in icing approval of the modified airplane, the following examples are modifications in which compliance to icing regulations need to be revisited:

(1) Engine changes

(2) APU

(3) Propeller changes

(4) Engine inlet or accessory inlet changes

(5) Antennae installations or other external modifications

(6) Gross weight increases

(7) CG envelope increase

(8) Flight envelope increase

(9) Turboprop conversion

(10) Modifications to lifting surfaces

(11) Installation of vortex generators

(12) Modifications to ice protection systems

(13) Addition of/or re-location of fuel vents

(14) Addition of/or autopilot replacement.

d. The icing regulations that are addressed in this appendix are:

(1) § 23.929

(2) § 23.1093

(3) § 23.1301

(4) § 23.1309

(5) § 23.1416

(6) § 23.1419

e. The following guidance address some specific, common modifications:

(1) Engine Changes.

(a) **Effects of increased engine power or thrust:**

1. On airplanes with a certification basis at amendment 23-14 or higher, any degradation in stall characteristics, stability or control, or marginal characteristics, due to increased engine power or thrust, will require re-evaluation with ice accretions. Since the pass/fail criteria are qualitative, testing (original airplane and modified airplane) should be accomplished back to back by the same test pilot. Stall warning should also be evaluated. Although the margins are not a concern at high power, they need to evaluate if higher power masks any stall warning cues. The following tests should be accomplished:

- Stall characteristics and stability at minimum weight and maximum weight, aft CG limit

- Controllability at forward CG limit and critical weight

2. Susceptibility to ice contaminated tailplane stall should be addressed for airplanes in which the engine thrust increase is greater than 10 percent or the airplane has a service history of ICTS susceptibility. Maximum power is usually more critical than idle. This cannot be done with analysis on a propeller airplane with reversible controls due to second order effects. Flight testing should be accomplished with 40-grit sandpaper and intercycle/residual ice on horizontal tailplane, intercycle/residual ice on vertical stabilizer, and 45-minute ice accretions on unprotected leading edge tail surfaces.

- **Engine Induction Icing**. Refer to AC 23-16A for guidance.

(c) Ice Shedding. Engine compliance data to **§** 33.77 should be compared between the currently installed engine and the proposed engine. If the ice slab used to show compliance is smaller for the proposed engine, ice shedding from the airframe should be re-addressed. Data on ice shedding may be available from the airplane TC holder. Engine inlet lip ice shedding should be addressed. The amount of ice mass that could be shed should be compared to a similar, approved engine installation or to part 33 engine compliance data.

(d) Effects of Decreased Engine Power, Thrust or Bleed Air.

1. Ice Protection System Operation. Bleed air mass flows, pressures and temperatures of the proposed engine and of the existing, certified engine should be compared. If there is a reduction, the effectiveness of the ice protection systems must be substantiated.

2. Airplane Performance. Airplane performance in icing conditions should be re-evaluated.

(2) Essential APU. When an essential APU is modified or added, operation in icing conditions should be addressed similarly to engines since essential APUs are covered by § 23.1093.

(3) Propeller Changes.

(a) Section 23.929 states that propellers (except wooden propellers) and other engine installations must be protected against the accumulation of ice as necessary to enable satisfactory functioning without appreciable loss of thrust when operated in the icing conditions for which certification is requested.

(b) If the deicing system is listed on the propeller TCDS, it does not indicate that compliance to § 23.929 was shown. It means that the deicing system was shown to function properly, the deicing system complies with propeller structural and vibration regulations, and deicing system failure modes, as discussed in § 23.929 of AC 23-16, cannot cause an un-airworthy condition.

(c) The typical analysis report from the deicing boot manufacturer is not sufficient by itself to show compliance to § 23.929. The typical report calculates intercycle ice thickness for various flight and icing conditions, but does not calculate the effect on propeller efficiency, which must be done to show no appreciable loss of thrust. For STCs, it would be acceptable to show that intercycle ice is equal to or less than the accretions obtained on the same propeller on an airplane that was flight tested in icing conditions and shown to have no appreciable loss in thrust.

(d) The typical deicing boot manufacturer report also contains a caveat that it does not address propeller runback ice. Similarity to another propeller that was flight tested in icing conditions is usually done to address runback. Similarity would include propeller and deicing boot aerodynamic and thermal similarity, deicing cycle time, propeller RPM, and flight conditions. Note that metal and composite propellers have different thermal masses.

(e) As a final qualitative check for both intercycle and runback ice on new airplane programs, airplane performance is checked during flight tests in icing conditions. A test point as close to minus 22 degrees F as possible should be included in the flight tests.

(f) The propeller installation, including spinner and cowl geometry, must be compared to previously tested installations in icing conditions. Changes that could allow moisture to reach the brush blocks must be avoided.

(g) If the proposed propeller is calculated to have higher efficiency than the existing, approved propeller, the guidance in paragraph 1e(1)(a) of this appendix should be followed.

(h) If the proposed propeller(s) and/or deicing system are predicted to increase the size of intercycle ice, the effects of propeller ice shed onto other parts of the airplane should be addressed.

(i) For New Propeller Deice Electrical Power Systems:

1. The surface temperature characteristics of the propeller boots should be shown to be the same as original certified system.

(aa) If the temperature characteristics and deice timing cycle are shown to be changed, flight testing in measured natural icing conditions are required to evaluate propeller deicing and airplane performance

(bb) If the temperature characteristics and deice timing cycle are shown to be unchanged, a demonstration of propeller deicing and airplane performance in natural icing conditions should be performed.

(cc) Flight testing should be accomplished as close to –22 degrees F as possible.

2. A rational analysis of the heat generated by the system should be made and compared to the existing system if the system is located in areas where ice accretion and runback could be affected, such as the spinner.

(4) Engine Inlet or Accessory Inlet Changes. Guidance is provided in the "engine changes" section above. It should be noted that **§** 23.1093 applies to engine oil and accessory cooling inlets as well as induction inlets.

(5) Antennas, Installations or Other External Modifications.

(a) When antennas, cameras, fairings for such installations, or other external installations such as drain masts are installed on aircraft, the installer should show the following:

1. The predicted ice accretion does not contribute significantly to drag;

2. There is no ice-shedding hazard due to impact or ingestion on downstream structure, engines or propellers. See paragraph 13 of the AC for guidance on ice shedding.

3. There is no ice related reduction performance of lifting surfaces;

4. There is no ice related effect on downstream air data sensors or ice detectors.

(b) A very conservative, simple analysis may be accomplished first to show the objectives (a)1 and (a)2. If the conservative analysis fails, the analysis can be refined to determine if the initial analysis was overly conservative. The conservative analysis can assume the following:

1. The water catch area is the full frontal area of the installation;

2. Collection efficiency is one.

3. No runback or evaporation of impinging water.

4. Assume the shape on blade antenna will be similar to airfoils and the shape on low profile antennae will be single horn shapes.

(c) The installer should determine the critical icing condition, and the 45-minute hold in continuous maximum conditions needs to be included. If the analysis shows a problem, then one or more of the following can be accomplished:

1. Determine realistic collection efficiency either with an ice accretion code or with the "FAA Icing Handbook";

2. Determine the real impingement limits by using an icing code, which may reduce the collection area;

3. Run the full configuration in an icing code to determine if the installation is in a shadow zone.

4. If drag is a problem, run an ice accretion code to determine a more realistic ice shape.

(d) Flight tests in measured natural icing or with simulated ice shapes should be accomplished to determine if there are any detrimental effects due to the ice accretions if:

1. The installation is upstream of air data sensors or an ice detector; or

2. The installation is on a lifting surface or

3. The installation could create a wake on a lifting surface. As an example, if an external modification is large enough (e.g. dish antenna), it may interfere with the flow field around the tail and the susceptibility to ICTS may need to be addressed.

(e) The one exception to (d) 2 is fairings. An analysis to show the impact on maximum lift coefficient, in combination with flight tests with no ice accretions, may be acceptable.

(6) Gross Weight Increases.

(a) At the increased angle of attack for a given airspeed, the impingement limits will change. An impingement analysis needs to be accomplished to show the ice protection coverage remains adequate.

(b) The impingement analysis should also evaluate unprotected areas such as fuel vents.

(c) If the following flight testing with no ice show no degradation from the unmodified aircraft, and no marginal characteristics, flight testing with ice (or simulated ice accretions) are not required:

<u>1</u>. Stall warning, stall characteristics, and stability at maximum weight, aft CG limit

<u>2</u>. Stall speeds and controllability at maximum weight, forward CG limit.

(d) Operational speeds and AFM/POH performance data in icing conditions need to reflect higher stall speeds.

(e) An analysis should show increased weight makes the airplane equal or less susceptible to tailplane stall. The analysis should evaluate tail trim requirements and tail ice accretion at the higher airplane angle of attack.

(7) CG Envelope Increase. Generally, the same guidance used for gross weight increases can be used for CG envelope increases. The one exception is when an increase of forward center of gravity limit on airplanes makes an airplane more susceptible to ice contaminated tailplane stall. This should be addressed by flight testing for airplanes with unpowered, reversible elevators or with propellers. An analysis may be acceptable for other configurations.

(8) Flight Envelope or Operating Procedure Changes.

(a) If an increase in maximum operating altitude is applied for, the applicant should demonstrate:

<u>1</u>. The ice protection system operating pressures (for pneumatic systems) or temperatures (for hot air systems) by dry air testing; and

<u>2</u>. The stall speeds and stall characteristics associated with ice accretions if these are shown to be influenced by Mach number.

(b) The effect of increased cruise airspeeds and increased altitudes that could affect windshield ice accretion, and adequacy of the windshield heat, should be addressed.

(c) The effect of different operating airspeeds and altitudes that could affect critical ice accretions.

(9) Turboprop Conversion.

(a) If the ice protection systems utilize engine bleed air for operation, the pneumatic lines may accumulate more water than the current unmodified type design. This water can subsequently refreeze and block the pneumatic lines, resulting in failure of some or all zones of the pneumatic system. The applicant needs to show that the pneumatic deicing system will continue to function in icing conditions.

(b) The pneumatic deicer operating pressure may also decrease at lower engine RPMs. A minimum engine RPM for acceptable pneumatic operating pressure, which should allow for descent, should be established and published in the AFM/POH.

(10) Modifications to Lifting Surfaces.

(a) Critical ice accretions (including pre-activation, intercycle, residual, and runback) may have to be re-defined, especially if the changes affect wing angle of attack. Stall strips are good collectors of ice and are an example where leading edge ice accretions should be re-defined. If ice accretions are changed or the modifications could affect control power or hinge moments, flight testing with simulated ice accretions should be accomplished to evaluate one or more of the following:

1. Stall warning, stall characteristics, and stability at maximum weight, aft CG limit;

2. Stall speeds, stall warning, controllability and performance at maximum weight, forward CG limit;

3. ICTS susceptibility at light weight, forward CG limit if the aircraft has unpowered, reversible elevators or propellers.

4. For unprotected winglets, flutter margins needs to be addressed.

(b) Susceptibility to ICTS should be addressed for either horizontal or vertical tail modifications or wing modifications that are predicted to increase ICTS susceptibility. ICTS susceptibility may be addressed by analysis on jet-powered aircraft with irreversible elevator controls.

(11) Installation of Vortex Generators.

For vortex generators that are installed near the leading edge, the applicant should provide data on expected ice accretions. Flight conditions to consider are the 45-minute hold, descent, and approach. Substantiation of the effects on stall speeds, stall characteristics, and stability and control should be provided.

(12) Modifications to Ice Protection Systems.

(a) Critical ice accretions may have to be re-defined. If ice accretions are changed or the modifications could affect control power or hinge moments, flight testing with simulated ice accretions should be accomplished to evaluate one or more of the following:

1. Stall warning, stall characteristics, and stability at maximum weight, aft CG limit;

2. Stall speeds, stall warning and controllability at maximum weight, forward CG limit;

3. ICTS susceptibility at light weight, forward CG limit if the aircraft has unpowered, reversible elevators or propellers.

(13) Addition of or Re-location of Fuel Vent.

As a minimum an impingement analysis and/or similarity should be used to show that ice does not obstruct the fuel vents.

(14) Addition or Replacement of Autopilot

(a) Guidance in this AC, paragraphs 11 and 12 for autopilots should be consulted. There are specific scenarios in which autopilots can get the pilot into trouble in an airplane approved for flight into known icing. Those scenarios resulted in accidents and are factual. Based on our service experience, even though there are no regulatory requirements addressing autopilots in airplanes approved for known icing, applicants are strongly encouraged to include features that mitigate these autopilot induced accident scenarios. Where it would be impractical to add such a feature, the design should include adequate trim in motion cues. For replacement autopilots, the design of the original and replacement autopilots should be compared.

APPENDIX D. GUIDELINES FOR CERTIFYING ICE PROTECTION SYSTEMS ON AIRPLANES NOT CERTIFICATED FOR FLIGHT IN ICING

1. APPLICABILITY. There may be times when applicants may want to certificate an ice protection system installation on an airplane that is to remain not certificated for flight in icing. This used to be called a “non-hazard” basis. This means that the aircraft is prohibited from flight in icing conditions but there is some ice protection to facilitate an exit from an inadvertent icing encounter. The following guidance provides a reference; novel systems may require additional considerations.

2. SUBPART B – FLIGHT.

a. The applicant must show that installation of the system (not operating) does not affect performance, stalls, controllability, maneuverability, stability, trim, ground/water handling, vibration and buffet, and, if applicable, high speed characteristics. If any of these are affected, it should be shown that applicable regulations are still complied with and place the appropriate information in the AFM. Compliance should be accomplished with dry air flight tests. If the system is being evaluated as an amended TC or STC, it is not necessary to investigate all weight and CG combinations and flight conditions when results from the airplane certification testing clearly indicate the most critical combination to be tested.

b. In some cases the effect of system operation may need to be evaluated. For pneumatic deicing boots, the operation of the boots (inflation) should have no hazardous affect on airplane performance and handling qualities. The effect of pneumatic boot operation on stall speed and stall warning should be evaluated and appropriate information placed in the AFM. Freezing point depressant systems when operating have been shown to increase drag.

3. SUBPART D – DESIGN AND CONSTRUCTION.

a. The ice protection systems should be evaluated to determine the impact to the airframe structure per the applicable regulations in subpart D. The load conditions determined from Subpart C should be used in this evaluation. The individual ice protection system components should also be evaluated to determine that they would withstand the load conditions from Subpart C if their failure can cause a hazard. Thermal effects on structure of thermal ice protection systems and fluid/structure compatibility of freezing point depressant systems should be evaluated.

b. An evaluation of flutter characteristics to account for the added mass of the ice protection systems should be made per § 23.629.

c. If a thermal windshield ice protection system is installed, an evaluation of the visibility due to distortion effects through the protected area should be made. In accordance with § 23.775(g), a probable single failure of a transparency heating system should not adversely affect the integrity of the airplane cabin or create a potential danger of fire.

d. For wing and empennage electrical deicing systems, the indirect effects of lightning maybe an issue. The airplane must be shown to be protected against catastrophic effects from lightning in accordance with § 23.867. As a minimum the effect of the ice protection system installation should be addressed by analysis and design.

4. SUBPART E – POWERPLANT. For an airplane not certificated for flight in icing, compliance to § 23.929 is not required but compliance to § 23.1093 is required.

5. SUBPART F – EQUIPMENT.

a. On airplanes with a certification basis of amendments 23-20 and higher, compliance to § 23.1301 must be shown. Compliance to § 23.1301 would entail a functional flight test in dry air supplemented by previous certification data on other, similar installations that showed the system functioned in part 25, Appendix C icing. If this data were not available the applicant would have to perform some testing in icing conditions.

b. Compliance to the latest applicable amendment of § 23.1309 should be shown. See AC 23.1309-1C for additional guidance. To show compliance to § 23.1309 the following would apply:

(1) Show that installation of the system, and normal operation of the system, does not affect operation of essential equipment. This should include electromagnetic interference testing.

(2) Show that hazards are minimized on single engine airplanes and prevented for multi-engine airplanes in the event of a probable failure. Examples of failures that should be addressed:

(a) Auto inflation of deicing boots

(b) Failures that could cause an asymmetric wing condition

(c) Bleed air leaks of thermal systems

(d) Electrical shorts in electrothermal systems.

(3) Compliance can be by analysis or test or a combination. The loss of the ice protection system would not have to be considered since the airplane is not approved for flight in icing. For the purposes of the current regulation, the system would not be an essential load.

(4) Show that the system when operating normally does not create a greater hazard than operating with no ice protection system. For example, on systems where there is runback the applicant should show that the runback ice does not cause a greater hazard than the ice accretion with no ice protection. Hazards to address would be stalls, tailplane stalls, and engine operation if applicable.

c. To show compliance to § 23.1351 an electrical load analysis should be done if the ice protection system utilizes the airplane's primary electrical power system. If the ice protection system utilizes its own alternator/generator, other regulations in § 23.1351 may be applicable.

d. Compliance to § 23.1416 and § 23.1419 are not required.

6. SUBPART G – OPERATING LIMITATIONS AND INFORMATION.

a. A cockpit placard in view of the pilot and the AFM should state that the airplane is prohibited from flight in icing conditions.

b. A description of all ice protection system controls and annunciations should be in the AFM.

c. If the airplane is equipped with a stall warning sensor(s) that are not heated, the AFM should caution that stall warning in icing conditions might not be reliable.

d. Instructions for continued airworthiness in accordance with § 23.1529 should be provided.

APPENDIX E. GUIDELINES FOR APPROVAL OF REPLACEMENT PARTS FOR AIRFRAME DEICING SYSTEMS

1. The requirements leading to approval of replacement airframe deicing systems (propeller-deicing systems will be addressed in a revision) or airframe thermal deicing or anti-icing systems are functions of the project certification basis and similarity with the original part(s), as summarized in Table E-1 and discussed in the following paragraphs:

TABLE E-1. SUMMARY OF TEST REQUIREMENTS FOR REPLACEMENT AIRFRAME DEICING COMPONENTS

Aircraft Approved for Flight in Icing Conditions?	Certification Basis	Approval Process Required	Tests to Show Safe Operation throughout Part 25, Appendix C Icing Conditions	Natural Icing Flight Tests
No		PMA	Not required	Not required
Yes	CAR § 3.712	STC	See paragraph b.	See paragraph b.
Yes	23-0 to 23-13	STC	See paragraph b.	See paragraph b.
Yes	23-14 to 23-42	STC	Required	See paragraph c.
Yes	23-43 or higher	STC	Required	Required

a. For aircraft whose certification basis does not include CAR § 3.712 or § 23.1419, the deicing system is optional equipment and not required. In this case, the replacement parts can be approved via the Parts Manufacturing Approval (PMA) process in 14 CFR, part 21, subpart K. The replacement parts must be shown to function properly, remove ice or prevent ice accretion as well as the previously installed equipment, and not introduce additional failure modes that could prevent continued safe flight and landing. Comparative tests of the original versus the replacement parts are acceptable.

b. For aircraft whose certification basis is CAR § 3.712 or an original issue under § 23.1419, an STC is required. Original certification of these aircraft only required that pneumatic deicers be installed per approved data and that they have a positive means of deflation. No icing flight tests were required, and airplanes were considered "approved for flight into known icing" when the airplane was equipped with a complement of certificated deicing or anti-icing equipment spelled out in operational requirements. For replacement parts in these aircraft it is advisable for the Aircraft Certification Office (ACO) to contact the ACO maintaining the original type design data to determine factors such as variance with the original design, the original certification requirements, and the service history of the original product. The replacement parts must be shown to function properly, remove ice or prevent ice accretion as well as the previously installed equipment, and not introduce additional failure modes that could prevent continued safe flight and landing. Comparative tests of the original versus the replacement parts may be acceptable. If the original certification basis is to be utilized, it is highly recommended that an entry in the AFM supplement limitations section, or a placard, with the following wording be required: "This airplane has not demonstrated compliance with the icing environment requirements of 14 CFR, part 25, Appendix C.

c. For replacement parts on an aircraft whose certification basis is § 23.1419, amendments 23-14 through 23-42, an STC is required. Flight testing in measured, natural icing conditions should be accomplished if the replacement parts are of different materials or have different design characteristics. Supplemental testing in artificial icing conditions (icing tunnel, tanker) should also be accomplished to cover the complete part 25, Appendix C envelope. The replacement parts must be shown to function properly, remove ice or prevent ice accretion as well as the previously installed equipment, and not introduce additional failure modes that could prevent continued safe flight and landing. A matrix of performance and flying qualities as discussed in paragraph 12a(2) of this AC should be accomplished. The Standards Office should be contacted since the requirement to flight test in measured, natural icing conditions is dependent on a number factors such as whether AFM performance in icing conditions is based on protected surface ice accretions, the service history of the airplane, and flight testing accomplished during the original certification with protected surface ice accretions. Follow-on applications of the new parts in aircraft other than the initial certification may then be approved through similarity provided the conditions in § 23.1419(c) are met. There may be cases where minor modifications would not require additional measured, natural flight tests.

d. For replacement parts on an aircraft whose certification basis is § 23.1419, amendment 23-43 or higher or those aircraft where the applicant wants to add "flight in icing conditions" operational approval, an STC is required. Flight testing in measured, natural icing conditions is required if the replacement parts are of different materials or have different design characteristics. Supplemental testing in simulated icing conditions (icing tunnel, tanker) may also be required to cover the complete part 25, Appendix C envelope. The replacement parts must be shown to function properly, remove ice or prevent ice accretion as well as the previously installed equipment, and not introduce failure modes that could prevent continued safe flight and landing. A matrix of performance and flying qualities as discussed in paragraph 12a(1) of this AC should be accomplished. Follow-on applications of the new parts in aircraft other than the initial certification may then be approved through similarity provided the conditions in § 23.1419(c) are met. There may be cases where minor modifications would not require additional measured, natural flight tests.

2. Engineering judgment must be used to determine that the modifications would not affect the effectiveness of the ice protection in natural icing conditions. If there is any question as to the need for a particular design to be subject to natural icing tests, the ACO should contact the Standards Office as well as the ACO that performed the original certification and the national resource specialist for aircraft icing. Again, seemingly benign differences can have significant negative effects on an aircraft's ice protection capability.

APPENDIX F. CHECKLIST

The left column of this appendix provides a simplified checklist of the various influence items that could affect the safety of small airplanes while operating in icing conditions. In the right column are suggested considerations for resolving the concerns of each of these influence items. Certain considerations may not be applicable depending on the certification basis of the airplane. See Table F-1.

TABLE F-1. CHECKLIST

Influence	Consideration
1. Crew Visibility	**a.** Conduct evaluations to verify adequate day and night visibility through the protected windshield or the protected windshield segment under dry air and icing conditions. **b.** Evaluate the cabin defogging system's capability to clear side windows for observation of boot ice protection system operation and ice accumulation. If a defogging system is not provided, the windows should be easily cleared by the pilot without adversely increasing pilot workload. **c.** Minimum light transmittance through the protected windshield or protected windshield segment and effected side windows should consider the requirements in § 23.775(e). **d.** Determine that the temperature gradient produced on heated windshields does not adversely affect pilot vision or windshield structural integrity.
2. Engine Installation and Cooling	Conduct flight tests, analyses, or refer to substantiation data to determine that complete engine installation, including propellers, functions without appreciable loss of power. Verify that engine oil and component cooling is adequate at critical design points throughout the operational and icing envelope. If data is analyzed in accordance with § 23.1043, the temperatures need to be corrected only to 32 degrees F, not a hot day. If ice is expected to accumulate at the generator during icing encounters, then cooling air inlet generator cooling tests should be performed with the maximum icing load on the electrical system and critical ice shapes installed on the engine and generator cooling air intake.
3. Propeller	**a.** Provide analyses to establish chordwise and spanwise protection required. Aerodynamic heating due to blade rotation, latent heat of fusion, and centrifugal force are important in determining areas requiring protection. Droplet size is the critical parameter for determining chordwise extent of areas requiring ice protection.

TABLE F-1. CHECKLIST (Continued)

Influence	Consideration
	b. Where the propeller ice protection system consumes power from the electrical system, pneumatic system, or bleed air system, a load analysis should be provided showing that the power source capacity is adequate to provide ice protection in addition to all other essential loads. **c.** Where fluid is required for ice protection, a limitation should be placed in the AFM on flight in icing conditions to prevent exhausting the fluid prior to exiting the icing condition. Sufficient margin in fluid capacity should be maintained to allow for alternate airport landing in accordance with operational requirements. **d.** Other specific areas of concern include: **(1)** The effect of deicer boot installation upon propeller blade and cuff, and hub structural integrity. **(2)** Surface temperature. **(3)** Timer or other control system reliability. **(4)** Spinner ice accumulation. **e.** Perform tests to verify that ice sheds from the blades and to demonstrate compliance with § 23.1301(d) and § 23.1419(a) and (b). During testing, verify that adequate ice protection is provided, propeller performance degradations are not excessive, vibration characteristics are satisfactory and ice being shed is small enough to avoid detrimental damage to other aircraft components. Tests should include examination of the structural integrity of the propeller assembly and associated equipment with ice protection (heater blankets, slip rings, wiring, and so forth) installed.
4. Equipment, Systems, Function, and Installation	**a.** Conduct a study as discussed in paragraph 9e (failure analysis) of this AC to assure that no probable failure or malfunction of any power source (electrical, fluid, bleed air, pneumatic, and so forth) will impair the ability of the remaining source(s) to supply adequate power to systems essential to safe operation during icing flight. **b.** Conduct a power source load analysis to verify proper power requirements are provided. **c.** Verify that power source failure warning is provided to the crew.

TABLE F-1. CHECKLIST (Continued)

Influence	Consideration
	d. Demonstrate that the alternator or generator is protected from detrimental ice accumulation.
	e. Determine if load shedding can be accomplished after a partial failure condition. If applicable, a load shedding sequence should be provided so the pilot may assure that adequate power is available to the ice protection equipment and other necessary equipment for flight in icing conditions.
	f. Determine that maximum windshield heat does not adverse affect structural integrity or pilot view.
5. Circuit and Protective Devices	**a.** Determine that the design incorporates electrical overload protection that opens regardless of operating control position.
	b. Verify that the design is such that no protective device is protecting more than one circuit essential to continued safe flight (for example, pitot heat and stall warning transducer heat are considered separate essential circuits and should be provided separate protection). Ice protection monitor and warning circuits should be considered separate from control circuits and each should provide individual circuit protection. On airplanes equipped with dual power sources, a power distribution system having a single bus and a single circuit breaker protecting the ice protection system is not acceptable.
6. Airfoil Leading Edge Protection System	**a.** Provide a means to indicate to the crew that the ice protection system is receiving adequate electrical power, bleed air pressure, vacuum, or fluid, and so forth, as appropriate, and it is functioning normally.
	b. Conduct droplet trajectory and impingement analysis of wing, and horizontal and vertical stabilizers to establish aft limits for ice formation. Areas of concern include adequacy of upper and lower limits of wing and stabilizer protection to allow safe flight in icing conditions.
	c. The maintenance manual should contain approved cleaning, surface treatment, and repair procedures for leading edge ice protection systems.

TABLE F-1. CHECKLIST (Continued)

Influence	Consideration
	d. Analyses and testing required for replacement-deicing systems are dependent on the certification basis of the project and the deicing system material and design characteristics. See Appendix E for guidance.
7. Static Pressure System	**a.** Each static port design or location should be such that correlation between air pressure in the static system and true ambient pressure is not altered when flying in icing conditions. Means of showing compliance include the following: anti-icing devices, alternate source for static pressure, or demonstration by test that port icing does not occur under any condition.
	b. Where the port is thermally protected, a thermal evaluation should be conducted to demonstrate that the protection is adequate.
8. Pitot, Static, Angle-of-Attack, and Stall Warning Sensors	**a.** Provide analysis (thermal analysis in the case of heated pitot tube and static ports) to establish anti-icing/deicing requirements.
	b. Perform tests to verify analyses and demonstrate compliance. Use these verified analyses to extrapolate to the critical conditions of part 25, Appendix C. Several combinations of parameters may be critical test points. For unprotected components, testing may be conducted to demonstrate that airspeed, altitude, and other indications remain within acceptable tolerances under the critical conditions. In some cases, adequate bench and flight testing may already have been accomplished on other airplanes to establish an approval basis by similarity on a specific airplane.
9. Magnetic Direction	Designs should minimize Magnetic Direction Indicator (MDI) deviations; however, if MDI deviations greater than ±10 degrees exist when operating electrical ice protection equipment, provide placarding.

TABLE F-1. CHECKLIST (Continued)

Influence	Consideration
	NOTE 7 If the ice protection system causes greater than an l0-degree deviation, then § 23.1327 (amendment 23-20) should be applied in lieu of previous requirements. The one exception is single-side Electronic Flight Information Systems (EFIS) installations in which the safety assessment uses magnetic heading as a backup. A policy to address this is being added in AC 23-17A.
10. Ice Inspection Light(s)	**a.** Night flight evaluation of light coverage and glare produced by the wing ice inspection light(s) should be evaluated. **b.** A hand-held flashlight is not acceptable as an ice detection light. **c.** The ice detection light(s) should be evaluated in icing conditions to verify that sufficient illumination is provided for the pilot to detect ice accumulation.
11. Antennas and Other Components	**a.** Conduct structural analysis to establish that critical ice build-ups on antennas, masts, and other components attached externally to the airplane do not result in hazards. **b.** Tests in natural icing or with simulated ice shapes may be used to substantiate the structural analysis. **c**. Ice shedding from these components should be evaluated to verify that size and trajectory do not damage other parts of the airplane.
12. Fluid Systems	**a.** Certain fluids used in ice protection systems are flammable. Components of these systems must meet the flammable fluid protection requirements of § 23.863. No components of these systems may be installed in passenger or crew compartments without the protection required by § 23.853(d) (prior to amendment 23-34) or § 23.853(e) (after amendment 23-34).

TABLE F-1. CHECKLIST. (Continued)

Influence	Consideration
	b. Fluid capacity should be established based on the operational capability of the airplane and on the ability to fly to an alternate airport and safely land. Means should be provided to monitor fluid capacity and flow rates as they relate to flight. The method for determining ice protection availability should be provided in the operating procedures of the AFM. **c.** The maintenance manual should list approved fluids and, if pilot and crewmembers are required to replace fluids, these approved fluids should be listed in the AFM. The fluid filler inlet should bear a placard stating that only approved fluids be used. Approved fluids may be listed on this placard or in the AFM. **d.** The compatibility of the fluid with airframe and engine components should be examined to verify that adverse reactions such as corrosion or contamination do not occur, or are prevented through inspection or other measures (for example, if ethylene glycol is a component fluid, then silver and silver-plated electrical switch contacts and terminals should be protected from contamination by the ethylene glycol to avoid a fire hazard).
13. Flight Tests	The certification rules require analyses and tests to demonstrate that the airplane can safely operate in the icing envelope of part 25, Appendix C. Compliance can be determined by similarities to previously approved configurations. If it should be necessary to conduct dry air tests with ice shapes, natural icing tests, or simulated icing tests, the goals and results should be in accordance with the guidance provided in Sections 11 and 12 of this AC.
14. Flight Manual and Placards	The AFM and appropriate placards in the airplane should be designed to provide the pilot with sufficient information to safely operate the airplane in an icing environment.

APPENDIX G. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43

TABLE G-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43

Regulation	14 CFR Section	Guidance
Proof of compliance	23.21	Only critical weight and CG loadings, as determined during the non-contaminated airplane tests, are required. Natural icing flight tests may be accomplished at a nominal CG.
Load distribution limits	23.23	Only critical weight and CG loadings, as determined during the non-contaminated airplane tests, are required. Tests in which lateral load is critical, such as stall characteristics, should include tests with maximum allowable fuel asymmetry. There should not be different load, weight, and CG limits for flight in icing. Operation in icing conditions should be essentially transparent to the flightcrew in that no icing-specific methods of operation (other than activating ice protection systems) should be required. This philosophy is also based on human factors issues to reduce operational complexity and flightcrew workload.
General (Performance)	23.45	Must comply, except performance should be determined up to a temperature of standard plus five degrees C instead of plus 30 degrees C. It can be assumed that ice accretion will not be present on the airframe at temperatures warmer than plus five degrees C. For deicing systems, the average drag increment and propeller efficiency determined over the deicing cycle may be used for performance calculations. Propeller deicing codes do not address propeller runback icing. Similarity to previously flight-tested configurations or qualitative performance evaluations in natural icing should be accomplished.
Stall speed	23.49	Must comply with critical ice accretions. See paragraph 12a(1)(c) for exemption considerations to the 61-knot stall speed requirement. Stall speeds with critical ice accretions should be determined and published in the AFM.
Takeoff speeds	23.51	When determining the takeoff speeds V_1, V_R, and V_2 for flight in icing conditions, the values of V_{MCG} and V_{MC} determined for non-icing conditions may be used.

TABLE G-1. PART 23 SUBPART B TEST FOR SECTION 23.1419 AT AMENDMENT 23-43
(Continued)

Regulation	14 CFR Section	Guidance
Takeoff speeds (Cont'd)	23.51 (Cont'd)	If the stall speed with "takeoff" ice at maximum takeoff weight with takeoff flaps, gear retracted exceeds that in non-icing conditions by more than the greater of three KCAS or three percent V_{S1}, the speed at 50 feet or V_2 must be increased to remain compliant.
Takeoff performance	23.53	The effect of operating ice protection systems on engine performance should be accounted for. Takeoff performance in icing conditions must be calculated with "takeoff" ice if: **a.** The stall speed with "takeoff" ice at maximum takeoff weight with takeoff flaps, gear retracted exceeds that in non-icing conditions by more than the greater of three KCAS or three percent V_{S1}; and **b.** If commuter category, the degradation of the gradient of climb determined in accordance with § 23.67(c)(2) is greater than one-half of the applicable actual-to-net takeoff path gradient reduction defined in § 25.61(b); and **c.** If multi-engine normal, utility or acrobatic category, the degradation of the gradient of climb determined in accordance with § 23.67(a) or (b) is greater than one-half of the applicable actual-to-net takeoff path gradient reduction defined in § 25.61(b).
Accelerate-stop distance	23.55	Applicable for commuter category only. The effect of any increase due to takeoff in icing conditions may be determined by analysis.
Takeoff path	23.57	
Takeoff distance and takeoff run	23.59	Applicable for icing for commuter category only if the conditions described above in 23.53 are met. May be calculated by a suitable analysis.
Takeoff flight path	23.61	
Climb: general	23.63	Must be compliant, except ambient temperatures above 41-degrees F do not need to be addressed.

TABLE G-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43
(Continued)

Regulation	14 CFR Section	Guidance
Climb: all engine operating	23.65	Must be shown to be compliant with engine power losses associated with operating ice protection equipment that are not prohibited for takeoff. Climb performance losses due to ice accretion are normally not appropriate below 400 feet since the airplane should not depart with ice on the airplane. However, if ice protection system operation is prohibited for takeoff or the AFM does not specifically prohibit takeoff with frost on the wing and control surfaces, effect of ice accretions must be considered if: **a.** the stall speed with "takeoff" ice at maximum takeoff weight with takeoff flaps, gear retracted exceeds that in non-icing conditions by more than the greater of three KCAS or three percent V_{S1}, and **b.** for airplanes in which 23.65(a) is applicable, the degradation of the gradient of climb determined in accordance with § 23.65(a)) with "takeoff" ice is greater than 1.6 percent, and **c.** for airplanes in which 23.65(b) is applicable, the degradation of the gradient of climb determined in accordance with § 23.65(b) with "takeoff" ice is greater than 0.8 percent.
**Takeoff climb: one engine inoperative*	23.66	If applicable must be compliant.
Climb: one engine inoperative	23.67	The effect of operating ice protection systems on engine performance must be accounted for. The effect of ice accretion on climb performance (lift, drag and climb speed) must be accounted for if: **a.** The stall speed with "takeoff" ice at maximum takeoff weight with takeoff flaps, gear retracted exceeds that in non-icing conditions by more than the greater of three KCAS or three percent V_{S1}; and

* Italicized regulations indicate tests not typically accomplished for 23.1419 at amendment 23-14.

TABLE G-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43 (Continued)

Regulation	14 CFR Section	Guidance
Climb: one engine inoperative (Cont'd)	23.67 (Cont'd)	**b.** If commuter category, the degradation of the gradient of climb determined in accordance with § 23.67(c)(2) is greater than one-half of the applicable actual-to-net takeoff path gradient reduction defined in § 25.61(b), and **c.** If multi-engine normal, utility or acrobatic category, the degradation of the gradient of climb determined in accordance with § 23.67(a) or (b) is greater than 0.3 percent. For paragraphs (b)(1), (c)(1), and (c)(2), "takeoff" ice applies, and for paragraph (c)(3) "Final Takeoff" ice applies, rather than critical ice accretions.
Enroute climb/descent	23.69	Must be accomplished with "Enroute" ice if the enroute climb speed selected in icing is more than the non-icing speed by the greatest of three KCAS or three percent V_{S1}.
Glide: single engines airplanes	23.71	If applicable and if ice protection systems become inoperative with engine out, the best glide speed in icing must be determined if different from the non-icing speed by more than three KCAS. May be determined analytically.
Reference landing approach speed	23.73	Must be based on stall speed with critical ice accretion if that speed exceeds V_{REF} in non-icing conditions by more than five percent or 5 knots, whichever is lower. The V_{MC} determined for non-icing conditions may be used if the vertical tail does not have ice accretion in normal system operation.
Landing distance	23.75	Must be determined with critical ice accretion if V_{REF} in icing conditions is greater than V_{REF} in non-icing conditions by more than five percent or five knots, whichever is lower. The effect of landing speed increase on the landing distance may be determined by analysis.
Balked landing	23.77	Must be compliant with critical ice accretions and all ice protection systems operational at an ambient temperature of 41 degrees F.

TABLE G-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43 (Continued)

Regulation	14 CFR Section	Guidance
General (control)	23.141	Only critical loadings as determined during the non-contaminated airplane tests and altitudes below 26,000 feet are required.
	23.143	If the non-icing V_{MC} is used for takeoff speeds, it must be shown that the airplane is safely controllable and maneuverable at the minimum V_2 for takeoff with the critical engine inoperative and with “takeoff” ice accretion. If the non-icing V_{MC} is used for V_{REF}, it must be shown that the airplane is safely controllable and maneuverable during a go-around starting at the minimum V_{REF} with the critical engine inoperative and with critical ice accretion. Susceptibility to ICTS should be evaluated as discussed in paragraph 12.e. of this AC. Susceptibility to aileron control anomalies in SLD conditions as discussed in paragraph 12.h. of this AC should be addressed.
Longitudinal control	23.145	The tests in paragraphs (a) and (b)(1) and (b)(2) must be accomplished. For the other tests, the results from the non-contaminated airplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, or if qualitative evaluations with ice accretions show control anomalies, these cases should be repeated with ice. Controllability may be degraded from the non-iced airplane but must still be compliant. Analysis, the results of the non-icing tests to show compliance to § 23.145(e), and the results of controllability tests with ice accretions may be used to show compliance to § 23.145(e).
Directional and lateral control	23.147	Critical configuration(s) determined from the non-contaminated airplane tests must be evaluated. Analysis, the results of the non-icing tests to show compliance to § 23.147(c), and the results of controllability tests with ice accretions may be used to show compliance to § 23.147(c).

TABLE G-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43
(Continued)

Regulation	14 CFR Section	Guidance
Minimum control speed	23.149	If the vertical tail is unprotected or has intercycle/residual/runback ice during ice protection system normal operation, V_{MC} speeds with critical ice must be evaluated to determine if the proposed V_{REF} speed in icing complies with § 23.73. Static V_{MC} tests may be used.
Acrobatic maneuvers	23.151	Not applicable for icing certification.
Control during landings	23.153	Must be shown to be compliant.
Elevator control force in maneuvers	23.155	Critical configuration(s) determined from the non-contaminated airplane tests must be evaluated.
Rate of roll	23.157	Airplane must comply with “takeoff” ice accretions for paragraph (a) and critical ice accretions for paragraph (b). Controllability may be degraded from the non-iced airplane but must still be compliant.
Trim	23.161	The results from the non-contaminated airplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, or if qualitative evaluations with ice accretions show any control anomalies, these cases should be repeated with ice. Otherwise, no dedicated tests with ice accretions required, qualitative evaluations can be accomplished concurrently with other tests.
General (stability)	23.171	Must be shown to be compliant.
Static longitudinal stability	23.173	Stability may be degraded from the non-iced airplane but must still be compliant.
Demonstration of static longitudinal stability	23.175	Critical configuration(s) determined from the non-contaminated airplane tests must be evaluated.

TABLE G-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43
(Continued)

Regulation	14 CFR Section	Guidance
Static directional and lateral stability	23.177	Must evaluate steady heading sideslips in accordance with paragraph (d). The results from the non-contaminated airplane tests to show compliance with paragraphs (a) and (b) should be reviewed to determine whether there are any cases where there was marginal compliance. If so, these cases should be repeated with ice. Stability may be degraded from the non-iced airplane but must still be compliant.
Dynamic stability	23.181	Critical configuration(s) determined from the non-contaminated airplane tests must be evaluated.
Wings level stall	23.201	As a minimum wings level stalls with cruise, approach and landing flaps, power off and on, should be evaluated. Roll may slightly exceed 15 degrees if characteristics qualitatively determined to be safe. Stall characteristics should also be evaluated when the airplane is stalled with the autopilot engaged, unless the design of the autopilot precludes its ability to operate beyond stall warning. For these designs the controllability at stall warning should be evaluated.
Turning flight and accelerated turning stalls	23.203	Turning stalls should be evaluated. Accelerated turning stalls not required unless tests with no ice show marginal compliance. Stall characteristics should also be evaluated when the airplane is stalled with the autopilot engaged, unless the design of the autopilot precludes its ability to operate beyond stall warning. For these designs the controllability at stall warning should be evaluated.
Stall warning	23.207 (a)-(c)	Should be evaluated concurrently with stall speed and stall characteristics tests. The type of stall warning and the stall warning margin with ice accretions should be the same as with the non-contaminated airplane. Biasing of the stall warning system in icing may be required to achieve acceptable margins to stall. The method of biasing should be evaluated. Adequacy of stall warning when airplane is decelerated with autopilot engaged should be evaluated.

TABLE G-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43 (Continued)

Regulation	14 CFR Section	Guidance
Maneuver margin	23.207 (d)	40-degree bank level altitude turns and 30 degree/30 degrees bank-to-bank rolls at the flight conditions specified in the regulation should be accomplished to demonstrate the airplane is free of buffet and stall warning with critical ice accretions. All takeoff and approach flap settings should be evaluated. For one-engine inoperative evaluations, only a 30-degree turn is necessary, and the appropriate thrust may be simulated with all engines operating at a reduced power/thrust.
Accelerated stall warning margin	23.207 (e)	Not required unless tests with no ice show marginal compliance.
Spinning	23.221	Not required.
Longitudinal stability and control	23.231	Must be shown to be compliant.
Directional stability and control	23.233	Must be shown to be compliant. The results of the steady heading sideslip tests with critical ice may be used to establish the safe cross wind component. If the flight test data show that the maximum sideslip angle demonstrated is similar to that demonstrated with the non-contaminated airplane, and the flight characteristics (e.g., control forces and deflections, bank angle) are similar, then the non-contaminated airplane crosswind component is considered valid. If the results of the comparison discussed above are not clearly similar, and in the absence of a more rational analysis, a conservative analysis based on the results of the steady heading sideslip tests may be used to establish the safe crosswind component. The crosswind value may be estimated from: $\mathbf{V_{CW} = V_{REF} * \sin(\text{sideslip angle}) / 1.5}$ where: $\mathbf{V_{CW}}$ is the crosswind component, $\mathbf{V_{REF}}$ is the landing reference speed appropriate to a minimum landing weight, and **sideslip angle** is that demonstrated at V_{REF}

TABLE G-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43
(Continued)

Regulation	14 CFR Section	Guidance
Operation on unpaved surfaces	23.235	Not applicable for icing certification.
Operation on water	23.237	Not applicable for icing certification.
Spray characteristics	23.239	Not applicable for icing certification.
Vibration and buffet	23.251	The non-icing tests should be accomplished with the ice protection systems installed. Should be qualitatively evaluated in conjunction with other dry air ice shape flight tests up to the lower of: 250 KCAS $V_{MO}/M_{MO}/V_{NE}$ A speed at which it is demonstrated that the airframe will be free of ice accretion. Vibration due to propeller icing/de-icing should be evaluated during the natural icing testing.
High speed characteristics	23.253	If applicable, compliance should be shown with airframe ice protection systems installed. Not required with ice accretions.

APPENDIX H. AFM LIMITATIONS AND NORMAL PROCEDURES SECTIONS

1. LIMITATIONS SECTION. The following text and warning information should be inserted in the limitations section of the AFM:

"a. Flight in meteorological conditions described as freezing rain or freezing drizzle, as determined by the following visual cues, is prohibited:

(1) Unusually extensive ice accreted on the airframe in areas not normally observed to collect ice.

(2) Accumulation of ice on the upper surface (for low-wing airplanes) or lower surface (for high-wing airplanes) of the wing aft of the protected area.

(3) Accumulation of ice on the propeller spinner farther back than normally observed.

If the airplane encounters conditions that are determined to contain freezing rain or freezing drizzle, the pilot must immediately exit the freezing rain or freezing drizzle conditions by changing altitude or course.

NOTE 7

The prohibition on flight in freezing rain or freezing drizzle is not intended to prohibit purely inadvertent encounters with the specified meteorological conditions; however, pilots should make all reasonable efforts to avoid such encounters and must immediately exit the conditions if they are encountered.

b. Use of the autopilot is prohibited when any ice is observed forming aft of the protected surfaces of the wing, or when unusual lateral trim requirements or autopilot trim warnings are encountered.

NOTE 8

The autopilot may mask tactile cues that indicate adverse changes in handling characteristics; therefore, the pilot should consider not using the autopilot when any ice is visible on the airplane.

c. All wing ice inspection lights must be operable prior to flight into known or forecast icing at night.

NOTE 9

This supersedes any relief provided by the Master Minimum Equipment List (MMEL)."

2. NORMAL PROCEDURES SECTION. The following text and warning information should be inserted in the normal procedures section of the AFM:

WARNING

- If ice is observed forming aft of the protected surfaces of the wing or if unusual lateral trim requirements or autopilot trim warnings are encountered, accomplish the following:

- If the flaps are extended, do not retract them until the airframe is clear of ice.

- The flight crew should reduce the angle-of-attack by increasing speed as much as the airplane configuration and weather allow, without exceeding design maneuvering speed.

- If the autopilot is engaged, hold the control wheel firmly and disengage the autopilot. Do not re-engage the autopilot until the airframe is clear of ice.

- Exit the icing area immediately by changing altitude or course; and

- Report these weather conditions to air traffic control.

CAUTION

Flight in freezing rain, freezing drizzle, or mixed icing conditions (supercooled liquid water and ice crystals) may result in hazardous ice build-up on protected surfaces exceeding the capability of the ice protection system, or may result in ice forming aft of the protected surfaces. This ice may not be shed using the ice protection systems, and it may seriously degrade the performance and controllability of the airplane.

a. The following shall be used to identify freezing rain/freezing drizzle icing conditions:

(1) Unusually extensive ice accreted on the airframe in areas not normally observed to collect ice.

(2) Accumulation of ice on the upper surface or lower surface of the wing aft of the protected area.

(3) Accumulation of ice on the propeller spinner farther back than normally observed.

b. The following may be used to identify possible freezing rain/freezing drizzle conditions:

(1) Visible rain at temperatures below plus five degrees C outside air temperature (OAT).

(2) Droplets that splash or splatter on impact at temperatures below plus five degrees C OAT.

(3) Performance losses larger than normally encountered in icing conditions. It is possible to experience severe ice accretions not visible to the flight crew, such as wing lower surface accretion on a low wing airplane or propeller blade accretion.

c. Procedures for Exiting the Freezing Rain/Freezing Drizzle Environment. These procedures are applicable to all flight phases from takeoff to landing. Monitor the outside air temperature. While ice may form in freezing drizzle or freezing rain at temperatures as cold as minus 18 degrees C, increased vigilance is warranted at temperatures around freezing with visible moisture present. If the visual cues specified in the AFM for identifying possible freezing rain or freezing drizzle conditions are observed, accomplish the following:

(1) Exit the freezing rain or freezing drizzle icing conditions immediately to avoid extended exposure to flight conditions outside of those for which the airplane has been certificated for operation. Asking for priority to leave the area is fully justified under these conditions.

(2) Avoid abrupt and excessive maneuvering that may exacerbate control difficulties.

(3) Do not engage the autopilot. The autopilot may mask unusual control system forces

(4) If the autopilot is engaged, hold the control wheel firmly and disengage the autopilot.

(5) If an unusual roll response or uncommanded control movement is observed, reduce the angle-of-attack by increasing airspeed or rolling wings level (if in a turn), and apply additional power, if needed.

(6) Avoid extending flaps during extended operation in icing conditions. Operation with flaps extended can result in a reduced wing angle-of-attack, with ice forming on the upper surface further aft on the wing than normal, possibly aft of the protected area.

(7) If the flaps are extended, do not retract them until the airframe is clear of ice.

(8) Report these weather conditions to ATC.

NOTE 10

An alternate means of providing this information in the AFM may be approved by the certifying agency.