U.S. Department
of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Certification of Part 23 Airplanes for Flight in Icing Conditions | **Date: 9/26/02** **Initiated By: ACE-100** | **AC No: 23.1419-2B** **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 23.1419-2A, Certification of Part 23 Airplanes for Flight in Icing Conditions, dated August 19, 1998, is canceled.

3. APPLICABILITY. The guidance provided here applies to the approval of airplane ice protection systems for operating in the icing environment defined by 14 CFR 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.

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 continue the current minimum ice protection requirements that have been found necessary for safe operation in icing conditions, to provide specific test requirements, to clarify the requirements for information that must be provided to the pilot, and to allow approval of equivalent components that have been previously tested and approved, and that have demonstrated satisfactory service if the installations are similar.

(2) 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 are also applicable, even without approval for flight in icing conditions.

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
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.

Date of Airplane Type Certification Application	***CAR/Title 14 CFR Status***	***Icing Certification Requirements***
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.
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.
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 & Guidance Library (RGL)

<www1.airweb.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/MainFrame?OpenFrameSet> 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
AC 20-117	Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing
AC 23-17A	Systems and Equipment Guide for Certification of Part 23 Airplanes
AC 23.143-1	Ice Contaminated Tailplane Stall (ICTS)
AC 23.629-1A	Means of Compliance with Section 23.629, Flutter
AC 23.1309-1C	Equipment, Systems, and Installations in Part 23 Airplanes

(1) 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

5. RELATED READING MATERIAL.

a. 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.

b. 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.

c. 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.

d. 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.

e. The FAA technical reports listed above can be obtained from the National Technical Information Service in Springfield, Virginia 22161.

f. Policy Statement ACE-01-23.1093(b), "Compliance with Induction System Icing Protection for Part 23 Airplanes," was published in the Federal Register on November 7, 2001, and provides the latest policy for engine induction ice protection for turbine powered part 23 airplanes.

g. The following SAE Documents can be ordered from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096:

Aerospace Recommended Practice (ARP) 4761, "Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment

Aerospace Information Report (AIR) 4367, "Aircraft Ice Detectors and Icing Rate Measuring Instruments"

AIR 5504 "Aircraft Inflight Icing Terminology"

h. The SAE and a working group for Task 11A of the FAA Inflight Aircraft Icing Plan are developing the following documents which will be available soon from the SAE:

Aerospace Recommended Practice (ARP) 5903, "Droplet Impingement and Ice Accretion Computer Codes"

ARP 5904, "Airborne Icing Tankers"

ARP 5905, "Calibration and Acceptance of Icing Wind Tunnels"

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), respectively. 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 continue the current minimum ice protection requirements that have been found necessary for safe operation in icing conditions, to provide specific test requirements, to clarify the requirements for information that must be provided to the pilot, and to allow approval of equivalent components that have been previously tested and approved, and that have demonstrated satisfactory service if the installations are similar.

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 ensure 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 by this applicability.

7. PLANNING. 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. It is imperative that the applicant obtains FAA concurrence prior to conducting certification tests. The certification plan should include the following basic information:

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

b. Ice protection systems description;

c. 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);

d. Analyses or tests performed to date;

e. Analyses or tests planned; and

f. Projected schedules of design, analyses, testing, and reporting.

8. DESIGN OBJECTIVES. The applicant should demonstrate by analyses, tests, or a combination of 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, not related to ice protection, exist. Appendix 1 lists various influence items that should be examined for their effect on safety when operating in icing conditions.

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

(4) Antennas and masts;

(5) Fuel tank vents;

(6) External tanks, including fuel tip tanks;

(7) Propellers;

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

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

(10) Forward fuselage nose cone and radome;

(11) Windshields;

(12) Landing gear;

(13) Retractable forward landing lights;

(14) Ram air turbines;

(15) Ice detection lights if required; and

(16) Any other external protuberance.

(a) 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. The 45-minute Hold Condition. The 45-minute hold criterion should be used in developing 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, paragraphs 12a and 18b. The applicant should determine the effect of the 45-minute hold in Continuous Maximum icing conditions.

(1) 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 represents 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.

(2) 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 artificial ice shapes to be used during dry air flight tests.

c. Flutter Analysis. A flutter investigation (see AC 23.629-1A) should be made to show that flutter characteristics are not adversely affected, taking into account the effects of mass distribution of ice accumulations. This investigation relates to unprotected surfaces and to protected surfaces where residual accumulations are allowed throughout the normal airspeed and altitude envelope; however, the effect of ice shapes on aerodynamic properties need not be considered for flutter analysis. Ice accretions due to failures of the ice protection system must also be addressed.

d. Power Sources. 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.

(1) 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.

(2) 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).

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

(b) Those that allow asymmetric ice accumulation.

(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 probability 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 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.

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

(d) 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. 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 protective coverage needed. Typically, 40-micron droplets for maximum continuous icing conditions and 50 micron drops for Intermittent Maximum icing conditions are used to establish the aft impingement limits. More specific information can be found in AC 20-73, Aircraft Ice Protection.

h. Induction Air System Protection. The induction air system for turbine engine airplanes is certificated for icing encounters in accordance with § 23.1093(b). 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 being modified.

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.

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

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

(2) Demonstrate 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;

(2) Dry air tests with predicted artificial ice shapes installed; and

(3) Flight tests in icing conditions, including simulated icing tests.

(a) 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. Often, it is more economical to verify specific analyses by ground tests where the design variables can be controlled to some extent. Flight tests in icing conditions, including flight behind 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. Pneumatic boots and all other anti-ice/deice equipment should operate throughout the entire flight envelope to demonstrate that no damage occurs. 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 Appendix C of part 25. 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. 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 in the AFM restrict the airplane to a lesser altitude range. Boots should be operated in flight at the minimum envelope temperature (-22 °F) of part 25, Appendix C, to demonstrate adequate inflation/deflation and throughout the entire flight envelope to demonstrate that no damage occurs. The appropriate speed and temperature (if any) limitation on activation of boots should be included in the AFM.

(a) 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.

(b) 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.

(c) 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. Consideration should be given to the potential for accumulation of liquid water in 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. 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 ensure that proper power is applied to the deicers. 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.

(a) The system operation should be checked throughout the full r.p.m. and propeller cyclic pitch range expected during icing flights. Any significant vibrations should be investigated. 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).

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

(3) Electric Windshield Anti-Ice. 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.

(a) An evaluation of the visibility, including distortion effects through the protected area, should be made in both day and night operations. In addition, 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. 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 aerodynamic 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. Natural icing flight tests should include a demonstration of proper stall warning 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 Anti/Deice Systems. Dry air testing should include evaluation of fluid flow paths to determine that adequate and uniform fluid distribution over the protected surfaces is achieved. 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. An accessible shutoff should be provided in systems using flammable fluids. 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 anti-ice systems should be tested to demonstrate that it does not become opaque at low temperature.

(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 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 ensure there is no engine cowl delamination.

(9) Ice Detection Light(s). Ice detection lights may be necessary if operations are dependent upon observing ice accumulations at night (§ 23.1419(d)). Ice detection 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 Artificial Ice Shapes. The installation of artificial 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 artificial 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. Dry air tests with artificial 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 artificial ice shapes prior to full span ice shape tests.

(1) The shape and texture of artificial ice shapes should be developed and substantiated using methods found acceptable to the FAA. Common practices include: use of computer codes, flight in measured natural icing conditions, icing wind tunnel tests, and flight in a controlled simulated icing cloud (for example: behind an airborne icing tanker). 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.

(2) Considerations should be given to the type of ice protection systems (for example: mechanical, fluid, thermal, or hybrid) to the most adverse ice conditions (shape or shapes, texture, location, and thickness) for the relevant aerodynamic characteristics for the following, where appropriate: delayed turn on; intercycle conditions; failure conditions; and residual ice. See Paragraph 11d.

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

(4) 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 the loss of engine power or thrust resulting from the applicable operating mode of the ice protection system.

(5) 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 bases before Amendment 23-43, Subpart B requirements are used as guidelines. For certification bases at Amendment 23-43 and higher, several Subpart B requirements also apply in icing conditions. This is addressed in paragraph 11.d. The results of these tests may be used in preparing specific AFM operating procedures and limitations for flight in icing conditions.

c. Flight Tests in Icing Conditions. Flight tests in measured natural icing and the use of simulated icing tools such as 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 artificial 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) 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 anemometer based instrument, calibrated drum, or other equivalent 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.

Note 1: The FAA Aircraft Icing Handbook, DOT/FAA/CT-88/8, defines median volumetric diameter the same as mean effective diameter, the difference being the former is measured while the latter is calculated assuming a drop size distribution.

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

(2) Simulated Icing. Testing in simulated 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 limited volume of the simulated icing environment, testing is usually limited 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.

- A simulated 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. Simulated icing clouds should be measured to ascertain that they contain the required cloud metrics (droplet sizes, liquid water content, temperature, and so forth) and accretions from these clouds can be used to show compliance with icing criteria. For those components where small droplet sizes are critical, simulated icing tests should be evaluated to ensure the conditions of concern are accurately simulated.

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

(a) 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.

(b) 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.

(c) Ice protection system tolerances on the production airplane, such as boot operating pressure, must be accounted for.

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

(e) Spray times can be adjusted for part 25, Appendix C cloud lengths. 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.

(f) An outboard 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. 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 (Items 25f and 25g(1)) provides additional information that would be useful when establishing a natural icing flight test program. 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.

- 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.

- During natural icing flight tests, ice accumulation on unprotected areas should be observed and documented. Remotely located cameras either on the test airplane or on a chase airplane have 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 analysis of ice accretions. 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.

- Sufficient data should be taken to allow correlation with dry air tests using artificial 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. For certification bases at Amendment 23-43 or higher, refer to Paragraph 11.d. for performance, stability, control and maneuverability requirements.

- 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.

- A delayed ice accumulation event of 30 seconds to 2 minutes has been used in these tests to simulate the flight crew's failure to recognize an icing condition. 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. Handling qualities should remain acceptable to the test pilot and the airplane should be capable of operating safely.

- All systems and components of the basic airplane should continue to function as intended when operating in an icing environment. Some considerations are:

(a) Engine and equipment such as generator under maximum ice protection load cooling should be monitored during icing tests and be found acceptable for this operation.

(b) Engine alternate induction air sources should remain functional in an icing environment.

(c) Fuel system venting should not be affected by ice accumulation.

(d) 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.

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

(f) With pre-activation, intercycle, or residual ice accumulations on the airplane, acceptable stall warning (aerodynamic or artificial) and stall protection system, if installed, should be provided. The stall warning should meet the requirements of § 23.207(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 2: This test and any handling qualities tests in natural icing should be accomplished in VFR conditions for safety.

(g) Ice detection cues that the pilot relies on for timely operation of ice protection equipment should be evaluated in anticipated flight attitudes.

(h) Ice detection 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.

(i) Primary and secondary flight control surfaces should remain operational after exposure to icing conditions. Demonstrate that aerodynamic balance surfaces are not subject to icing throughout the airplane's operating envelope (weight, center of gravity, 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.

(j) Ice accretions forward of pitot probes and static sources, such as accretions on radomes or other probes, should not affect the position error of the aircraft's production air data system.

(k) 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."

(l) 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, simulated 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 program per recommended maintenance procedures.

d. Performance and Handling Qualities – § 23.1419 at Amendment 23-14 or earlier. Airplane performance and handling qualities are degraded by ice accumulations in various ways depending upon type, shape, size, and location of these accumulations. Because of these variations in degradation, it is difficult to establish a standard method of demonstrating such degradations. However, certain minimum tests, as suggested below, should be used to demonstrate that the airplane does not have unsafe features or characteristics that prevent it from being capable of operating safely in part 25, Appendix C, icing envelope. If numerous unprotected areas exist, the weight and center of gravity effects of the ice formations should also be evaluated.

- The FAA and the Joint Aviation Authorities (JAA) are harmonizing the performance and handling qualities of part 25. The Aviation Rulemaking Advisory Committee (ARAC) Flight Test Harmonization Working Group will complete the harmonization project to standardize performance, handling requirements, and additional guidance material for certification of part 25/Joint Aviation Requirements 25 (JAR 25) airplanes to safely operate in the icing conditions of Appendix C. These performance and handling qualities issues will be considered for part 23 requirements and guidance information (future rulemaking and ACs that are being publicized by the ARAC) where appropriate.

(1) Performance. For normal, utility, and acrobatic category airplanes, performance losses are normally demonstrated in icing conditions only for the all engines operating condition. For commuter category airplanes, however, which have takeoff and landing weight limitations based on one engine inoperative climb performance, testing for one engine inoperative performance loss is appropriate. Climb performance losses should be established either by flight tests or by a conservative analysis acceptable to the FAA certifying office. Artificial ice shapes used for performance evaluation should be those critical shapes as found under the conditions in the icing envelope of part 25, Appendix C, and determined for the critical operating conditions under which such performance is expected. The following performance loss determinations are normally considered minimum:

(a) Section 23.65, Climb: All engines operating. Climb performance losses due to ice formation for the configuration defined in § 23.65 are normally not appropriate below 400 feet since the airplane should not depart with ice on the airplane. Takeoff climb performance should be determined considering any losses associated with operating anti-ice/deice equipment since that equipment could be utilized for takeoff into an icing environment. Ice accretion during takeoff needs to be accounted for on airplanes that turn off the airframe ice protection to minimize bleed/power extractions. It should be assumed no flightcrew action to activate the ice protection will occur until at least 400 feet above ground level, or higher if an AFM procedure allows.

(b) Section 23.67(b) and (c), Climb: one engine inoperative. Climb performance losses should consider related power extractions, additional icing drag, and any required changes to operational climb speeds for at least the following:

1. One engine inoperative takeoffs to 400 feet are conducted without ice, above 400 feet ice accretion should be considered;

2. Climb with one engine inoperative in the en route configuration; and

3. Climb with one engine inoperative in the approach configuration.

- Ice accretion during takeoff needs to be accounted for on airplanes that turn off the airframe ice protection to minimize bleed/power extractions. It should be assumed no flightcrew action to activate the ice protection will occur until at least 400 feet above ground level, or higher if an AFM procedure allows.

(c) Section 23.75, Landing. The landing performance should be calculated or measured considering the effects of critical ice accumulations upon landing. Minimum speeds, landing configuration, and landing distance (based on increased stall speeds) degradation should be established.

(d) Section 23.77, Balked landing. For normal, utility, and acrobatic category airplanes, the airplane with ice accumulations and all icing systems operational (for example, bleed air systems) should meet the all engine minimum climb requirements on a 32 °F day at sea level as is required for the non-iced (icing systems off) airplane under § 23.77(a) at sea level on a standard day. For commuter category airplanes, climb performance losses should be measured and the maximum weight adjusted, if required.

(e) Propeller Efficiency. 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 Supercooled Large Droplet (SLD) conditions have shown ice accretions on the full span of the propeller blades. Although this condition was outside of 14 CFR part 25, Appendix C, there is a possibility that this may occur within some portions of 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.

(2) Handling Qualities. Handling qualities evaluation should include actual flight investigation of at least the following with the artificial ice shapes:

(a) Stall characteristics, stall warning and stall speeds;

(b) Trim;

(c) Lateral directional stability/control;

(d) Longitudinal stability/control;

(e) V_{MC};

(f) Landing approach speeds, maneuvering and landing characteristics; and

(g) Appropriate high speed characteristics up to $V_{MO}/M_{MO}/V_{NE}$, or 250 knots continuous airspeed, whichever is less.

(h) Stall characteristics and adequacy of stall warning 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 angle of attack. For these designs the controllability of the airplane at autopilot disconnect should be evaluated.

1. The stall warning should meet the requirements of § 23.207(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.

(i) 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).

(3) 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 center-of-gravity 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, 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 the new AC 23.143-1, Ice Contaminated Tailplane Stall (ICTS).

e. Performance and Handling Qualities – § 23.1419 at Amendment 23-43 or later. In addition to the guidance of Paragraph 11.d., 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. This means that the aircraft must comply with the applicable requirements in § 23.45 through § 23.157 and § 23.171 through § 23.181, with the exception discussed in Paragraph 11.e.(1).

(1) Performance. 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. Multi-engine airplanes under 6,000 pounds are required to meet § 23.67(a)(1) in icing conditions and therefore would not be subject to the 61-knot stall speed requirement. 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 single engine 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.

- 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 is 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 much more fatal accidents in icing conditions attributed to the latter.

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

(b) The airplane with critical ice accretions complies with stall warning requirements of § 23.207.

1. For aircraft with artificial stall warning systems, item (b) though, would require a bias in the stall warning schedules to maintain adequate stall warning margins.

2. For aircraft without artificial stall warning systems, item (b) may require one 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.

(c) The AFM performance data in icing conditions reflects the higher stall and operating speeds.

(d) 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.

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

(f) 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.

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

(h) 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).

(i) 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.

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

- Critical ice accretions include 45-minute shapes on unprotected surfaces; and pre-activation, intercycle and residual shapes/roughness on protected surfaces.

- The above approach represents only the minimum consideration, other issues may have to be considered depending on the aircraft design.

- When analyzing climb performance data to determine if Subpart B climb performance requirements are met, it can be assumed that ice accretions will not be present on the airframe at outside air temperatures (OAT) at and above +5 °C. The minimum climb requirements on a standard day at sea level as required on the non-iced (icing systems off) are to be applied to the iced airplane at +5 °C OAT at sea level.

(2) Handling Qualities. The handling qualities test matrix with ice shapes can be reduced, with Administrator concurrence, from the no-ice basic test matrix to critical flight conditions and configurations as determined by the no-ice basic certification testing. Controllability, maneuverability and stability can be degraded from the non-iced airplane but must still meet Subpart B pass/fail criteria.

(3) Ice Contaminated Tailplane Stall (ICTS). Maximum landing flaps may be limited to the "takeoff/approach" configuration due to ice contaminated tailplane stall (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.

f. 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 analysis or 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.

g. 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" be 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.

- 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 can detect and recognize the specified ice accumulation thickness. The following test criteria have been accepted for previous flight test programs:

(1) 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.

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

- 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 3: 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.

- 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. Recent part 23 applicants 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.

h. 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.

12. 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°").

(3) Speed restrictions (for example, "Maximum Speed for Boot Operation—175 KIAS").

(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. 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 or maximum altitude for boot operation).

(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 Kinds of Operation Equipment List (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 sustained operations in icing conditions.

(i) For severe icing 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 2 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.

(j) 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 severe 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 ___ 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 ___ r.p.m. higher to ensure 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 can 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 FAR 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.

S/

James Jackson
Acting Manager, Small Airplane Directorate
Aircraft Certification Service

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APPENDIX 1. 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.

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 °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.

Influence	***Consideration***
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. **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.

Influence	*Consideration*
4. Equipment, Systems, Function, and Installation	**a.** Conduct a study as discussed in Paragraph 9e (failure analysis) of this AC to ensure 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. **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 ensure that adequate power is available to the ice protection equipment and other necessary equipment for flight in icing conditions.
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 that 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.

Influence	***Consideration***
	c. The Maintenance Manual should contain approved cleaning, surface treatment, and repair procedures for leading edge ice protection systems.
	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 3 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^{o} exist when operating electrical ice protection equipment, provide placarding.
	Note: If the ice protection system causes greater than a 10^{o} 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. Policy to address this is being added to AC 23-17A.

Influence	*Consideration*
10. Ice Detection Light(s)	**a.** Night flight evaluation of light coverage and glare produced by the wing ice detection 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).
	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).

Influence	***Consideration***
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. See Appendix 3 for guidance on airframe deicing systems. 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 Item 11.
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 2. AFM LIMITATIONS AND NORMAL PROCEDURES SECTIONS

1. LIMITATIONS SECTION. In the case of severe icing, the following text and warning information should be used as 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 1: 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.

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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 2: 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.

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

Note 3: This supersedes any relief provided by the Master Minimum Equipment List (MMEL).

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2. NORMAL PROCEDURES SECTION. In the case of severe icing, the following text and warning information should be used as in the Normal Procedures Section of the AFM:

a. "**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:

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

(2) 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.

(3) 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.

(4) Exit the icing area immediately by changing altitude or course; and

(5) Report these weather conditions to Air Traffic Control."

b. "**Caution.** Severe icing comprises environmental conditions outside of those for which the airplane is certificated. 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."

c. "**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 (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."

d. “**The Following May Be Used to Identify Possible Freezing Rain/Freezing Drizzle Conditions:**

(1) Visible rain at temperatures below +5 °Celsius (outside air temperature (OAT)).

(2) Droplets that splash or splatter on impact at temperatures below +5 °Celsius OAT.”

e. “**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 severe icing may form at temperatures as cold as –18 °Celsius, 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 severe 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 Air Traffic Control."

Note 4: Alternate means of providing this information in the AFM may be approved by the certifying agency.

APPENDIX 3. 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 follows:

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, a Supplemental Type Certificate (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.

c. For replacement parts on an aircraft whose certification basis is § 23.1419, Amendment 23-14 or higher, or those aircraft where the applicant wants to add "flight in icing conditions" operational approval, 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 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 additional failure modes that could prevent continued safe flight and landing. Comparative tests with the original parts and the replacement parts will be required if the applicant does not have access to the original certification data. 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 Small Airplane Directorate 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.