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

Advisory Circular

Subject: CERTIFICATION OF PART 23 AIRPLANES FOR FLIGHT IN ICING CONDITIONS

Date: June 28, 2007
Initiated by: ACE-100
AC No: 23.1419-2D
Change: 1

1. PURPOSE. This change revises existing material in two sentences. The change number and the date of the changed material are shown at the top of each changed page. Vertical bars in the margin indicate the changed material. Pages having no changes retain the same heading information.

2. PRINCIPAL CHANGES.

Paragraphs 12c(3)(b)2 and 12c(3)(c) are revised.

PAGE CONTROL CHART

Remove Pages	Dated	Insert Pages	Dated
27-28		27-28	

S/

Kim Smith
Manager, Small Airplane Directorate
Aircraft Certification Service.

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of Transportation
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Advisory Circular

Subject: CERTIFICATION OF PART 23 AIRPLANES FOR FLIGHT IN ICING CONDITIONS

Date: April 19, 2007
Initiated by: ACE-100

AC No: 23.1419-2D

FOREWORD

This advisory circular (AC) sets forth an acceptable means of showing compliance with Title 14 Code of Federal Regulations (14 CFR), part 23, for the approval of airplane ice protection systems for operating in the icing environment defined by part 25, Appendix C.

S/Charles L. Smalley

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Aircraft Certification Service.

CONTENTS

TABLES

1. What is the purpose of this AC? 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. Who does this AC apply to? The guidance provided in this document is directed to airplane manufacturers, modifiers, foreign regulatory authorities, and FAA small airplane type certification engineers, and their designees. This AC applies to airplane ice protection systems in any normal, utility, acrobatic or commuter category part 23 airplane.

3. Cancellation. AC 23.1419-2C, Certification of Part 23 Airplanes for Flight in Icing Conditions, dated July 21, 2004, and AC 23.143-1, Ice Contaminated Tailplane Stall (ICTS), dated December 20, 2001, are canceled. In addition, all policy related to the certification of ice protection systems on part 23 airplanes, issued prior to this AC, and is superseded by this AC.

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

5. 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 or earlier, and through part 23 at amendment 23-13, the application of these sections may be limited to the equipment being used for ice protection. Some systems that were previously approved on the airplane may need to be modified to improve their reliability when those systems are utilized as part of that airplane's icing approval.

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

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

(3) In addition to the previously mentioned requirements (§§ 23.929, 23.1309, and 23.1419), other sections should be applied depending upon the ice protection system design and the original certification basis of the airplane. Refer to AC 20-73A, Appendix C, Table C-2. Many of the requirements in Table C-2 of AC 20-73A are also applicable, even without approval for flight in icing conditions. Further guidance on establishing a certification basis for flight in icing approval can be found in Appendix 2 of this AC.

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

AC 20-73A	"Aircraft Ice Protection," August 16, 2006.
AC 20-115B	"Radio Technical Commission for Aeronautic, Inc. Document RTCA/DO-178B," January 11, 1993.
AC 20-117	"Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing," December 3, 1982.
AC 20-147	"Turbojet, Turboprop, and Turbofan Engine Induction System Icing and Ice Ingestion," February 2, 2004.
AC 21-16E	"RTCA Document DO-160E, Environmental conditions and Test Procedures for Airborne Equipment," December 20, 2005.
AC 21-40	"Application Guide for Obtaining a Supplemental Type Certification," May 6, 1998.
AC 21.101-1	"Change 1, Establishing the Certification Basis of Changed Aeronautical Products," April 28, 2003.
AC 23-16A	"Powerplant Guide for Certification of Part 23 Airplanes and Airships," February 23, 2004.
AC 23-17B	"Systems and Equipment Guide for Certification of Part 23 Airplanes," February 23, 2004.
AC 23.629-1B	"Means of Compliance with Title 14 CFR, Part 23, § 23.629, Flutter," September 28, 2004.

AC 23.1309-1C	“Equipment, Systems, and Installations in Part 23 Airplanes,” March 23, March 12, 1999.
AC 91-74	“Pilot Guide Flight in Icing Conditions,” December 12, 2002.
AC 120-58	“Pilot Guide Large Aircraft Ground Deicing,” September 30, 1992.
AC 120-60B	“Ground Deicing and Anti-icing Program,” December 20, 2004.
AC 135-16	Ground Deicing & Anti-icing Training & Checking,” December 12, 1994.
AC 135-17	Pilot Guide-Small Aircraft Ground Deicing (pocket),” December 14, 1994.

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

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

6. Related Reading Material.

a. FAA Orders.

FAA Order 8110.4C, “Type Certification,” October 26, 2005.

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

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

http://aar400.tc.faa.gov/Programs/FlightSafety/icing/eaihbk.htm

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

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

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

(5) FAA Technical Report DOT/FAA/CT-TN86/11, "Fluid Ice Protection Systems," July 1986.

(6) National Aeronautics and Space Administration (NASA)/TP—2000-209908, "NASA/FAA Tailplane Icing Program: Flight Test Report" (March 2000), provides reference information on Ice Contaminated Tailplane Stall (ICTS). Assumptions, ice shapes, and certain other data are not necessarily representative or appropriate for use with other projects. The above report and other reference material on ICTS are also available at the NASA Glenn Research Center Icing Branch website: icebox.grc.nasa.gov.

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

TSO-C16	"Air-Speed Tubes (Electrically Heated)," September 1, 1948.
TSO-C16a	"Electrically Heated Pitot and Pitot-Static Tubes," October 6, 2006.
TSO-C54	"Stall Warning Instruments," October 15, 1961.

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

ARP4761	"Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment," December 1, 1996.
AIR4367	"Aircraft Ice Detectors and Icing Rate Measuring Instruments, "April 1, 1995.

AIR5504 “Aircraft Inflight Icing Terminology,” September 17, 2002.

AIR1168/V1 “Ice, Rain, Fog, and Frost Protection,” July 1, 1989, part of “Applied Thermodynamics Manual,” September 1, 1992.

ARP4087 “Wing Inspection Lights – Design Criteria,” September 12, 2006.

AS393 “Airspeed Tubes Electrically Heated,” August 14, 2002.

AS8006 “Minimum Performance Standard for Pitot and Pitot Static Tubes, “April 28, 1988.

AS403 “Stall Warning Instrument,” July 15, 1958.

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

ARP5903 “Droplet Impingement and Ice Accretion Computer Codes, October 16, 2003.

ARP5904 “Airborne Icing Tankers,” October 21, 2002.

ARP5905 “Calibration and Acceptance of Icing Wind Tunnels,” September 18, 2003.

e. Miscellaneous Documents.

(1) British Specification (BS) 2G-135, “Specification for Electrically-Heated Pitot and Pitotstatic Pressure Heads,” 1967.

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

7. Background.

AC 20-73A contains a detailed history of ice protection regulations for part 23 airplanes.

8. Planning.

a. Flight in Icing Approval. The applicant should submit a certification plan in accordance with FAA Order 8110.4C and AC 20-73A. The certification plan should describe all of the applicant's efforts intended to lead to certification. This plan should identify, by item to be certificated, the certification methods that the applicant intends to use. It should provide for a certification checklist. Regarding § 23.1419, it should clearly identify analyses and tests, or references to similarity of designs that the applicant intends for certification of the ice protection system. These methods of showing compliance should be agreed upon between the applicant and the FAA early in the type certification program. Detailed guidance for STCs or amended TCs on part 23 airplanes approved for flight in icing can be found in Appendix 3 of this AC. It is imperative that the applicant obtains FAA concurrence prior to conducting certification tests.

b. Installations without Flight in Icing Approval. There may be times when applicants may want to certificate an ice protection system installation but do not want to obtain flight in icing approval. In the past these systems have been called "non-hazard" installations. This means that the aircraft is prohibited from flight in icing conditions but there is some ice protection to facilitate an exit from an inadvertent icing encounter. Guidance for the approval of these types of ice protection systems can be found in Appendix 4 of this AC.

c. Replacement Parts for Airframe Ice Protection Systems. The requirements leading to approval of replacement airframe deicing systems or airframe thermal deicing or anti-icing systems are detailed in Appendix 5 of this AC.

9. Design Objectives. The applicant must demonstrate by analyses and tests that the airplane is capable of safely operating throughout the icing envelope of part 25, Appendix C. The envelope can be reduced for airplanes certificated for operation where systems or performance limitations (e.g., altitude), not related to ice protection, exist.

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

a. Areas and Components to be Protected. The applicant should examine the areas listed in AC 20-73A to determine the degree of protection required.

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

b. Ice Accretion Analyses.

(1) Impingement Limit Analyses. The applicant should prepare a drop impingement and water catch analysis of the wing, horizontal and vertical stabilizers, propellers, and any other leading edges or protuberances such as antennas that may require protection. This analysis should consider the various airplane operational configurations and associated angles of attack. This analysis is needed to establish the upper and lower aft droplet impingement limits that can then be used to establish the aft ice formation limit and the extent of the protection surface coverage needed. The applicant should consult AC 20-73A, "Aircraft Ice Protection" for more detailed information.

(2) Critical Ice Accretions. The critical ice accretions for which operational characteristics are to be evaluated should be determined for each flight phase as discussed in paragraph 13.b. of this AC. The parameters to be considered are the flight conditions (e.g., airplane configuration, airspeed, angle of attack, altitude) and the icing conditions of part 25, Appendix C (temperature, liquid water content, mean effective drop diameter). The applicant should substantiate the critical mean effective drop diameter, Liquid Water Content (LWC), and temperature that result in the formation of an ice accretion that is critical to the airplane's operational characteristics. For deicing systems, intercycle, residual, and runback ice accretions should be considered.

(3) The 45-Minute Hold Condition. The 45-minute hold criterion should be evaluated when determining critical ice shapes for which the operational characteristics of the overall airplane are to be analyzed. See AC 20-73A for more information.

(a) A mean effective droplet diameter of 22 microns and a liquid water content of 0.5 gm/m^3 with no horizontal extent correction are normally used for this analysis; however, the applicant should substantiate the specific values used, including temperature, which represent the critical conditions for the airplane's performance and handling qualities. Critical flight conditions should be considered such as weight and speed for critical angle of attack, and airspeed and altitude for maximum water catch. For example, minimum holding speed should be evaluated, but a higher airspeed that the airplane may operate at may be more critical because of the lower angle of attack and higher water catch.

(b) The critical ice shapes derived from this analysis should be compared to critical shapes derived from other analyses (climb, cruise, and descent, approach) to establish the most critical simulated ice shapes to be used during dry air flight tests.

c. Airframe.

(1) Structural Analyses.

(a) The structural analyses should include analyses which establish that critical ice build-ups on antennas, masts, and other components attached externally to the airplane do not result in hazards. Flight tests in simulated or natural icing conditions or with simulated ice shapes may be used to substantiate the structural analyses; however similarity to previous approved designs is a common method of compliance.

(b) Determine that the temperature gradient produced on heated windshields does not adversely affect windshield structural integrity.

(2) Flutter Analyses. AC 23.629-1B, "Means of Compliance with Title 14 CFR, Part 23, § 23.629, Flutter," provides guidance for showing compliance with § 23.629. The flutter analyses should reflect any mass accumulations on unprotected and protected surfaces from exposure to part 25, Appendix C icing conditions, including any accretions that could develop on control surfaces. The 45-minute hold should also be considered. Ice accretions due to failure of the ice protection system should also be addressed.

d. Power Sources.

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

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

(a) Two-Engine Airplanes require two sources in accordance with § 23.1309(c). All power sources that affect engine or engine ice protection systems for multi-engine airplanes must comply with the engine isolation requirements of § 23.903(c).

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

(c) Load Shedding. Determine if load shedding can be accomplished after a partial failure condition. If applicable, a load shedding sequence should be provided so the pilot may assure that adequate power is available to the ice protection equipment and other necessary equipment for flight in icing conditions.

(3) Electromagnetic Compatibility. The effect, if any, of ice protection system operation on other airplane systems must be determined to show compliance to § 23.1309(a).

(a) Designs should minimize Magnetic Direction Indicator (MDI) deviations. If the ice protection system causes greater than an l0-degree deviation, then the placard requirement of § 23.1327 (amendment 23-20) should be applied in lieu of previous requirements. Refer to AC 23-17B for guidance on using a magnetic compass as a mitigating factor in a system safety assessment for cockpit heading display.

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 an ice shape to accrete in size greater than design levels , to accrete asymmetrically, or accrete in areas that were normally protected; or

(b) System failures such as loss of pneumatic boot vacuum, overheat of a thermal system, or leak in a hot air bleed air line.

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

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

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

(3) Power Source Failure. Assure that no probable failure or malfunction of any power source (electrical, fluid, bleed air, pneumatic, and so forth) will impair the ability of the remaining source(s) to supply adequate power to systems essential to safe operation during icing flight.

(4) Failure Annunciations. Warning information must be provided to alert the crew to unsafe system operating conditions and to enable them to take appropriate corrective action in accordance with § 23.1309(b)(3).

(a) The requirement for warning information in § 23.1309(b)(3) is dependent on the severity of the failure, not dependent on the probability of the failure.

(b) A means to indicate to the crew that the ice protection system is receiving adequate electrical power, bleed air pressure, vacuum, or fluid pump output, and so forth, as appropriate, and it is functioning normally. Annunciation would not be required for obvious, inherent failures, such as failure of a fluid windshield system.

(c) Means to indicate that the pneumatic deicing boot system is receiving adequate pressure is required in accordance with § 23.1416.

1. The boots should be shown to operate at the pressure threshold of the annunciation.

2. Annunciation when the boots are receiving adequate pressure has been used in previous certifications. For boots that cycle automatically, annunciation lights may be provided when the boots are not receiving adequate pressure when commanded, in lieu of lights that illuminate during each inflation cycle. This promotes the dark cockpit concept, and it's easier to detect the presence of a light rather than the absence of a light.

3. Annunciations of failures should be consistent with § 23.1309(b)(3) and § 23.1322.

(5) Circuit and Protective Devices.

(a) Determine that the design incorporates electrical overload protection that opens regardless of operating control position.

(b) Verify that the design is such that no protective device is protecting more than one circuit essential to continued safe flight (for example, pitot heat and stall warning transducer heat are considered separate essential circuits and should be provided separate protection).

(c) Ice protection monitor and warning circuits should be considered separate from control circuits and each should provide individual circuit protection.

(d) 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) Windshield Heat Systems. There are requirements in § 23.775(g). A probable single failure of a transparency heating system should not adversely affect the integrity of the airplane cabin or create a potential danger of fire.

f. Similarity Analyses.

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

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

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

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

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

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

g. Induction Air System Protection. The induction air system for airplanes is certificated for ice protection in accordance with § 23.1093. These requirements are for all airplanes even those not certificated for flight in icing conditions. Thus ice protection systems installed on previously type certificated airplanes to protect the engine induction air system should be adequate and need not be re-examined, unless the inlet is being modified, the original certification basis is inadequate, or an in-flight AFM limitation was used to comply with the falling and blowing snow regulation. When natural icing flight tests are conducted to show compliance to § 23.1419, engine operation, engine ice protection system procedures, and engine inlet ice accretion should be evaluated if flight tests in measured, natural icing conditions were not previously accomplished on the engine/inlet configuration. See AC 23-16A and AC 20-147 for more information.

(1) Engine Ice Protection – Flight Idle. Turbojet engine ice protection should be automatic once the engine ice protection system is activated. The engine must be protected from ice with the throttle against the idle stop, which may require an automatic increase in thrust when the engine ice protection system is activated.

(2) Delay of Icing Approval. Manufacturers have chosen to delay showing compliance to § 23.1419, and therefore receive flight in icing approval, until after type certification. The main reason is usually not to delay obtaining type certification of the basic airplane for marketing or contractual reasons. The airplane is prohibited from flight in known or forecast icing conditions until a finding of compliance to § 23.1419 is made. However, the airplane may inadvertently encounter icing conditions, and the engines should operate without a sustained loss of power and there should not be a need to shutdown an engine in flight. Compliance to § 23.1093 is required for basic type certification, and the engine as a result will have ice protection capability. An example would be an ice protection system for the engine inlet. Airframe ice protection systems can be considered part of the engine ice protection system if the possibility exists of ice accreting on the airframe in an inadvertent encounter and shedding into the engines. An example is ice accreting on the inboard wing of airplanes with aft fuselage mounted engines. Applicants who delay icing certification until after type certification must show compliance to § 23.901(d) by one of the following methods:

(a) A trajectory analysis, supplemented by flight testing in measured natural icing or flight testing behind an airborne icing tanker, as described in paragraph 14 of this AC, to show the amount of ice that accretes in five minutes at critical part 25, Appendix C continuous maximum conditions does not shed into any engine; or

(b) Analysis which shows the mass of ice that accretes in five minutes in critical part 25, Appendix C continuous maximum conditions is less than the mass of ice shown to be ingested by the engine for compliance to § 33.77. This analysis should assume:

1. The spanwise length of the ice shape is the maximum length that can be ingested without striking the inlet lip or engine spinner.

2. The ice shape on the wing leading edge does not break chordwise, i.e., the ice above and below the stagnation line should be considered.

3. In lieu of five minutes of ice accretion, credit can be used for operational ice protection systems, with the exception in paragraph (4). The most critical of the following should be used:

(aa) Two minutes representing delayed system activation;

(bb) Intercycle/residual ice for deicing systems for operating speeds above 160 Knots Calibrated Airspeed (KCAS). Below 160 KCAS, empirical data should substantiate that deicing systems shed ice at each cycle.

(cc) Runback ice in 5 minutes for thermal systems.

4. Flight testing in measured natural icing or flight testing behind an airborne icing tanker would be required for novel ice protection systems, such as the graphite thermal deicing system.

h. Propeller Ice Protection.

(1) An analysis should be provided for part 25, Appendix C icing conditions that:

(a) Substantiates the chordwise and spanwise ice protection coverage

(b) Substantiates the ice protection system power density or fluid rate

(c) Calculates intercycle ice accretions and resulting efficiency losses.

(2) See AC 20-73A for additional guidance on propeller analysis.

i. Pitot Probe Ice Protection.

(1) Conditions Within the Part 25, Appendix C Icing Envelope.

(a) Airplanes Incorporating Airspeed Systems With TSO C16 Authorizations. Compliance to the TSO-C16 qualification standard for electrically heated pitot probes is not sufficient by itself in demonstrating compliance to the installation requirements of § 23.1309(b)(1) and § 23.1419. Section 23.1309(b)(1) requires that the system must perform its intended function under any foreseeable operating condition. Section 23.1419 requires that an airplane certificated for flight in icing must be able to safely operate in part 25, Appendix C icing conditions. It is unlikely that the conditions of part 25, Appendix C that are critical to the air data system equipment will be encountered during flight tests. Although functioning of pitot probes are evaluated in natural icing conditions during certification test programs, there is no requirement to flight test at the part 25, Appendix C icing limits because the low probability of finding those conditions imposes a burden. TSO C16, Air-speed tubes (electrically heated) require compliance to the performance specifications of SAE Aeronautical Standard AS393. This standard and AS393A (out-of-date), are non-current. SAE AS393A includes a test to demonstrate deicing and anti-icing capability, but only temperature and airspeed are specified. Liquid water content is not specified but it influences heat requirements. Consequently certification programs should supplement the icing flight tests with an icing tunnel test and/or airborne icing tanker test data, as necessary, or reference testing that has been accomplished by the pitot probe manufacturer, or show similarity to a similar, icing approved airplane with no negative service history. In-service experience during severe atmospheric conditions has shown that pitot tubes qualified to the older standards have resulted in airspeed fluctuations and even loss of indicated airspeed. As these components should perform as intended in all expected atmospheric environments, it is reasonable to require that they be qualified to the Continuous and intermittent maximum icing conditions defined in part 25, Appendix C.

(b) Airplanes Incorporating Airspeed Systems With TSO C16a Authorizations. TSO C16a, Electrically heated pitot and pitot-static tubes, references SAE Aeronautical Standard AS8006 and supplements the icing requirements with specific part 25, Appendix C icing conditions and specific liquid water content tests from British Specification (BS) 2G.135 "Specification for Electrically-Heated Pitot and Pitot-Static Pressure Heads".

Analysis, icing tunnel tests, or flight tests dedicated to probe heat evaluation, are not required. See paragraph 12.c.(3) for air data system evaluations that are accomplished during a natural icing flight test program.

(2) Conditions Outside of the Part 25, Appendix C Icing Envelope. Although part 25, Appendix C only considers the liquid water content of icing conditions, recent cloud characterization research has indicated that approximately 40 percent of icing condition events consist of liquid water drops and ice crystals (mixed phase icing conditions). The operating rules do not prohibit operations in mixed phase and ice crystal icing conditions. The incident history indicates that flightcrews have experienced temporary loss of or misleading airspeed indications in icing. It is likely that some of these incidents were due to ice crystals. Pitot tubes are mounted such that they typically are high efficiency collectors of ice crystals. Encountering high concentrations of ice crystals can lead to blocked pitot probes as the energy required to melt the ice crystals can exceed Appendix C design requirements.. More recent standards indicate that these components should be qualified for operation in atmospheric conditions beyond the environment described by part 25, Appendix C, specifically during ice crystal and mixed phase icing conditions. Recently, some aircraft manufacturers and foreign certification authorities have required pitot and pitot-static probes to be tested in ice crystal and mixed phase icing conditions along with supercooled liquid water conditions. As a result, some pitot tube manufacturers now use the icing environment of British Specification (BS) 2G.135 “Specification for Electrically-Heated Pitot and Pitot-Static Pressure Heads,” as modified by the maximum rate that the icing tunnel facility can produce ice crystal, in addition to the requirements of the TSO. Even though the part 23 and part 25 regulations only address liquid water and testing in the mixed phase or ice crystal conditions are not required for FAA approval, it is good design practice to assure the pitot heat is sufficient for the ice crystal and mixed phase conditions of BS 2G.135.

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

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

(2) Conditions Outside of the Part 25, Appendix C Icing Envelope. The same comments from paragraph 10i(2) above apply to stall warning ice protection systems.

k. Static Pressure Systems. 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. Where the port is thermally protected, a thermal evaluation should be conducted to demonstrate that the protection is adequate.

l. Ice Detection

(1) Regulation. Requirements for ice detection are in § 23.1419(d).

(a) A means must be identified or provided, and described in the AFM, for identifying ice accretion.

(b) Adequate lighting must be provided for ice detection at night.

1. An ice inspection light that illuminates a reference surface or a wing leading edge is normally provided.

2. A hand-held flashlight is not acceptable as ice detection light.

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

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

(b) Primary Flight Ice Detection System. A Primary FIDS (PFIDS) is considered the sole means used to determine when the IPS must be activated. The IPS may be automatically activated by the PFIDS or the PFIDS may provide a flight deck signal that will direct the crew to manually activate the IPS.

(c) Certification of FIDS. Installation of an ice detection system is considered a safety enhancement since the icing conditions may be identified or confirmed at an early stage and appropriate actions can be initiated in a timely manner. However, recent investigations have shown that previously certificated ice detection systems may not detect airframe and engine icing in some part 25, Appendix C conditions. It has been demonstrated in an icing wind tunnel that atmospheric moisture may fail to freeze on ice detector probes even though ice may be accreting on other airplane surfaces in low freezing fraction conditions. With the continuing development of ice detection systems and due to recent in-service incidents, the FAA has determined there is a need to define specific criteria to certify ice detection systems that are used as the sole means of determining when the ice protection systems are activated. See AC 20-73A.

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

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

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

(2) Fluid Capacity. The fluid capacity does not have to exceed the maximum endurance of the airplane but the minimum should be as follows in Table 1.

TABLE 1. FLUID CAPACITY

<table>
<tr><th>Airplane Type</th><th>Minimum Fluid Capacity is the greater of:</th></tr>
<tr><td>Turbojet powered airplanes</td><td rowspan="2">90 minutes or 15 percent of the maximum endurance based on the flow rate required in continuous maximum icing conditions</td></tr>
<tr><td>Turbopropeller airplanes with maximum operating altitude above 30,000 feet</td></tr>
<tr><td>Turbopropeller airplanes with maximum operating altitude 30,000 feet and below</td><td rowspan="2">150 minutes or 20 percent of the maximum endurance based on the flow rate required in continuous maximum icing conditions</td></tr>
<tr><td>Reciprocating engine powered airplanes</td></tr>
</table>

(3) Fluid Quantity.

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

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

(4) Fluid Characteristics.

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

(b) Certain fluids used in ice protection systems, such as the alcohol used in older propeller 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). An accessible shutoff should be provided in systems using flammable fluids.

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

(d) The effect of fluid compatibility with electrical contacts and with airframe components, particularly composite materials, should be evaluated. The applicant should 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).

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

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

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

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

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

11. Flight Test Planning. When operating any airplane in an icing environment, degradation in performance and flying qualities may be expected. The primary purposes for flight testing an airplane equipped for flight in icing conditions is to evaluate such degradation, determining that the flying qualities remain adequate, and that performance levels are acceptable for this flight environment. For airplanes with a certification basis of 23-43 or higher, § 23.1419(a) requires that an airplane comply with the performance, stability, controllability and maneuverability regulations of part 23, Subpart B. Flight testing in measured, natural icing conditions is required by § 23.1419(b) unless similarity is used as the method of compliance. In addition, unless similarity can be used, § 23.1419(b) requires at least tunnel testing, dry air testing, or airborne tanker testing.

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

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

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

(3) Verify the analyses conducted to show adequacy of the ice protection systems 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 for a typical part 23 airplane icing certification are generally conducted in three stages:

(1) Initial Dry Air Tests With Ice Protection Equipment Installed And Operating. Initial dry air tests are usually the first steps conducted to extend the basic airplane certification to evaluate the airplane with the ice protection system installed and operating. The initial dry air tests are conducted to verify that the ice protection system does not affect the flying qualities of the basic airplane in clear air. Dry air tests are used to: 1) verify proper ice protection system operation, 2) collect protected surface temperature data to validate thermal analysis, and 3) evaluate the effect of increased electrical and/or bleed demands on the engines and other installed systems.

(2) Dry Air Tests With Predicted Simulated Ice Shapes Installed. Dry air tests with predicted, simulated critical ice shapes installed are usually the second step for certification for flight in icing. Airplane performance and handling characteristics are evaluated with these simulated ice shapes.

(a) Simulated ice on unprotected areas are typically determined by analysis codes.

(b) Simulated ice on protected areas is typically determined by a combination of analysis and empirical data. Analyses are usually validated by ground tests such as icing tunnel tests where the design variables can be controlled to some extent, and the testing is more economical, versus icing flight tests.

c. Flight Test Safety. FAA Order 4040.26A "Aircraft Certification Service Flight Safety Program" should be consulted for flight test risk assessments and risk mitigations. Many ice shape test flights, and stall testing with ice accretions, are considered high risk. Many applicants have equipped their ice shape flight test airplane with a stall/spin chute.

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

12. 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. .Several commonly used ice protection system components are discussed below to illustrate typical flight test practices. Other types of equipment should be evaluated as their specific design dictates.

(1) Pneumatic Leading Edge Boots.

(a) Operation. Boot inflation rate and inflated boot shape are important parameters in ice accretion removal. Tests should demonstrate a rapid rise and decrease in operating pressures for effective ice removal. This pressure rise time, as well as the maximum operating pressure for each boot, should be evaluated throughout the altitude band of part 25, Appendix C—Mean Sea

Level (MSL) to 22,000 feet above MSL—unless performance constraints or aircraft limitations unrelated to the ice protection system in the AFM restrict the airplane to a lesser altitude range.

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

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

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

(2) Electric Propeller Boots.

(a) Dry Air Function Flight Test.

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

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

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

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

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

(3) Electric Windshield Anti-Ice.

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

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

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

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

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

(6) Pitot Tube. Section 23.1323 requires a heated pitot tube or an equivalent means of preventing malfunction due to icing for airplanes certificated for instrument flight rules or flight in icing conditions. Section 23.1326 requires a pitot tube heat indicating system if a flight instrument pitot heating system is installed to comply with § 23.1323.

(7) Fluid (Freezing Point Depressant) Systems.

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

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

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

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

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

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

(9) Ice Inspection Light(s). Ice inspection lights may be necessary if operations are dependent upon observing ice accumulations at night (§ 23.1419(d)). Ice inspection lights should be evaluated both in and out of clouds during night flight to determine that adequate illumination of the component of interest is available without excessive glare, reflections or other distractions to the flight crew. These tests may be conveniently accomplished both in and out of clouds during dry air tests. Use of a hand-held flashlight for ice detection is not acceptable. As described in § 23.1419(d), "The Airplane Flight Manual or other approved manual material must describe the means of determining ice formation and must contain information for the safe operation of the airplane in icing conditions." A primary ice detection system may be certificated (see AC 20-73A for guidance), but such a system would require an Equivalent Level of Safety (ELOS) for section 23.1419(d) if an ice inspection light is not installed.

b. Dry Air Tests with Simulated Ice Shapes.

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

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

(3) Simulated Ice Shapes.

(a) Critical Ice Accretions. Consideration should be given to the type of ice protection systems (for example: mechanical, fluid, thermal, or hybrid), and the most adverse ice conditions (shape or shapes, texture, location, and thickness) for the relevant aerodynamic characteristics for the following, as appropriate: delayed system turn on, intercycle ice, failure conditions, runback ice, and residual ice. Consideration should also be given to unprotected areas. See paragraph 13b for more information. These predictive methods should be conservative and should address the conditions associated with the icing envelope of part 25, Appendix C, that are critical to the airplane's performance and handling qualities in critical phases of the airplane's operational envelope, including climb, cruise, descent, holding pattern, approach, and landing. Ice shapes critical for performance may not necessarily be critical for handling qualities. See AC 20-73A for more information on determining critical ice shapes and corroboration of these ice shapes with natural icing flight test ice accretions. See AIAA-2007-1090, "Residual and Intercycle Ice on Lower Speed Aircraft with Pneumatic Boots" for more information on critical ice shapes for pneumatic deicing boots.

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

(c) Engine and Cooling Inlets. If ice is expected to accumulate at the engine or cooling inlets during icing encounters, then tests should be performed with critical ice shapes, typically representing a 45 minute hold, installed on these inlets. Tests should consider the critical operating temperatures and altitudes within Appendix C icing conditions. Generator cooling tests should be performed with the maximum icing load on the electrical system.

(4) Flight Test Objectives.

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

(b) Handling Qualities. Handling characteristics are expected to degrade in icing conditions and should be investigated to determine that the "airplane is capable of operating safely." For certification basis before amendment 23-43, subpart B requirements are used as guidelines. For certification basis at amendment 23-43 and higher, several subpart B requirements also apply in icing conditions. This is addressed in paragraph 13a. The results of these tests may be used in preparing specific AFM operating procedures and limitations for flight in icing conditions.

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

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

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

(a) Altitude, airspeed, and engine power.

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

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

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

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

(2) Artificial Icing.

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

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

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

1. Scaling. A full-scale test article is preferable due to uncertainties in ice accretion scaling. Refer to AC 20-73A for more information on scaling test parameters.

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

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

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

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

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

(3) Natural Icing.

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

(b) What Icing Conditions Should Be Tested?

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

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

3. **Number of Icing Encounters.** There should be sufficient icing encounters to achieve all test plan objectives. The natural icing performance and handling qualities matrix in Table 3 of this AC consists of at least three encounters.

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

1. **Normal Ice Protection System Operation.** Sufficient data should be taken to allow correlation with dry air tests using simulated ice shapes. This should be accomplished with a target accretion thickness equivalent to the 45-minute dry air ice shapes on an unprotected part of the wing. Handling qualities and performance should be subjectively reviewed and determined to be in general correlation with those found in dry air testing. Refer to paragraph 13.a. for performance, stability, control and maneuverability requirements.

2. **Delayed Ice Protection System Activation.** In addition, flying qualities and performance should be qualitatively evaluated with the ice accumulations existing just prior to operation of deice (as opposed to anti-ice) components. The ice protection systems are to be activated by the flight crew in accordance with approved AFM procedures when icing conditions exist; however, for anti-ice components, tests should be conducted that simulate inadvertent icing encounters in which the pilot may not recognize that the airplane is about to enter an icing condition and the anti-ice component may not be activated until actual ice build-up is noticed. A delayed ice accumulation event of 30 seconds to two minutes has been used in these tests to simulate the flight crew's failure to recognize an icing condition. For engine ice protection systems, which for aft fuselage mounted engines can include the inboard wing ice protection system, a delay of two minutes is utilized to validate the ice shedding analyses and § 33.77 ice slab test results. For the delayed ice accumulation time event, consideration should be given to the icing conditions; the icing recognition means available, recommended crew procedures, and ice protection system performance of the particular aircraft. The tests to be accomplished are summarized in Table 3 of paragraph 13c of this AC.

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

1. Engine operation and equipment operation such as oil cooling and generator cooling under maximum load should be monitored during icing tests and be found acceptable for this operation If data is analyzed in accordance with § 23.1043, the temperatures need to be corrected only to 32 degrees F, not a hot day. Natural icing flight tests should include evaluation of ice protection systems with bleed air from engines when the throttle is at the flight idle stop. Refer to AC 20-147 for additional guidance for turbojet engines.

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

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

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

5. Ice shedding from components including antennas and propellers should cause no more than cosmetic damage to other parts of the airplane, including aft-mounted engines and propellers. If flight testing is used to validate shedding trajectories, there should be dedicated test points to evaluate shedding. Examples would be flying in warmer temperatures to facilitate ice shedding, and evaluating various operational angles of attack and sideslip.

6. Stall Warning and Maneuver Margin. With ice accretions on the airplane, acceptable stall warning (aerodynamic or artificial) and stall protection, if a stall protection system is installed, should be provided to validate the results of the dry air ice shape testing. The stall warning should meet the requirements of § 23.207(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, i.e. resetting trigger points to lower angles of attack when ice protection is initiated, may be necessary to achieve required maneuver margins to stall. The maneuver margin requirements § 23.207(d) should be demonstrated in icing conditions. The stall warning margin should be evaluated with various ice accretions as summarized in Table 3. See paragraph 13.c.

NOTE 1: This test and any stall or handling qualities tests should be accomplished in daytime visual meteorological conditions, after accreting ice, for safety. .

7. Performance, Stability, Controllability. See paragraph 13.c.

8. Ice detection cues or ice detection system operation that the pilot relies on for timely operation of ice protection equipment should be evaluated in all anticipated flight conditions, including night.

<u>9</u>. **Ice inspection lights** should be evaluated in natural icing and night conditions to verify that they illuminate ice build-up areas, are adequate under the conditions encountered, and do not introduce objectionable glare. 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.

<u>10</u>. **Flight Control Systems.** Primary and secondary flight control surfaces should remain operational after exposure to icing conditions. Evaluations should confirm that aerodynamic balance surfaces are not subject to icing throughout the airplane's operating envelope (weight, Center Of Gravity (CG), and speed), or that any ice accumulation on these surfaces does not interfere with or limit actuation of the control for these surfaces including retraction of flaps, slats and/or landing gear for a safe go around from the landing configuration.

<u>11</u>. **Air Data Systems.** Ice accretions on pitot probes, static sources, temperature probes, angle of attack and stall warning sensors, and accretions forward of these sensors such as accretions on radomes or other probes should be evaluated to determine the effect, if any, on the position error of the aircraft's production air data system and proper operation of stall warning or stall protection systems.

<u>12</u>. **Autopilot.** All autopilot modes should be evaluated in natural icing conditions to validate the dry air ice shape test results. All autopilot modes should function properly in icing conditions. Airframe leading edge ice accretions could affect control power and control hinge moments resulting in incorrect autopilot gains. These evaluations should also show that autopilot actuators function properly and do not freeze up. The autopilot should be engaged for an extended period of time in natural icing conditions to check for unusual trimming and potential for ice to accrete in control surface gaps and jam controls."

<u>13.</u> **Vibration and Buffet.** Should be evaluated, including propeller vibration.

<u>14</u>. **Pilot Workload.** The workload in icing conditions should be evaluated when showing compliance to § 23.1523. Ice detection, ice protection system operation and monitoring, and autopilot operation and monitoring (including periodic disconnects), as a minimum should be evaluated.

<u>15.</u> **Documentation of Ice Accretions.** Ice accumulation on unprotected and protected areas, and behind protected 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 dimensional analysis of ice accretions. Care should be taken since some measuring devices may accrete ice and alter analysis of accretions on a surface of importance. Surfaces may be painted a dark color since rime and mixed ice accretions may be difficult to see on white surfaces. 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.

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

a. Flight Tests

(1) Section 23.1419 at Amendment 23-43 or Later. In accordance with § 23.1419(a), "capable of operating safely" means that airplane performance, controllability, maneuverability, and stability may be degraded from the non-iced airplane but must not be less than the requirements in part 23, subpart B. Guidance for each subpart B regulation, as related to icing, is in Appendix 6 of this AC. Unless noted otherwise, the guidance is applicable to all airplane categories for which compliance to § 23.1419 is being shown.

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

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

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

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

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

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

2. The airplane with critical ice accretions as defined in paragraph 13b of this AC complies with the stall warning requirements of § 23.207.

(aa) For aircraft with artificial stall warning systems, paragraph 13a (1)2, may require a bias in the stall warning schedules (resetting trigger points to lower angles of attack when ice protection is initiated) to maintain adequate stall warning margins.

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

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

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

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

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

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

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

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

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

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

(2) Section 23.1419 at Amendment 23-14. The definition of "capable of operating safely" is not defined in the regulation. The tests and pass/fail criteria of paragraph 13a (1) should be used as a guide to develop a test program that demonstrates the airplane is capable of operating safely in the part 25, Appendix C, icing envelope. The regulations italicized in Appendix 6 of this AC are not typically addressed in showing compliance to § 23.1419 at amendment 23-14.

b. Ice Accretions.

(1) Airframe Ice Accretions.

(a) Definition of Ice Accretions. The most critical ice accretions in terms of handling characteristics and/or performance for each flight phase should be determined. The parameters to be considered are the flight conditions (e.g., airplane configuration, airspeed, angle of attack. altitude) and the icing conditions of part 25, Appendix C (temperature, liquid water content, mean effective drop diameter). Table 2, parts I and II summarize the ice accretions for each flight phase for normal ice protection system operation.

TABLE 2. ICE ACCRETION DEFINITIONS, PART 1 of 2

<table>
<tr><th>Ice Accretion</th><th>Normal, Utility and Acrobatic Categories or Turbojet Airplane with a takeoff configuration that includes leading edge high lift devices</th><th>Commuter Category or Turbojet Airplanes with a takeoff configuration that does not include leading edge high lift devices</th></tr>
<tr><td>Takeoff</td><td>None if the AFM prohibits takeoff with any ice, snow and frost on the wing and control surfaces. Otherwise, “polished” frost, as permitted by the parts 91 and 135 operating rules should be defined by the applicant, show that procedures are practical (pilot can determine when it is acceptably polished), and simulated for flight test evaluation if not prohibited for takeoff in the AFM.</td><td>Ice accretion occurring between liftoff and 400 feet above the takeoff surface, assuming accretion starts at liftoff in the “takeoff maximum icing’ conditions, on:

• unprotected surfaces; and

• the protected surfaces appropriate to normal IPS operation; or

• the protected surfaces if IPS operation is prohibited for takeoff. (It should be assumed no flight crew action to activate the ice protection will occur until at least 400 feet above the ground level, or higher if specified in the AFM.)

“Takeoff maximum icing” conditions defined as:

• cloud liquid water content of 0.35 g/m^3;

• cloud droplets Mean Effective Diameter (MED) of 20 microns; and ambient air temperature at ground level of minus nine degrees Centigrade (C)

This ice accretion may be simulated by 100 grit sandpaper on the leading edge, unless another roughness is substantiated.</td></tr>
</table>

TABLE 2. ICE ACCRETION DEFINITIONS, PART 1 of 2 (Continued)

Ice Accretion	Normal, Utility and Acrobatic Categories or Turbojet Airplane with a takeoff configuration that includes leading edge high lift devices	Commuter Category or Turbojet Airplanes with a takeoff configuration that does not include leading edge high lift devices
		Also the following ice accretions should be addressed: • Takeoff ice accretions defined under Normal, Utility and Acrobatic Categories, if required. • If a turbojet airplane without wing leading edge high lift devices, contamination simulated by 40-grit sandpaper on wing leading edges and the entire upper wing surface should be flight tested unless the AFM requires a pre-takeoff visual and tactile inspection of the wing leading edge and upper surface, and any other surface deemed critical, in ground icing conditions.

TABLE 2. ICE ACCRETION DEFINITIONS, PART 2 of 2

Ice Accretion	Normal, Utility and Acrobatic Categories or Turbojet Airplane with a takeoff configuration that includes leading edge high lift devices	Commuter Category or Turbojet Airplanes with a takeoff configuration that does not include leading edge high lift devices
Final Takeoff	Not applicable.	Same as "takeoff" ice except ice accretion occurs between liftoff and 1,500 feet above the takeoff surface.
Enroute	Ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, during the en route phase, in part 25, Appendix C, continuous or intermittent maximum icing conditions.	
Holding	Ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, during a 45-minute hold in part 25, Appendix C, continuous maximum icing conditions.	
Approach And Landing	Ice accretion on unprotected surfaces same as "Holding" ice, and ice accreted on protected surfaces appropriate to normal system operation during an approach and landing. Upper surface impingement due to reduced angle of attack with flap extension, ice on flap leading edge, and ice on leading devices when extended need to be addressed. Runback ice has been observed to develop on leading edge slats on some designs when extended, but not when retracted. Duration of approach phase is time to accrete 0.5 inches of ice on unprotected part of wing with highest collection efficiency. Duration of landing phase is time to accrete 0.25 inches of ice on unprotected part of wing with highest collection efficiency.	
Pre-Activation	The ice accretion prior to normal system operation is the ice accretion formed on the unprotected and normally protected surfaces prior to activation and effective operation of any ice protection system in continuous maximum atmospheric icing conditions. Ice detection procedures, ice detector system design and performance, and operating procedures (e.g., boot activation, fluid system flow rate) should be considered.	
Intercycle	See Appendix 1 of this AC for definition. For airspeeds below 160 KCAS, empirical data should substantiate that deicing systems shed ice at each cycle.	
Residual	See Appendix 1 of this AC for definition.	
Runback	See Appendix 1 of this AC for definition. This ice type is frequently a byproduct of partially evaporative (running wet) ice protection systems and thermal deicing systems, but can also occur on deicing boots at a small temperature band near freezing. Empirical data should be obtained at the following conditions, as a minimum, at the LWC values within part 25, Appendix C: a. outside air temperatures of 24 degrees to 28 degrees F;	

TABLE 2. ICE ACCRETION DEFINITIONS, PART 2 of 2 (Continued)

Ice Accretion	Normal, Utility and Acrobatic Categories or Turbojet Airplane with a takeoff configuration that includes leading edge high lift devices	Commuter Category or Turbojet Airplanes with a takeoff configuration that does not include leading edge high lift devices
Runback (Cont.)	b. total air temperatures of 24 degrees to 35.5 degrees F; c. time required to transit a continuous maximum cloud of up to 55 nm, correcting liquid water content for horizontal extent.	
Critical	The ice accretion, applicable to the phase of flight that has the most adverse effect on performance and flying qualities. For protected surfaces, intercycle ice, residual ice, and runback ice should be accounted for. Pre-activation ice should be accounted for if the AFM requires the flightcrew to wait for a specified amount of ice accretion prior to activation the ice protection systems, or for systems, such as fluid systems, in which system effectiveness may take several minutes. In order to reduce the number of ice accretions to be considered when demonstrating compliance: (1) The more critical of takeoff ice and final takeoff ice may be used throughout the takeoff phase. (2) Holding ice may be used for the en route, holding, approach, landing, and go-around flight phases if it can be substantiated to be more critical than the ice accretions in those phases. (3) Holding ice may also be used for the takeoff phase provided it can be substantiated to be more critical than takeoff ice and final takeoff ice. (4) The ice accretion that has the most adverse effect on handling characteristics may be used for climb performance tests provided any difference in climb performance is conservatively taken into account. (5) In some instances the shapes determined in the various flight phases and flight conditions may be "enveloped" into one critical shape.	

(b) Shape and Texture of Simulated Ice. The shape and texture of the simulated ice should be developed, and substantiated by agreed methods. The ice shapes should be agreed to by the FAA prior to ice shape flight testing.

1. Common practices for developing ice shapes include:

(aa) Use of computer codes;

(bb) Flight in measured natural icing conditions;

(cc) Icing wind tunnel tests; and

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

2. The ice accretion resulting from the largest drops possible in Appendix C icing conditions should be considered for critical ice shapes. A Langmuir D drop distribution, 40 μm median drop diameter, continuous maximum icing conditions, should be considered. See AC 20-73A.

3. Natural icing or airborne tanker testing may show ice shapes or accretion locations more critical than those simulated. Ice shape testing of critical test points would then need to be re-flown with these more critical shapes.

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

(2) Propeller Icing. To date, climb performance analyses and climb flight testing with ice shapes have not taken into account propeller efficiency losses due to ice accretion on the propeller blades. Deicing boot manufacturer's analyses show that intercycle ice does exist with propeller deicing systems and their analyses do not account for ice runback. The outer part of the blade, which normally is not protected, theoretically has sufficient centrifugal force to shed ice. Stop frame video of recent flight testing of a part 23 aircraft in Super-Cooled Large Drop (SLD) conditions have shown ice accretions on the full span of the propeller blades. Although this condition was outside of part 25, Appendix C icing conditions, there is a possibility that this may occur within some portions of part 25, Appendix C.

(a) Airplane performance in icing conditions should include the propeller efficiency losses caused by propeller intercycle ice. This may be accomplished by analysis.

(b) Propeller efficiency loss should be at least 10 percent to account for runback ice and intercycle ice, unless data substantiates another amount.

(c) Airplane performance during natural icing flight testing should be quantitatively compared with performance during ice shape flight tests. On reciprocating and turboprop powered airplanes, if there is degradation in performance compared to the ice shape results, propeller efficiency losses due to propeller ice accretions should be investigated.

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

(a) Failure ice accretion is defined as:

1. "Holding" ice as defined in Table 2 for unprotected surfaces; and

2. For protected surfaces, one-half the accretion specified for unprotected surfaces (22.5 minutes) if the associated AFM operating procedure requires the airplane to leave the icing conditions as soon as possible, unless another value is agreed to by the responsible aircraft certification office.

3. For failure conditions that are: (a) not annunciated to the flight crew, or (b) annunciated to the flight crew, but the associated AFM procedure does not require exiting the icing conditions, the guidance in this AC for a normal (i.e., non-failure) condition is applicable with the failure ice accretion

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

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

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

3. To exit the icing conditions.

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

c. Natural Icing Flight Tests. Whether the performance and handling qualities flight testing has been performed with simulated ice shapes or in natural icing conditions, additional limited flight testing described in this section should be conducted in natural icing conditions.

Where flight testing with simulated ice shapes is the primary means for showing compliance**,** the objective of the tests described in this section is to corroborate the handling characteristics and performance results obtained in flight testing with simulated ice shapes. It is acceptable for some ice to be shed during the testing due to air loads or wing flexure, etc., or during transit to a higher altitude or test area for safety reasons. However, an attempt should be made to accomplish the test maneuvers as soon as possible after exiting the icing cloud to minimize the atmospheric influences on ice shedding. During any of the maneuvers specified in Table 3, the performance and behavior of the airplane should be consistent with that obtained with simulated ice shapes. There should be no unusual control responses or uncommanded airplane motions. Additionally, during the level turns and bank-to-bank rolls, there should be no buffeting or stall warning.

TABLE 3. NATURAL ICING PERFORMANCE AND HANDLING QUALITIES TESTS

Configuration	Ice Accretion	Trim Speed	Maneuver
Flaps up, gear up	Equivalent to 45-minute hold at critical conditions.	Minimum Holding	• Level, 40-degree banked turns; • Bank-to-bank rapid rolls, 30 degrees – 30 degrees; • Climb or level performance evaluation; • Autopilot tests • Straight stall (1 knot/sec. deceleration rate, wings level, power off)
Landing flaps, gear down	Time to accrete 0.75 inches on unprotected part of wing with highest collection efficiency	V_{REF}	• Level, 40-degree banked turns; • Bank-to-bank rapid rolls, 30 degrees – 30 degrees; • Climb or level performance evaluation; • Straight stall (1 knot/sec. deceleration rate, wings level, power off).
Flaps up, gear up	Defined pre-activation ice	Optional	• Level, 40-degree banked turns; • Bank-to-bank rapid rolls, 30 degrees – 30 degrees; • Climb or level performance evaluation; • Autopilot tests • Straight stall (1 knot/sec. deceleration rate, wings level, power off).

d. Control System and Stall Protection System Tolerances. The same airplane and system production tolerances used in the non-icing tests should be used when evaluating performance and handling qualities with ice accretions. Ice protection system production tolerances should be addressed during flight testing in natural icing conditions. Examples are provided in Table 4. Stall speed and warning system tolerance are critical when establishing tolerances for production acceptance flights.

TABLE 4. FLIGHT TEST TOLERANCES

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

e. ICTS. To remove the risk of contaminated tailplane stall from the operating envelope of the airplane, the applicant should demonstrate by tests or a combination of analyses and tests, that the airplane is safely controllable and maneuverable during all phases of flight.

(1) Background. See Appendix 7 of this AC.

(2) Evaluation of Susceptibility to ICTS by Flight Test

(a) Longitudinal control and susceptibility to ICTS should be evaluated during the following flight tests with critical ice shapes installed:

1. Flap extensions

2. Recovery from stalls

3. Level flight accelerations

4. Longitudinal control tests required by 14 CFR 23.145.

(b) Susceptibility to ICTS should also be evaluated by conducting the zero-g pushover maneuver and steady heading sideslip.

1. Configuration.

(aa) All combinations of wing flaps and landing gear should be tested beginning with zero flaps up to the maximum flap setting to be approved for landing following an icing encounter. Since increased flap extension will increase the potential for ICTS, flight testing should proceed cautiously as the flaps are further extended.

(bb) Critical weight and CG position (normally full forward at light weight).

(cc) Speeds from 1.2 VS_1 or Reference Landing Approach Airspeed (V_{REF})-5 knots, as appropriate to the wing flap position, up to the maximum speed to be encountered operationally in a given flap or gear configuration that will not result in exceeding Flaps Extended Speed (V_{FE}) or Landing Gear Extended Speed (V_{LE}), as applicable, during the maneuver. The speeds VS_1 and V_{REF} may have to be redefined with critical ice shapes.

(dd) Power or thrust: flight idle to maximum go-around.

<u>**2.**</u> **Ice Shapes:** The applicant specifies the critical ice case(s) for investigation in terms of location, shape, thickness, and texture, and obtains FAA concurrence for the ice shape(s) to be investigated.

(aa) The critical shape(s) should contribute to the largest adverse hinge moment, lowest stall angle, greatest tail lift loss, and lowest control surface effectiveness.

(bb) More than one shape may require testing. If a clean wing (no ice accretion) can result in increased negative Angle-of-Attack (AOA) on the horizontal tail, ice shapes on the wing should be removed. The critical ice accretion case(s) should include an allowance for the ice shape accreted during any time delays in activation of the ice protection system associated with ice detection or observation systems, intercycle and residual ice, runback ice, or the accretion that may be reasonably expected in service.

(cc) It should be noted that ice accreted with the flaps retracted might result in a more critical condition than ice accreted with the flaps extended. Ice accretion shape and thickness need not be greater than that resulting from exposure to the icing conditions defined in Appendix C to Part 25 or the 45-minute hold condition of this AC, whichever is more critical.

(dd) Ice on the vertical stabilizer should also be considered for the sideslip case.

(ee) ICTS susceptibility should be evaluated with pre-activation ice. In many cases the pre-activation ice may be simulated by sandpaper ice. A thin ice layer simulated by sandpaper has been found to be critical on some aircraft and should be evaluated along with critical ice accretions on airplanes with a reversible longitudinal control system.

(ff) Failure conditions of the ice protection system should also be addressed. Maximum landing flap extension with a failed ice protection system may be defined at an intermediate position. This should become an airplane limitation for a failure.

<u>**3.**</u> **Zero-g pushover maneuver.** This is a maneuver to generate a nose down pitch rate so as to increase the angle-of-attack of the air flow over the horizontal stabilizer. Before the maneuver, the test pilot determines initial entry speeds and pitch attitudes to achieve the target load factor and target airspeed as the airplane pitches through approximately level flight.

(aa) The objective of the pushover maneuver is to push the pitch control in the nose-down direction to obtain the test load factor (g level) and be at the test airspeed as the nose passes through the horizon. Note any lightening of the pitch control push force during the build-up to the test end. Begin the maneuver with the airplane trimmed or trimmed as nearly as possible at the test power, configuration, and test (target) speed. The airplane is dived to gain sufficient airspeed above the test airspeed to allow a pull-up (nose above the horizon), followed up by a rapid pitch over as the test airspeed is approached to achieve the test load factor and airspeed as the nose passes through the horizon.

(bb) The pushover series begins by moving the control column forward while evaluating for any reduction of required control force or force reversal. Continue the test points incrementally by increasing the amplitude of forward control inputs to obtain lower target load factors until a zero-g flight condition is obtained or, if limited by elevator power, to the lowest load factor attainable. The target load factors need to be maintained long enough to allow an evaluation of the longitudinal force required. During the pitch down maneuver, the test pilot should not change the rate of longitudinal control or reverse control movement as this may alter pitch rate and tail surface geometry to disqualify that test point.

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

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

(ee) A push longitudinal control force should be required throughout the test maneuver. Stop the test if a control force lightening to less than zero, or a pull pitch control force is required to achieve the test load factor (g level).

(ff) The airplane should demonstrate suitable controllability and maneuverability throughout the maneuver, including recovery, with no tendency to diverge in pitch or other indications of a stalled tailplane.

(gg) During the pitch-down maneuver, any pilot produced change in elevator deflection toward the nose-up direction disqualifies that test point.

4. **Steady state sideslip maneuver.** Establish the airplane incrementally in a straight, steady heading sideslip, up to the sideslip angle appropriate to normal operation of the airplane used to demonstrate compliance with § 23.177, Static directional and lateral stability. The airplane should demonstrate suitable controllability and maneuverability throughout the maneuver with no tendency to diverge in pitch.

(c) Other Parameters that May Indicate a Stalled Tailplane. If the test aircraft is instrumented, the following parameters may indicate a stalled tailplane:

1. The relationship of pitch rate (q) versus elevator deflection (δ_E) after the elevator is returned Trailing Edge-Up (TEU). If stalled, the elevator could deflect substantially before the airplane pitch rate starts to return to zero. This also appears as reduced elevator effectiveness, $C_{m\delta E}$.

2. If the elevator stalls, the aircraft will continue toward zero-g regardless of the force applied by the pilot to return to one-g flight. This may be determined by examining the slope of the plot of vertical load factor (N_z) vs. pitch control force ($F_{ELEVATOR}$) after the elevator is returned TEU.

3. Flow visualization methods (tufts) will usually indicate the onset of destabilization by flow reversal over a substantial portion of the suction (lower) surface of the horizontal tail. This indication often appears slightly before pilot tactile force cues. Critical tests would have to be repeated without the tufts to demonstrate the tufts have no effect on tail stall.

(4) Compliance by Analysis. For turbojet powered airplanes with irreversible, powered pitch control systems, the flight tests described in paragraph 13 (e) (2) (b) may not be necessary. However, a detailed analysis, as a minimum, should show that:

(a) The airplane has adequate (consult Small Airplane Directorate) margin to tail stall angle of attack; and

(b) Airplanes of similar size, configuration and operating envelope have demonstrated an acceptable service history with respect to ICTS.

(5) AFM Limitations and Procedures.

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

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

f. Pneumatic Deicer Boots. Many AFMs specify a minimum ice accumulation thickness prior to activation of the deicer boot system. This practice has been in existence due to the belief that a bridge of ice could form if the boots are operated prematurely. Flight testing and icing tunnel testing of several "modern" boot designs have not shown evidence of "ice bridging", and no degradation in ice shedding performance, when the boots were activated at the first sign of ice accretion. Although the ice may not shed completely with one cycle of the boots, this residual ice will be removed during subsequent boot cycles. Tunnel testing is documented in FAA Technical Report DOT/FAA/AR-02/68, "Effect of Residual and Intercycle Ice Accretions on Airfoil Performance" (May 2002), and recommends that activating the deicing boots "early and often" are given more consideration as a means of limiting the size of intercycle and residual ice accretions. "Modern" boots are defined as high operating pressure (nominal greater than 15 Pounds Per Square Inch Gauge (PSIG)) and fast inflation and deflation times. Both one-inch diameter tube designs operating at a nominal 18 PSIG, and 1.75-inch diameter tube designs operating at a nominal 15 PSIG, have been evaluated. The tests documented in FAA Technical Report DOT/FAA/AR-02/68 were conducted at approximately 175 KCAS. Additional tunnel tests at airspeeds typical of many part 23 airplanes are documented in AIAA-2007-1090, "Residual and Intercycle Ice for Lower Speed Aircraft with Pneumatic Boots." These tests conducted at 145 KCAS and below, showed that it may take many boot cycles to effectively shed the ice. It may appear that the boots are not having any effect at all until shedding occurs. Waiting for a specified amount of ice did not improve ice shedding. The recommended AFM procedure for boot operation should be to operate the boots in an appropriate continuous mode at the first sign of ice and not to wait for a specific amount of ice to accumulate. The boots should be operated until icing conditions are exited and ice no longer adheres to the airframe.

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

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

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

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

NOTE 2: Usually, selection of the deicing boots to operate causes one cycle of inflation and deflation of all boots, but not necessarily at the same time. Some systems are designed such that all the boots do not complete the cycle if the deicing boots are selected off during the middle of one cycle. For these systems, there should be an AFM warning to the flight crew to select the ice protection on for at least one complete cycle of the deicing boots. This note is equally applicable to any deicing system.

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

g. Emergency and Abnormal Operating Conditions. Flight investigations should be conducted to verify that, after pilot recognition of emergency and abnormal operating conditions, the airplane handling qualities have not deteriorated to the extent that the AFM procedures for the condition are ineffective, that AFM procedures and recommended airspeeds are safe, and that the airplane can be landed safely. These demonstrations should be conducted with anticipated residual ice accumulation on normally protected surfaces. The tests in Table 5 represent a sample matrix for a part 23 airplane with failure ice shapes defined in paragraph 13b(3).

TABLE 5. FAILURE ICE ACCRETION FLIGHT TESTS

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

h. Super Cooled Large Drop (SLD) Conditions. Accidents and incidents related to loss of airplane control have raised the concern that airplanes operating in certain meteorological conditions can accrete ice, not only aft of the protected areas but also on the wing lower surface. This may result in lateral control difficulties due to disturbed flow over the control surfaces, stall at a reduced angle of attack, and/or drag penalties. The meteorological conditions involved are called SLD because they consist of drop sizes larger than those defined in part 25, Appendix C. An inadvertent encounter of such conditions may result in an unsafe condition that must be addressed. The FAA and EASA are currently harmonizing rulemaking and guidance for flight in icing conditions that exceed part 25, Appendix C icing conditions. This policy in this paragraph is in the interim and will be replaced when the harmonized regulations and guidance are issued for part 23 airplanes.

(1) Roll Control in SLD Conditions. The following guidance, with some modifications, is contained in a July 23, 1997 Policy Memorandum issued by the Transport Directorate and coordinated with the Standards Office. This policy memorandum was applicable to certain part 25 and part 23 airplanes. In October 1994, a fatal accident involving a transport category airplane occurred in which severe icing conditions were reported in the area. During extensive testing, the accident profile was replicated by ice shapes developed from testing in an icing cloud having droplets in the size range of freezing drizzle at a temperature near freezing. This condition created a ridge of ice aft of the deicing boots and forward of the ailerons, which resulted in uncommanded motion of the ailerons and rapid roll of the aircraft. The NTSB recommended that the FAA develop a test procedure to identify the unsafe aileron hinge moment characteristics. The FAA has identified the susceptibility to loss of control following exposure to supercooled large droplets as an unsafe condition that may exist on other aircraft. The FAA is particularly concerned with airplanes that are equipped with non-powered roll control systems, since non-powered roll flight controls do not have the physical advantage of hydraulic or electrical power to assist the pilot in overcoming the large control forces that may exist from differential pressure resulting from flow separation over the roll control surfaces. Therefore, airplanes certified for flight in icing equipped with non-powered roll control systems should be evaluated for susceptibility to roll upset in the event the airplane is exposed to certain freezing drizzle conditions.

(2) Stall. In March 2001, a transport category, regional turboprop airplane reported encountering icing conditions and within several minutes experiencing a loss of control in stall, losing approximately 8,000 feet before recovering at 10,000 feet. The NTSB determined that the lift curve (slope and maximum lift coefficient) derived from the flight data recorder was significantly lower than the lift curve determined by flight testing simulated intercycle ice which was developed by icing tunnel tests of part 25, Appendix C conditions. The FAA has identified the reduction in lift due to supercooled large droplets, and subsequently possible stall prior to warning, as an unsafe condition that may exist on other aircraft.

(3) Icing Conditions. Ice accretions to be addressed are:

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

(b) An LWC of approximately 0.33 grams per cubic meter.

NOTE 3: For this condition, the LWC strongly affects the rate at which the ice feature develops. A higher LWC results in more rapid formation of the ice feature, while a lower LWC results in a slower formation of the ice feature. The LWC should be adequate to produce an ice feature during the exposure interval that will start to shed on its own accord and then reform.

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

NOTE 4: The cloud physics instrumentation, calibration, and data processing methodologies should be presented for acceptance by the FAA.

(d) Temperatures near freezing such that runback conditions exist at the stagnation line (as a minimum total air temperatures of 24 degrees to 35.5 degrees F should be investigated); and

NOTE 5: For this test, temperature is a critical factor. Not only is the temperature critical to the development of the ice shape and dimension, static air temperature excursions above freezing, although short in duration, can reverse the ice accretion process.

(e) Operation at holding speeds and holding configurations. Light weight and maximum possible holding airspeed should be evaluated to obtain lowest possible angle of attack.

(f) An encounter of 20 minutes.

(4) Flight Tests.

(a) Tests. The tests in Table 3 should be evaluated at minimum holding airspeed, maximum weight, all possible holding configurations and at V_{REF}, maximum weight, all possible approach and landing configurations, except deceleration to stall may be stopped at a low speed alarm, or natural stall warning.

(b) Simulated Ice Shapes. Simulated ice shapes representing the ice accretions determined in paragraph 13.h (3) should be conducted. Alternatively, a quarter round, forward facing step shape may be flown, with the height calculated analytically based on water catch in the icing conditions in paragraph 13.h.(3). The shapes should be installed symmetrically along the full span of the wings, behind the protected area on the upper and lower surface.

(c) Pass/Fail Criteria

1. When manually flying the airplane:

(aa) There shall be no hazardous degradation of the handling qualities of the airplane**.**

(bb) It should be possible to readily arrest and reverse roll rate using only lateral control input, and the lateral control force should not reverse with increasing control deflection.

2. Any autopilot disconnect in altitude hold, attitude hold and heading hold mode must not result in the following:

(aa) bank angle of more 60 degrees,

(bb) a load on any part of the structure exceeding the lesser of either the structure's load limit or 2g,

(cc) a normal acceleration less than 0 g,

(dd) a roll force greater than 50 lbs. during the recovery action,

(ee) an excessive altitude loss,

(ff) hazardous degradation of the handling qualities of the airplane,

(gg) engagement or disengagement of a mode leading to hazardous consequences.

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

(6) There should be appropriate crew information provided in the AFM that describes the limitations and procedures to be observed while exiting the supercooled large droplet environment. The FAA has found that the limitations and procedures specified in Appendix 8 of this AC are an acceptable means of providing this information, unless tanker testing has shown other cues or ice shape flight testing has shown other procedures are more appropriate.

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

15. Placarding and AFM. This AC provides guidance on airplanes for which the certification basis requires an AFM. Guidance for AFMs in this AC also applies to AFM supplements.

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

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

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

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

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

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

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

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

(b) Minimum airspeed limitations for each configuration approved for icing conditions.

(c) Maximum airspeed limitation (if any)

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

(e) 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 Kind of Equipment List (KOEL).

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

(g) A list of required placards.

(h) Performance limitations should be presented for flight in icing that reflect any effects on lift, drag, thrust, and operating speeds related to operating in icing conditions. These limitations may be presented in the Performance Information section of the AFM and included as limitations by specific reference in the Limitations section of the AFM

(i) The Limitations section of the AFM should include, as applicable, a statement similar to the following: "In icing conditions the airplane must be operated, and its ice protection systems used as described in the operating procedures section of this manual. Where specific operational speeds and performance information have been established for such conditions, this information must be used."

(j) The Limitations section should include a statement similar to "Takeoff is prohibited with any frost, ice, snow or slush adhering to the wings, horizontal stabilizer, control surfaces, propeller blades, or engine inlet." Modify as applicable or add any other surface deemed critical.

(k) Visual/Tactile Pre-Takeoff Contamination Check for Turbojet Powered Airplanes

<u>1.</u> Turbojet airplanes without wing leading edge high lift devices. The AFM Limitations section should also require a visual and tactile inspection of the wing leading edge and upper surface in ground icing conditions. The Limitations section should specify a time limit for the tactile check. Nominally the tactile check must be accomplished within 5 minutes of takeoff, except it may be accomplished any time between final application of deicing fluid and takeoff if the airplane is deiced in accordance with an approved deicing program that complies with Section 121.629(c), and takeoff is accomplished within the maximum holdover time in a certificate holder's holdover timetable. In the case of the inability to ascertain if the fuel temperature is above freezing, the requirement to perform a visual/tactile check can be deleted if it can be shown that undetected ice accumulation does not occur on the wing upper surface due to cold soaked fuel. Ground icing conditions should be defined by the airplane manufacturer, but one example is defined as the Outside Air Temperature (OAT) below 5 degrees C (41 degrees F), or if it cannot be ascertained that the wing fuel temperature is above 32 degrees F (0 degrees C), and one of the following conditions:

<u>(aa)</u> Visible moisture (rain, drizzle, sleet, snow, fog, etc.) is present; or

(bb) The airplane was exposed to visible moisture (rain, drizzle, sleet, snow, fog, etc.) since the previous landing; or

(cc) The airplane experienced in-flight ice accretion since the previous takeoff; or

(dd) The difference between the dew point temperature and the OAT is 3°C (5°F) or less; or

(ee) Water is present on the wing

2. Turbojet airplanes without leading edge high lift devices and engines mounted behind wing. The manufacturer should either:

(aa) Show that undetected ice accumulation does not occur on the wing upper surface due to cold soaked fuel; or

(bb) Show that undetected ice accumulation on the wing upper surface caused by cold soaked fuel does not result in a hazard to the airplane due to engine ice ingestion; or

(cc) Add an AFM Limitation that requires a visual/tactile pre-takeoff check if it cannot be ascertained that the wing fuel temperature is above 32 degrees F (0 degrees C), and the ground icing conditions listed above exist.

(l) Configuration limitations, if any (for example, a reduced flap setting for approach and landing, and flaps up for holding or extended operations in icing conditions).

(m) 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. For exceedance icing conditions that may result from environmental conditions outside the icing envelope established as the basis of the approval defined in part 25, Appendix C, information should be provided as follows (see Appendix 8 of this AC 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, minimum airspeeds, configuration of high lift devices, drag devices, automatic flight guidance system, engine power/propeller settings (as appropriate), and ice protection system operation.

(n) 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. Section 23.1585(a) requires the pilot be provided with the necessary procedures for safe operation. 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.

(a) Preflight action necessary to minimize the potential of enroute emergencies associated with the ice protection system should be included when a flight is planned in IMC at temperatures below freezing.

1. Ice protection systems should be checked by operating the systems and verifying proper cockpit annunciations. Mechanical systems such as pneumatic boots should be visually observed for operation. Fluid systems should be visually observed for evidence of fluid along the entire protected span. It may take several minutes for the entire panels to receive fluid, or the system may have air in it, particularly after a long period of inactivity.

2. The quantity of fluid in the reservoir tank, if a fluid ice protection system, should be checked. The AFM should specify the fluid types that are approved.

3. If two sources of electrical power or two pumps for fluid systems are provided, both should be checked during pre-flight.

(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 electrical 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. For airplanes not equipped with an autothrottle, there should be a WARNING that the autopilot will NOT maintain airspeed if ice accretes on the airplane. MONITOR airspeed closely.

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

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

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

Exceptions:

- Balked landing climb data with critical ice accretions should be presented in the AFM in the same format as the basic non-icing data.

- Approach climb data, if required to be determined, should be presented in the AFM in the same format as the basic non-icing data.

- Effects of ice protection system operation and/or ice accretions, if applicable, on takeoff distance should be presented.

- For airplanes in which the service ceiling with critical ice accretions is less than 22,000 feet, enroute climb performance with critical ice accretions should be presented in the AFM in the same format as the basic non-icing data.

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

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

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

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

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

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

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

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

16. Instructions for Continued Airworthiness.

a. Requirements. Instructions for Continued Airworthiness (ICA) are required in accordance with 14 CFR 21.50(b) and 23.1529. ICA should be prepared in accordance with part 23, Appendix G. As a minimum the following should be addressed:

(1) Basic description of the ice protection system operation, components, and installation

(2) Servicing information, such as fluid type and quantities

(3) Location of panels used for inspection, and/or instructions to access components

(4) Scheduling information for each applicable component including cleaning, inspecting, adjusting, testing and lubrication

(5) Overhaul or replacement periods for components, if any

(6) Instructions for removing and replacing components

(7) Precautions, such as toxicity of freezing point depressant fluid or flammability of some cements

(8) Cleaning instructions, such as only soap and warm water for pneumatic deicing boots

(9) Limitations on the materials that can be applied, such as ice adhesion inhibitors, rubber preservatives, cosmetic coatings

(10) Recommendations on the frequency of use of ice adhesion inhibitors

(11) Special equipment or materials, such solvents, cements, edge filler, conductive edge sealer, rollers for pneumatic boot installation.

b. Fluid Ice Protection Systems. The tailcone, empennage and other areas aft of the TKS de-icing fluid flow should be inspected after each use of the ice protection system. This inspection should concentrate on extraneous fluid build-up on electrical contacts, flight control surface bearings, bellcranks, etc. The ice protection system fluid evaporates very slowly. Therefore, contaminates that collect in the fluid in areas of joints, skin laps, etc. may cause the acceleration of corrosive action.

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

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

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

(b) Cold Temperature Cycling. The testing in (1) (a) should be repeated at a temperature of 0 degrees F or colder.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

17. Ground Deicing Fluids.

a. Background. Notices (Flight Standards Information Bulletins for Air Transportation, FSAT, prior to 2006) are published yearly by the FAA, containing the latest deicing and anti-icing fluid holdover time guidelines and the most recent information available on operating in ground icing conditions. Airplane operators use this information to develop aircraft ground deicing and anti-icing programs required by 14 CFR §§ 121.629(c) and 135.227(b) (3). Operators who operate under § 135.227(b) (1) or (2) may still utilize the Notice information as guidance in their ground deicing plan. AC 20-117, AC 135-16, AC 135-17, AC 120-58, and AC 120-60B provide additional information on deicing and anti-icing of aircraft before takeoff.

(1) Why use ground deicing fluids? Aircraft are deiced before takeoff and, as required, anti-iced using thickened pseudo-plastic fluids. This procedure provides temporary protection from ice adhering to the aircraft's surfaces before takeoff. The thicker fluids (Type II, IV) provide considerably higher holdover times than the Type I fluids.

b. Potential Issues. The following have occurred in service resulting in re-designs and modified takeoff procedures and limitations when certain ground deicing fluids are applied before takeoff.

(1) Performance. The presence of thickened fluid may affect the airplane's performance because the fluids may not completely flow off the aircraft wing and lift devices before liftoff.

(2) Longitudinal Control. Fluid residue may cause increased pilot control forces during takeoff rotation and climb for airplanes with reversible control surfaces.

(3) Vibration and Controllability. The fluid may also collect in the balance bays of aerodynamically or weight balanced control surfaces, due to inadequate drainage. This may result in unbalanced control surfaces, unexpected changes in control forces, and control surface vibrations. Additionally, there has been one turbojet airplane in which the elevator tab was found to be aerodynamically sensitive to accumulation of foreign materials on its surface, in this case ground anti-icing fluid, causing severe vibration and limit cycle oscillations.

(4) Freezing of Controls. Anti-icing fluid may collect and evaporate in quiet cove areas, like those along control surface hinge lines. When the residue of the evaporated anti-icing fluid is re-hydrated by humidity, rain or during washing of the airplane, it may freeze and lock the control surface when the airplane climbs to altitudes with subfreezing temperatures. The residue does not contain a freezing point depressant, usually a glycol compound, which evaporates when the anti-icing fluid dries. Rehydrated fluid has been found in and around gaps between stabilizers, elevators, tabs, and hinge areas. This especially can be a problem with non-powered controls. Some pilots reported that they have had to reduce altitude until the frozen residue melted, which restored flight control movement. This phenomenon has not been experienced when a two-step deicing/anti-icing procedure is used. The first step is generally a hot Type I fluid mixture which flushes out residue.

c. When Should These Issues Be Addressed? The evaluations of the above issues are not required for showing compliance to 14 CFR § 23.1419. Typically the effect of fluids on the airplane are evaluated by the airframe manufacturer, after type certification, at the request of an operator that is seeking approval of a ground deicing and anti-icing program incorporating Type II or Type IV fluid. However, there are design features, analyses and tests that an airplane manufacturer may want to consider during certification to prevent re-designs after type certification if it is anticipated operators will use ground deicing/anti-icing fluids. This information is provided in this AC at the request of several airplane manufacturers.

d. How Should These Issues Be Addressed? Some issues can be addressed by design. There is currently no requirement to test for airplane performance or controllability after the application of deice/anti-ice fluids. The aerodynamics working group of the SAE G-12 Aircraft Ground Deicing Committee has been tasked to develop a SAE recommended practice for approving the use of fluids on airplanes. This recommended practice will be considered for part 23 guidance in a subsequent revision to this AC. The following paragraphs summarize methods that have been used by manufacturers in previous projects to address these issues. They are provided to assist airplane manufacturers in evaluating fluids for their specific designs.

(1) Design.

(a) The airplane design should be analyzed for possible collection sites.

(b) The design should incorporate drain holes, particularly in control surface balance bays.

(2) Airplane Performance. There have been various methods to evaluate performance. Typically the lowest takeoff gross weight and maximum flap position approved for takeoff is considered critical because of the lower scheduled takeoff rotation speed. Three methods that have been used by airplane manufacturers:

(a) Takeoff parameters such as time to rotate/lift-off and rotate/lift-off airspeeds have been compared during takeoffs with and without fluids. Flow-off of fluids from the wing was simultaneously documented during takeoff roll and rotation. Stall speeds have been checked at altitude with 1 knot/sec decelerations.

(b) Takeoffs with and without fluids have been performed back to back and the lift loss decrement at liftoff determined. The flight test measured lift loss was then corrected by computational fluid dynamics (CFD) to determine the lift loss decrement at stall. A 5.24% decrement in maximum lift coefficient due to fluid has been considered acceptable for jet powered airplanes, and an 8% decrement has been considered acceptable for propeller powered airplanes.

(c) Takeoffs at fixed pitch angles are performed with and without fluid. Several pitch angles representing the range of pitch angles at liftoff are tested. A 6% decrement in lift coefficient at liftoff has been considered significant.

(3) Controllability.

(a) The following has been evaluated at minimum practical gross weight, with minimum approved and maximum approved takeoff flap position, with all engines operating:

1. Control power and control force during rotation at the scheduled V_R.

2. Control power and control force during rotation at 10 knots or 7%, whichever is less, below the scheduled V_R.

3. Controllability tests (± 40º bank angle changes, ± 0.5g or stall warning) with takeoff flaps, as soon as practical after liftoff, either at V_2 +10 or the speed at 50 feet + 10 KIAS, depending on airplane category.

4. Vibration/buffet at Vne or Vmo.

(b) The following has been evaluated for multi-engine airplanes at minimum practical gross weight, with maximum approved takeoff flap position, with simulated one engine inoperative:

1. Control power and control force during rotation at V_R

2. Controllability tests (± 30º bank angle changes, +1.3/-0.8g or stall warning) with takeoff flaps, as soon as practical after liftoff, either at V_2 or the speed at 50 feet, depending on airplane category.

(4) Fluids.

(a) Number of Fluids. The airplane manufacturer should evaluate the type and brand of fluids to be approved for the airplane. A representative Type II fluid, and a Type IV fluid if approved in the AFM, should be tested. The viscosity of the fluid should be considered when determining the brand of fluid to test. Type III fluid need not be tested if Type II or IV fluid is tested and showed acceptable lift loss. If the Type II and IV testing showed takeoff procedures needed to be modified, than Type III fluid may not need to be tested if the takeoff procedures for Type III are similarly modified.

(b) Fluid Application.

1. Type II, III, and IV fluids should be applied undiluted.

2. Procedures for de-icing and anti-icing should follow the proposed recommended procedures. All applicable surfaces (including the horizontal stabilizer) should be treated. Slats/flaps should be in the recommended position for fluid application.

3. Takeoff tests should be conducted as soon as possible following anti-icing fluid application.

(c) It is preferable to test at the coldest outside air temperature at which the fluid can be used undiluted.

(5) Airplane Systems. Any adverse effect on aircraft systems should be noted (e.g. ECS, APU inlet, vent blocking)

(6) Post Flight Inspections. Several flights should be conducted after one step applications of the thickened pseudo-plastic fluids to be approved for the airplane. Post flight inspections should be conducted to determine if fluid residue is present on the airplane in areas that may cause one of the problems discussed in paragraph 17.b.

e. Airplane Flight Manual

(1) Fluids. The type and brands of fluid approved, along with any minimum outside air temperature limitation, should be in the Limitations section.

(2) Limitations. Procedures modified as a result of ground fluids should be in the Limitations section. Examples for part 23 airplanes are an increase in takeoff speeds and use of flaps.

(3) Procedures. Pre-flight or post-flight inspection and cleaning of areas in which fluid residue is shown to occur.

(4) Performance. Any increases in takeoff distance due to takeoff speeds increased above the established threshold should be presented in the Performance section. It should be noted that the takeoff testing is not required to be conducted on contaminated runways. Since runways may be contaminated in conditions in which these fluids will be used in operation, there should be a CAUTION that states the takeoff distance data is based on a dry runway, and that takeoff distances will be increased on contaminated runways.

f. Instructions for Continued Airworthiness. The following, if applicable, should be addressed in maintenance manual:

(1) Inspection.

(a) Drain holes.

(b) Control balance bays.

(c) Identified aerodynamically quiet areas.

(2) Cleaning. High-pressure washing with a hot Type I fluid/water mix in areas where fluid could accumulate. For those locations equipped with Type III fluids, in lieu of Type I fluids, it is suggested that a high pressure washing with a heated Type III/water mix be employed. Such a procedure may require subsequent lubrication.

g. Runway Deicing Fluids. Airplane manufacturers should be aware that since 1997 a problem of catalytic oxidation has been occurring on aircraft using carbon brakes. In 1997, airports started using more environmentally friendly fluids to deice runways. This resulted in the use of potassium formates and/or acetates. These chemicals (organic salts) attack the carbon in the brake and create a catalytic oxidation which softens the carbon, causing it to flake and crumble undetected and unpredictably over time thus reducing the life and long-term efficiency of the brakes themselves. SAE G-12F, among other industry working groups, has been working for some time to try and reduce these effects from runway de-icers. These runway fluids are now being found to adversely affect anti-icing fluid applied to aircraft and also to promote the formation of anti-icing fluid residue gel in aerodynamically quiet areas of the aircraft.

APPENDIX 1. DEFINITIONS

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

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

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

NOTE 6: In part 25, Appendix C, the term "mean effective diameter" refers to what is now called the "Median Volume Diameter (MVD)," determined using rotating multi-cylinders and assuming a Langmuir distribution.

c. Artificial Ice. A structure formed from material other than frozen water, but intended to represent an ice accretion. See "simulated ice shapes."

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

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

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

g. Freezing Precipitation. Freezing rain or drizzle falling through or outside a visible cloud.

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

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

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

k. Intercycle Ice. Ice that builds up on a deiced surface and exists immediately before actuation of the deice system.

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

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

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

o. Mixed Phase Icing Conditions. Partially glaciated clouds at an ambient temperature below 0°C. The clouds contain ice crystals and supercooled liquid water drops.

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

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

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

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

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

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

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

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

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

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

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

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

z. Supercooled Drops. Water drops that remain unfrozen at temperatures below 0°C. Supercooled drops exist in clouds, freezing drizzle, and freezing rain in the atmosphere. These drops may impinge and freeze after contact on aircraft surfaces

2. DEFINITION OF ACRONYMS.

AC	Advisory Circular
ACO	Aircraft Certification Office
AFM	Airplane Flight Manual
AIR	Aerospace Information Report
AOA	Angle of Attack
APU	Auxiliary Power Unit
ARP	Aerospace Recommended Practice
AS	Aerospace Standard

ATC	Air Traffic Control
C	Centigrade
CAR	Civil Air Regulations
CFR	Code of Federal Regulations
CG	Center of Gravity
CS	Certification Specification (EASA)
ELOS	Equivalent Level of Safety
F	Fahrenheit
FAA	Federal Aviation Administration
FPM	Feet Per Minute
FSAT	Flight Standards Information Bulletins for Air Transportation
EASA	European Aviation Safety Agency
EFIS	Electronic Flight Information Systems
FIDS	Flight Ice Detection Systems
ICA	Instructions for Continued Airworthiness
ICTS	Ice Contaminated Tailplane Stall
IMC	Instrument Meteorological Conditions
IPS	Ice Protection System
KCAS	Knots Calibrated Airspeed
KIAS	Knots Indicated Airspeed
KOEL	Kind of Equipment List
LOUT	Lowest Operational Use Temperature
LWC	Liquid Water Content
MDI	Magnetic Direction Indicator
MED	Mean Effective Diameter
M_{FC}	Maximum Mach number for stability characteristics
MMEL	Master Minimum Equipment List
MOC	Means Of Compliance
MSL	Mean Sea Level
MVD	Median Volume Diameter
NASA	National Aeronautics and Space Administration
NTSB	National Transportation Safety Board
OAT	Outside Air Temperature
PFIDS	Primary Flight Ice Detection Systems
PMA	Parts Manufacturing Approval
POH	Pilot's Operating Handbook
PSI	Pounds Per Square Inch
PSIG	Pounds Per Square Inch Gauge
RGL	Regulatory and Guidance Library
RPM	Revolutions Per Minute
SAE	Society of Automotive Engineers
SLD	Supercooled Large Drops
STC	Supplemental Type Certificate
TC	Type Certificate
TCDS	Type Certificate Data Sheet

TEU	Trailing Edge Up
TSO	Technical Standard Order
V_{FE}	Flaps Extended Speed
VIT	Variable Incidence Tailplane
V_{LE}	Landing Gear Extended Speed
V_{MC}	Minimum Control Airspeed
V_{MO}	Maximum Operating Airspeed
M_{MO}	Maximum Operating Mach Number
V_{NE}	Never Exceed Airspeed
V_R	Takeoff rotation speed
V_{REF}	Reference Landing Approach Airspeed
V_2	Takeoff safety speed

APPENDIX 2. GUIDELINES FOR DETERMINING CERTIFICATION BASIS ON FLIGHT IN ICING APPROVAL STCS AND AMENDED TCS

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

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

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

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

It depends on what is meant by another system. If it is replacement parts, such as replacing pneumatic deicing boots with those from another manufacturer, the certification basis can remain unchanged; see Appendix 5 of this AC for more information. If it is another type of system, for example replacing a pneumatic deicing system with a freezing point depressant system or electrothermal system, compliance to § 23.1419, amendment 23-14 must be shown. Section 23.1419, amendment 23-43 would not be required since a modification to an ice protection system is considered "not significant" under the Changed Product Rule.

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

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

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

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

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

It is recognized that compliance to § 23.1419(a), which requires that the airplane meet Subpart B performance in icing conditions, may be impractical for some CAR 3 airplanes. The Changed Product Rule allows the applicant to elect compliance to amendment 23-14 for that particular paragraph of § 23.1419. In this case the performance regulations are used as guidelines as discussed in paragraph 13a (2) of this AC.

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

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

APPENDIX 3. GUIDELINES FOR SUPPLEMENTAL TYPE CERTIFICATES (STC) AND AMENDED TYPE CERTIFICATES ON AIRPLANES

1. APPLICATION.

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

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

(1) Aircraft performance

(2) Flying qualities,

(3) Engine operation

(4) Essential system operation.

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

(1) Engine changes

(2) APU

(3) Propeller changes

(4) Engine inlet or accessory inlet changes

(5) Antennae installations or other external modifications

(6) Gross weight increases

(7) CG envelope increase

(8) Flight envelope increase

(9) Turboprop conversion

(10) Modifications to lifting surfaces

(11) Installation of vortex generators

(12) Modifications to ice protection systems

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

(14) Addition of/or autopilot replacement.

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

(1) § 23.929

(2) § 23.1093

(3) § 23.1301

(4) § 23.1309

(5) § 23.1416

(6) § 23.1419

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

(1) Engine Changes.

(a) Effects of increased engine power or thrust:

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

(aa) Stall characteristics and stability of minimum weight and maximum weight, aft CG limit

(bb) Controllability at forward CG limit and critical weight.

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

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

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

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

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

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

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

(3) Propeller Changes.

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

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

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

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

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

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

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

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

(i) For New Propeller Deice Electrical Power Systems:

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

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

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

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

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

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

(5) Antennas, Installations or Other External Modifications.

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

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

2. There is no ice-shedding hazard due to impact or ingestion on downstream structure, engines or propellers. See paragraph 14 of the AC for guidance on ice shedding.

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

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

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

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

2. Collection efficiency is one.

3. No runback or evaporation of impinging water.

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

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

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

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

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

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

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

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

2. The installation is on a lifting surface or

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

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

(6) Gross Weight Increases.

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

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

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

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

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

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

(e) **C**limb performance in icing conditions should be evaluated to determine if the airplane is capable of operating safely.

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

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

(8) Flight Envelope or Operating Procedure Changes.

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

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

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

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

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

(9) Turboprop Conversion.

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

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

(10) Modifications to Lifting Surfaces.

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

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

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

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

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

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

(11) Installation of Vortex Generators.

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

(12) Modifications to Ice Protection Systems.

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

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

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

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

(13) Addition of or Relocation of Fuel Vent.

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

(14) Addition or Replacement of Autopilot

Guidance in this AC, paragraphs 12 and 13 for autopilots should be consulted. There are specific scenarios in which autopilots can get the pilot into trouble in an airplane approved for flight into known icing. Those scenarios resulted in accidents and are factual. Based on our service experience, even though there are no regulatory requirements addressing autopilots in airplanes approved for known icing, applicants are strongly encouraged to include features that mitigate these autopilot induced accident scenarios. Where it would be impractical to add such a feature, the design should include adequate trim in motion cues. For replacement autopilots, the design of the original and replacement autopilots should be compared.

APPENDIX 4. GUIDELINES FOR CERTIFYING ICE PROTECTION SYSTEMS ON AIRPLANES NOT CERTIFICATED FOR FLIGHT IN ICING

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

2. SUBPART B – FLIGHT.

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

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

3. SUBPART D – DESIGN AND CONSTRUCTION.

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

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

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

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

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

5. SUBPART F – EQUIPMENT.

a. On airplanes with a certification basis of amendments 23-20 and higher, compliance to § 23.1301 must be shown. Compliance to § 23.1301 would entail showing the airplane can safely exit inadvertent icing encounters by providing the data in paragraphs (1) through (5). Subsequent installations on other aircraft models can be based upon similarity to the natural icing tests that were conducted provided that the installations can be shown to be sufficiently similar (ref. paragraph 10.f.). Airfoil size, shape, operating envelope, and airplane ice accretion sites should be included in the similarity analysis:

(1) A functional flight test in dry air

(2) Icing tunnel tests in part 25, Appendix C icing conditions

(a) Evaluate the ice protection system operation

(b) Determine protected area ice accretion such as runback, intercycle ice

(3) Empirical flight test data (natural icing or tanker)

(a) Validate ice accretions for ice shape flight testing

(b) Evaluate and document susceptibility of movable control surfaces to fixed surface bridging/freezing and subsequent lockup of controls

(c) Evaluation of autopilot operation and recommended operation in icing

(d) Qualitatively evaluate climb performance

(e) Evaluate degradation in windshield visibility

(4) Dry air ice shape flight tests

(a) Ice shapes

<u>1.</u> Five minute accretions on unprotected areas

__2.__ Protected area ice accretions

(b) Objectives

__1.__ Evaluate stability and controllability

__2.__ Evaluate increase in stall speed.

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

(1) Show that installation of the system, and normal operation of the system, does not affect operation of essential equipment. Examples are:

(a) Electromagnetic interference testing

(b) Operation of the stall warning system.

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

(a) Auto inflation of deicing boots

(b) Failures that could cause an asymmetric wing condition

(c) Bleed air leaks of thermal systems

(d) Electrical shorts in electrothermal systems.

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

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

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

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

6. SUBPART G – OPERATING LIMITATIONS AND INFORMATION.

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

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

c. The AFM should caution that stall warning in icing conditions might not be reliable and must not be relied upon in icing conditions, even with a heated stall warning sensor.

d. Stall speeds with the system installed or system operating, if increased from the baseline airplane, should be published in the AFM. An incremental delta increase may be used for all configurations, if appropriate.

e. Procedures to mitigate locked controls due to ice accretion, if applicable.

f. Autopilot operation procedures.

(1) 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.

(2) There should be a WARNING that the autopilot will NOT maintain airspeed if ice accretes on the airplane. MONITOR airspeed closely.

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

APPENDIX 5. GUIDELINES FOR APPROVAL OF REPLACEMENT PARTS FOR AIRFRAME DEICING SYSTEMS

1. The requirements leading to approval of replacement airframe deicing systems (propeller-deicing systems will be addressed in a revision) or airframe thermal deicing or anti-icing systems are functions of the project certification basis and similarity with the original part(s), as summarized in Table 5-1 and discussed in the following paragraphs:

TABLE 5-1. SUMMARY OF TEST REQUIREMENTS FOR REPLACEMENT AIRFRAME DEICING COMPONENTS

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

a. For aircraft whose certification basis does not include CAR § 3.712 or § 23.1419, the deicing system is optional equipment and not required. In this case, the replacement parts can be approved via the Parts Manufacturer 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, not introduce additional failure modes that could prevent continued safe flight and landing, and not affect stall characteristics, stability or control of the airplane in dry air. Comparative tests of the original versus the replacement parts are acceptable to show how the part removes or prevents ice accretion.

b. For aircraft whose certification basis is CAR § 3.712 or an original issue under § 23.1419, an STC is required. Original certification of these aircraft only required that pneumatic deicers be installed per approved data and that they have a positive means of deflation. No icing flight tests were required, and airplanes were considered "approved for flight into known icing" when the airplane was equipped with a complement of certificated deicing or anti-icing equipment spelled out in operational requirements. For replacement parts in these aircraft it is advisable for the Aircraft Certification Office (ACO) to contact the ACO maintaining the original type design data to determine factors such as variance with the original design, the original certification requirements, and the service history of the original product.

The replacement parts must be shown to function properly, remove ice or prevent ice accretion as well as the previously installed equipment, and not introduce additional failure modes that could prevent continued safe flight and landing. Comparative tests of the original versus the replacement parts may be acceptable. If the original certification basis is to be utilized, it is highly recommended that an entry in the AFM supplement limitations section, or a placard, with the following wording be required: “This airplane has not demonstrated compliance with the icing environment requirements of 14 CFR, part 25, Appendix C.

c. For replacement parts on an aircraft whose certification basis is § 23.1419, amendments 23-14 through 23-42, an STC is required. Flight testing in measured, natural icing conditions should be accomplished if the replacement parts are of different materials or have different design characteristics. Supplemental testing in artificial icing conditions (icing tunnel, tanker) should also be accomplished to cover the complete part 25, Appendix C envelope. The replacement parts must be shown to function properly, remove ice or prevent ice accretion as well as the previously installed equipment, and not introduce additional failure modes that could prevent continued safe flight and landing. A matrix of performance and flying qualities as discussed in paragraph 13a (2) of this AC should be accomplished. The Standards Office should be contacted since the requirement to flight test in measured, natural icing conditions is dependent on a number factors such as whether AFM performance in icing conditions is based on protected surface ice accretions, the service history of the airplane, and flight testing accomplished during the original certification with protected surface ice accretions. Follow-on applications of the new parts in aircraft other than the initial certification may then be approved through similarity provided the conditions in § 23.1419(c) are met. There may be cases where minor modifications would not require additional measured, natural flight tests.

d. For replacement parts on an aircraft whose certification basis is § 23.1419, amendment 23-43 or higher or those aircraft where the applicant wants to add “flight in icing conditions” operational approval, an STC is required. Flight testing in measured, natural icing conditions is required if the replacement parts are of different materials or have different design characteristics. Supplemental testing in simulated icing conditions (icing tunnel, tanker) may also be required to cover the complete part 25, Appendix C envelope. The replacement parts must be shown to function properly, remove ice or prevent ice accretion as well as the previously installed equipment, and not introduce failure modes that could prevent continued safe flight and landing. A matrix of performance and flying qualities as discussed in paragraph 13a (1) of this AC should be accomplished. Follow-on applications of the new parts in aircraft other than the initial certification may then be approved through similarity provided the conditions in § 23.1419(c) are met. There may be cases where minor modifications would not require additional measured, natural flight tests.

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

APPENDIX 6. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43

1. In accordance with § 23.1419(a), Amendment 23-43, "capable of operating safely" means that airplane performance, controllability, maneuverability, and stability may be degraded from the non-iced airplane but must not be less than the requirements in part 23, subpart B. Guidance for each subpart B regulation, as related to icing, is in the following Table 6-1.

2. The definition of "capable of operating safely" is not defined in the regulation at Amendment 23-14. For airplanes with a certification basis before 23-43, the tests and pass/fail criteria in the Table 6-1 should be used as a guide to develop a test program. The regulations italicized in the table are not typically addressed in showing compliance to § 23.1419 at amendment 23-14.

TABLE 6-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43

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

TABLE 6-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43 (Continued)

Regulation	14 CFR Section	Guidance
Stall speed	23.49	Must comply with critical ice accretions. See paragraph 13a (1) (c) for exemption considerations to the 61-knot stall speed requirement. Stall speeds with critical ice accretions should be determined and published in the AFM.
Takeoff speeds	23.51	When determining the takeoff speeds V_1, V_R, and V_2 for flight in icing conditions, the values of V_{MCG} and V_{MC} determined for non-icing conditions may be used. If the stall speed with "takeoff" ice at maximum takeoff weight with takeoff flaps, gear retracted exceeds that in non-icing conditions by more than the greater of three KCAS or three percent V_{S1}, the speed at 50 feet or V_2 must be increased to remain compliant.
Takeoff performance	23.53	The effect of operating ice protection systems on engine performance should be accounted for. Takeoff performance in icing conditions must be calculated with "takeoff" ice if: **a.** The stall speed with "takeoff" ice at maximum takeoff weight with takeoff flaps, gear retracted exceeds that in non-icing conditions by more than the greater of three KCAS or three percent V_{S1}; and **b.** If commuter category, the degradation of the gradient of climb determined in accordance with § 23.67(c)(2) is greater than one-half of the applicable actual-to-net takeoff path gradient reduction defined in § 25.61(b); and **c.** If multi-engine normal, utility or acrobatic category, the degradation of the gradient of climb determined in accordance with § 23.67(a) or (b) is greater than one-half of the applicable actual-to-net takeoff path gradient reduction defined in § 25.61(b).
Accelerate-stop distance	23.55	Applicable for commuter category only. The effect of any increase due to takeoff in icing conditions may be determined by analysis.

TABLE 6-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43 (Continued)

Regulation	14 CFR Section	Guidance
Takeoff path	23.57	
Takeoff distance and takeoff run	23.59	Applicable for icing for commuter category only if the conditions described above in 23.53 are met. May be calculated by a suitable analysis.
Takeoff flight path	23.61	
Climb: general	23.63	Must be compliant with critical ice accretions, except ambient temperatures above 41-degrees F do not need to be addressed.
Climb: all engine operating	23.65	Must be shown to be compliant with engine power losses associated with operating ice protection equipment that are not prohibited for takeoff. Climb performance losses due to ice accretion are normally not appropriate below 400 feet since the airplane should not depart with ice on the airplane. However, if ice protection system operation is prohibited for takeoff or the AFM does not specifically prohibit takeoff with <u>frost</u> on the wing and control surfaces, effect of ice accretions must be considered if: **a.** the stall speed with "takeoff" ice at maximum takeoff weight with takeoff flaps, gear retracted exceeds that in non-icing conditions by more than the greater of three KCAS or three percent V_{S1}, and **b.** for airplanes in which 23.65(a) is applicable, the degradation of the gradient of climb determined in accordance with § 23.65(a)) with "takeoff" ice is greater than 1.6 percent, and **c.** for airplanes in which 23.65(b) is applicable, the degradation of the gradient of climb determined in accordance with § 23.65(b) with "takeoff" ice is greater than 0.8 percent.
**Takeoff climb: one engine inoperative*	23.66	If applicable must be compliant.

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

TABLE 6-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43 (Continued)

Regulation	14 CFR Section	Guidance
Climb: one engine inoperative	23.67	The effect of operating ice protection systems on engine performance must be accounted for. The effect of ice accretion on climb performance (lift, drag and climb speed) must be accounted for if: **a.** The stall speed with "takeoff" ice at maximum takeoff weight with takeoff flaps, gear retracted exceeds that in non-icing conditions by more than the greater of three KCAS or three percent V_{S1}; and **b.** If commuter category, the degradation of the gradient of climb determined in accordance with § 23.67(c)(2) is greater than one-half of the applicable actual-to-net takeoff path gradient reduction defined in § 25.61(b), and **c.** If multi-engine normal, utility or acrobatic category, the degradation of the gradient of climb determined in accordance with § 23.67(a) or (b) is greater than 0.3 percent. For paragraphs (b) (1), (c) (1), and (c) (2), "takeoff" ice applies, and for paragraph (c) (3) "Final Takeoff" ice applies, rather than critical ice accretions.
Enroute climb/descent	23.69	Must be determined with "Enroute" ice if the enroute climb speed selected in icing is more than the non-icing speed by the greatest of three KCAS or three percent V_{S1}, or if the service ceiling with "Enroute" ice is less than 22,000 ft. MSL. The enroute climb speed must be at least the minimum airspeed specified in the AFM limitations section.
Glide: single engines airplanes	23.71	If applicable and if ice protection systems become inoperative with engine out, the best glide speed in icing must be determined if different from the non-icing speed by more than three KCAS. May be determined analytically.
Reference landing approach speed	23.73	Must be based on stall speed with critical ice accretion if V_{REF} in icing exceeds V_{REF} in non-icing conditions by more than 4 knots at maximum landing weight. The V_{MC} determined for non-icing conditions may be used if the vertical tail does not have ice accretion in normal system operation. If based on the non-ice V_{REF}, the airplane with critical ice accretions should still comply with the stall warning and maneuver margin requirements of § 23.207.

TABLE 6-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43 (Continued)

Regulation	14 CFR Section	Guidance
Landing distance	23.75	Must be determined with critical ice accretion if V_{REF} in icing conditions is greater than V_{REF} in non-icing conditions by more than four knots. The effect of landing speed increase on the landing distance may be determined by analysis.
Balked landing	23.77	Must be compliant with critical ice accretions, all ice protection systems operational, all landing flap settings, at an ambient temperature of 41 degrees F.
	23.143	If the non-icing V_{MC} is used for takeoff speeds, it must be shown that the airplane is safely controllable and maneuverable at the minimum V_2 for takeoff with the critical engine inoperative and with "takeoff" ice accretion. If the non-icing V_{MC} is used for V_{REF}, it must be shown that the airplane is safely controllable and maneuverable during a go-around starting at the minimum V_{REF} with the critical engine inoperative and with critical ice accretion. Susceptibility to ICTS should be evaluated with critical ice accretions, sandpaper ice and pre-activation ice as discussed in paragraph 13.e. of this AC. Susceptibility to control anomalies in SLD conditions as discussed in paragraph 13.h. of this AC should be addressed.
Longitudinal control	23.145	The tests in paragraphs (a) and (b) (1) and (b) (2) must be accomplished. For the other tests, the results from the non-contaminated airplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, or if qualitative evaluations with ice accretions show control anomalies, these cases should be repeated with ice. Controllability may be degraded from the non-iced airplane but must still be compliant. Analysis, the results of the non-icing tests to show compliance to § 23.145(e), and the results of controllability tests with ice accretions may be used to show compliance to § 23.145(e).

TABLE 6-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43 (Continued)

Regulation	14 CFR Section	Guidance
General (control)	23.141	Must be shown to be compliant with critical ice accretions.
Directional and lateral control	23.147	Critical configuration(s) determined from the non-contaminated airplane tests must be evaluated. Analysis, the results of the non-icing tests to show compliance to § 23.147(c), and the results of controllability tests with ice accretions may be used to show compliance to § 23.147(c).
Minimum control speed	23.149	If the vertical tail is unprotected or has intercycle/residual/runback ice during ice protection system normal operation, V_{MC} speeds with critical ice must be evaluated to determine if the proposed V_{REF} speed in icing complies with § 23.73. Static V_{MC} tests may be used.
Acrobatic maneuvers	23.151	Not applicable for icing certification.
Control during landings	23.153	Must be shown to be compliant with critical ice accretions.
Elevator control force in maneuvers	23.155	Critical configuration(s) determined from the non-contaminated airplane tests must be evaluated.
Rate of roll	23.157	Airplane must comply with "takeoff" ice accretions for paragraph (a) and critical ice accretions for paragraph (b). Controllability may be degraded from the non-iced airplane but must still be compliant. Tests should be conducted with 1/3, 2/3, and full roll control authority. In addition, to check for hinge moment reversals other roll control anomalies, perform this test with holding ice accretions, minimum holding speed, at maximum weight, at all approved holding configurations. Recovery roll control should not be initiated until the airplane has rolled through 50 degree bank.
Trim	23.161	The results from the non-contaminated airplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, or if qualitative evaluations with ice accretions how any control anomalies, these cases should be repeated

TABLE 6-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43 (Continued)

Regulation	14 CFR Section	Guidance
Trim (Cont.)	23.161 (Cont)	with ice. Otherwise, no dedicated tests with ice accretions required, qualitative evaluations can be accomplished concurrently with other tests.
General (stability)	23.171	Must be shown to be compliant with critical ice accretions.
Static longitudinal stability	23.173	Stability may be degraded from the non-iced airplane but must still be compliant.
Demonstra-tion of static longitudinal stability	23.175	Critical configuration(s) determined from the non-contaminated airplane tests must be evaluated.
Static directional and lateral stability	23.177	Must evaluate steady heading sideslips in accordance with paragraph (d). These tests should check for hinge moment reversals about the lateral and directional axis up to full rudder deflection. The results from the non-contaminated airplane tests to show compliance with paragraphs (a) and (b) should be reviewed to determine whether there are any cases where there was marginal compliance. If so, these cases should be repeated with ice. Stability may be degraded from the non-iced airplane but must still be compliant.
Dynamic stability	23.181	Critical configuration(s) determined from the non-contaminated airplane tests must be evaluated with critical ice accretions.
Wings level stall	23.201	As a minimum wings level stalls with cruise, approach and landing flaps, power off and on, should be evaluated with critical ice accretions. Roll may slightly exceed 15 degrees if characteristics qualitatively determined to be safe. Stall characteristics should also be evaluated when the airplane is stalled with the autopilot engaged, unless the design of the autopilot precludes its ability to operate beyond stall warning. For these designs the controllability at stall warning should be evaluated. Recovery at stall warning should also be

TABLE 6-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43 (Continued)

Regulation	14 CFR Section	Guidance
Wings level stall (Cont.)	23.201 (Cont.)	evaluated by only applying engine power or thrust. Evaluations should be accomplished by trimming at minimum AFM icing airspeed, setting the autopilot in altitude hold (for turns commanding a heading change), reducing power/thrust to establish a 1 kt/sec deceleration rate, and at stall warning apply power/thrust. Evaluate the aircraft response, need for directional/lateral control, airspeed increase, and altitude loss (assuming autopilot will disconnect as designed at stall warning).
Turning flight and accelerated turning stalls	23.203	Turning stalls should be evaluated with critical ice accretions similarly to wings level stalls. Accelerated turning stalls not required unless tests with no ice show marginal compliance. Stall characteristics should also be evaluated when the airplane is stalled with the autopilot engaged, unless the design of the autopilot precludes its ability to operate beyond stall warning. For these designs the autopilot operation up to stall warning and controllability at stall warning should be evaluated.
Stall warning	23.207 (a)-(c)	Should be evaluated concurrently with stall speed and stall characteristics tests. The type of stall warning with critical and pre-activation ice accretions should be the same as with the non-contaminated airplane. The stall warning margin with critical ice accretions should be compliant. For pre-activation ice, the margin can be less than the Subpart B requirement but it should be positive and shown to be adequate. Biasing of the stall warning (resetting trigger points to lower angles of attack when ice protection is initiated) may be required to achieve acceptable margins to stall. The method of biasing should be evaluated. Adequacy of stall warning when airplane is decelerated with autopilot engaged, and recovery at stall warning with power only, should be evaluated.
Maneuver margin	23.207 (d)	40-degree bank level altitude turns and 30 degree/30 degrees bank-to-bank rolls at the flight conditions specified in the regulation should be accomplished to demonstrate the airplane is free of buffet and stall warning with critical ice accretions. All takeoff and approach flap settings should be evaluated. For one-engine inoperative evaluations, only a 30-degree turn is necessary, and the appropriate thrust may be simulated with all engines operating at a reduced power/thrust.

TABLE 6-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43 (Continued)

Regulation	14 CFR Section	Guidance
Accelerated stall warning margin	23.207 (e)	Not required unless tests with no ice show marginal compliance.
Spinning	23.221	Not required.
Longitudinal stability and control	23.231	Must be shown to be compliant.
Directional stability and control	23.233	Must be shown to be compliant with critical ice accretions. The results of the steady heading sideslip tests with critical ice may be used to establish the safe cross wind component. If the flight test data show that the maximum sideslip angle demonstrated is similar to that demonstrated with the non-contaminated airplane, and the flight characteristics (e.g., control forces and deflections, bank angle) are similar, then the non-contaminated airplane crosswind component is considered valid. If the results of the comparison discussed above are not clearly similar, and in the absence of a more rational analysis, a conservative analysis based on the results of the steady heading sideslip tests may be used to establish the safe crosswind component. The crosswind value may be estimated from: $\mathbf{V_{CW} = V_{REF} * \sin(sideslip\ angle) / 1.5}$ where: $\mathbf{V_{CW}}$ is the crosswind component, $\mathbf{V_{REF}}$ is the landing reference speed appropriate to a minimum landing weight, and **sideslip angle** is that demonstrated at V_{REF}
Operation on unpaved surfaces	23.235	Not applicable for icing certification.

TABLE 6-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-43 (Continued)

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

APPENDIX 7. ICE CONTAMINATED TAILPLANE STALL (ICTS) BACKGROUND

1. BACKGROUND. When the leading edge of a horizontal tailplane becomes contaminated with ice accretions, control of the aircraft may be severely affected. The ICTS phenomenon in its extreme form may result in an uncontrollable nose-down pitching event.

a. What is ICTS? ICTS occurs due to airflow separation on the lower surface of the tailplane that is caused by the angle-of-attack of the horizontal tailplane being increased above the reduced stall angle-of-attack that can result when even small quantities of ice have formed on the tailplane leading edge. The increase in tailplane angle-of-attack can result from airplane configuration (for example, increased flap extension increasing the downwash angle or trim required for the CG position) and/or flight conditions (for example, high approach speed resulting in reduced tail angle-of-attack, gusts, maneuvering or engine power changes). ICTS is characterized by a reduction or loss, sometimes sudden, of pitch control or stability while operating in, or recently departing from, icing conditions. For airplanes with longitudinal control systems that are not powered (reversible control systems), the pressure differential between the upper and lower surfaces of the stalled tailplane may result in a high elevator hinge moment, forcing the elevator trailing edge down. This elevator hinge moment reversal can be of sufficient magnitude to draw the control column forward with a level of force that is beyond the combined efforts of the flightcrew to overcome. ICTS reduces tail lift or diminishes the effectiveness of the primary and secondary control surfaces. Diminished control effectiveness ranges from reduced elevator authority to sudden, large and unexpected changes in required control forces. Tab driven reversible pitch control designs may have insufficient authority to overcome the elevator hinge moments resulting from ICTS. 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.

b. Has ICTS occurred on airplanes? Following a number of accidents and incidents involving airplanes certificated under 14 CFR parts 23 and 25 for flight in icing conditions, and specifically an accident involving a British Aerospace BA-3101 airplane on December 26, 1989, the NTSB issued Safety Recommendation A-90-087.

c. What has been done to evaluate susceptibility of airplanes to ICTS?

(1) In 1991, the FAA reviewed the pitch control and stability factors of various airplanes to determine the susceptibility of those airplanes to ice contaminated tailplane stall. The review included discussions with manufacturers of airplanes certificated for flight in known icing, analysis of stall margin design parameters, and methods used to show compliance with 14 CFR 23.143, Controllability and Maneuverability. Findings included:

(a) Lack of clear understanding and uniformity in applying the regulations due to complexity of the issue.

(b) Need for uniform and detailed guidance.

(c) Shortage of basic data on the subject.

(2) Before 1994, no uniform quantitative criteria or standardized acceptance procedures were available to show compliance with Title 14 CFR part 23, § 23.143 or its predecessor, CAR Part 3, § 3.106. In 1994, after examining available engineering data and its own guidance on this subject, the FAA decided to give more detailed and uniform guidance on demonstrating compliance. The FAA issued policy letters applicable to all airplanes and sponsored research with NASA to understand better ice contaminated tailplane stall. Based on the results of the data and guidance review, and with input from the joint FAA/NASA research project, the FAA determined that guidance would be helpful for two steps in the process leading to certification. The first step is the design phase when the preliminary design parameters of the airplane are determined. The second step is the method of evaluation of compliance with the regulations.

(a) During the design process, the manufacturer can evaluate airplane response characteristics and efficiently resolve serious problems using various modeling tools such as wind tunnel testing and computational fluid dynamics analysis. This AC does not address this process.

(b) Susceptibility of an airplane design to ICTS should be considered when demonstrating compliance to the pitch control requirements of CFR 23.143. The demonstration should include:

1. flight at the critical airspeed;

2. artificial ice accretions on the horizontal tailplane; and

3. flight testing in the critical trailing edge flap and power configuration.

(3) In 2001, the FAA incorporated the 1994 policy letters into AC 23.143-1, "Ice Contaminated Tailplane Stall."

(4) The guidance in AC 23.143-1 has been incorporated into this AC and AC 23.143-1 has been cancelled.

d. When can ICTS occur?

(1) Tailplane stall can occur with ice accretions on the tailplane when:

(a) wing flaps are extended;

(b) engine power is increased;

(c) the pilot makes a nose-down control input;

(d) the airplane increases speed or encounters gust conditions; or

(e) a combination of these factors with flaps extended.

(2) Tailplane stall has been reported on several airplane type designs with small quantities of ice observed on the airplane. In some cases, the critical ice accretion for susceptibility to ICTS has been a thin rough layer of ice on the protected and unprotected portions of the leading edge that accretes during the time that:

(a) The airplane enters icing conditions.

(b) The flightcrew recognizes the icing conditions and activates the ice protection system.

(c) The ice protection system performs its intended function.

(3) Since flaps are normally only extended to the landing position during final approach to landing, an ICTS event under these conditions has a high probability of being catastrophic due to the associated low ground clearance

e. What are some pilot cues to ICTS? Pilots may sense ICTS or impending ICTS as one or a combination of:

(1) difficulty to trim in the pitch axis;

(2) a pulsing or buffeting of the longitudinal control; or

(3) a lightening of longitudinal control push force (or an increase in pull force) necessary to command a new pitch attitude.

f. How does a pilot recover from ICTS? These may not be recognized as cues of ICTS. The pilot may incorrectly interpret these cues as aerodynamic warning of an impending wing stall and perform the wrong, possibly catastrophic, corrective action since recovery techniques for a wing stall are opposite those of an ICTS. It is critical for the pilot to promptly and correctly diagnose the abnormal condition and apply the right corrective measures, which typically are a pull up, flap retraction, and power reduction.

2. FACTORS AFFECTING SUSCEPTIBILITY OF AN AIRPLANE TO ICTS.

a. Airplane Design Variables. The aft location of the tailplane relative to the wing, the lift generated by the wing, and the spanwise lift distribution of the wing will affect the wing downwash induced tailplane AOA. Lift generated by wings with airfoils capable of high lift and equipped with efficient trailing edge flaps may induce a significant increase in the tailplane AOA. The airplane AOA, the wing downwash induced AOA, the tailplane fixed incidence angle, the tailplane design stall AOA, and the adverse effects of surface roughness on the tailplane stall AOA all influence the tailplane AOA margin and susceptibility to stall.

b. Tail Design Variables.

(1) Vertical position of the horizontal tail and the aerodynamic effects of the surfaces forward of the horizontal tail. ("T", cruciform, conventional).

(2) Fixed incidence tailplane with elevator and trim tab.

(3) Variable Incidence Tailplane (VIT) with elevator.

(4) All-moving tailplane (stabilator) with and without a trim-servo tab.

(5) Characteristics of vertical stabilizer interaction with T and cruciform tails.

(6) C_{LMax}, Coefficient of Maximum Lift of wing and tailplane.

c. Center of Gravity (CG). Most forward CG loading conditions are usually most adverse to 1-g tailplane stall because of the greater balancing down load required by the tail. A greater download on the tail is developed by either increased incidence on a VIT, or greater trailing edge up deflection of the elevator.

d. Flap Extension. Extension of flaps increases the downwash at the tail and moves the wing center of lift aft, increasing nose-down pitching moment and requiring more tail download. In addition, the AOA of the airplane is reduced for the same lift. The tail is subjected to a negative increase in local AOA. The extension of wing flaps, therefore, brings the horizontal tail closer to its stall AOA. Extending flaps from the retracted position may involve an increase in effective wing chord as well as an increase in camber. These changes in wing geometry:

(1) shift the center of pressure aft;

(2) increase the nose-down pitching moment;

(3) increase the wing lift coefficient at the same AOA; and

(4) likely increase the local airflow downwash angle aft of the flaps (even for T-tail configurations).

Because of these tests, maximum landing flap extension may be defined at an intermediate position which then must become an airplane limitation for flights into icing conditions. In this instance, landing gear position warnings as a function of flap position and degraded landing performance data should be considered.

e. Speed/Load Factor. In 1-g flight, higher airspeeds result in reduced aircraft AOA and a more negative tailplane AOA. For the same reasons as described in paragraph 4 above, higher speed is more adverse to ICTS in 1-g flight. Also, during dynamic maneuvers (such as pushovers), lower speeds put the tailplane at a more critical state (more negative AOA) due to the ability to generate higher pitch rates.

f. Engine Power. The effects of power or thrust on ICTS susceptibility are airplane specific. Increasing engine power on high thrust line aircraft (thrust line above the CG) requires more nose-up trim. This raises the risk of ICTS. In addition, increasing engine power on propeller driven airplanes tends to be adverse to ICTS due to increases in strength and angle of wing downwash, especially with flaps extended.

g. Maneuvering. There are two elements of maneuvering that increase vulnerability to ICTS: nose-down pitch control input, and for some configurations, sideslip.

(1) Nose-down pitch control input. When the elevator is deflected to the nose-down position, horizontal tail camber is changed and tail lift is reduced. Since a nose-down pitching moment exists that is not completely balanced by the tail, the airplane will pitch nose-down and there will be angular rotation rate about the CG. The resultant aerodynamic effect on the horizontal tailplane due to this rotation rate in the nose-down direction is an increased negative AOA which may increase susceptibility to tailplane stall.

(2) Side slip. On "T" and cruciform tail configurations, local flow separation on the tailplane can start with sideslip due to initiation of separation at the junction of the horizontal and vertical stabilizer. This condition is worsened by ice accretions on the vertical stabilizer or structure forward of the horizontal stabilizer even if, in some cases, the horizontal tail leading edge is uncontaminated. The effects of a contaminated vertical stabilizer should also be considered when evaluating the susceptibility of a contaminated horizontal tailplane to ICTS in a sideslip. On low tail configurations, impingement of flap tip vortices on the empennage may result in elevator self deflection and lead to similar control problems in the pitch axis. Sideslip can also result in asymmetric conditions on the horizontal stabilizer due to prop wash effects. Airplanes without counter-rotating propellers produce asymmetric local flow conditions. The steady heading sideslip should evaluate the effects of both left and right sideslip conditions.

h. Gusts and Turbulence. Gust or airplane gust response may contribute to ICTS. Gusts may occur parallel to any airplane axis. The direct effect of a gust on the resultant airflow may be adverse. The flight tests should be robust enough to evaluate the characteristics of the tail for various combinations of conditions.

APPENDIX 8. AFM LIMITATIONS AND NORMAL PROCEDURES SECTIONS

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

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

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

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

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

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

NOTE 7: The prohibition on flight in freezing rain or freezing drizzle is not intended to prohibit purely inadvertent encounters with the specified meteorological conditions; however, pilots should make all reasonable efforts to avoid such encounters and must immediately exit the conditions if they are encountered.

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

NOTE 8: The autopilot may mask tactile cues that indicate adverse changes in handling characteristics; therefore, the pilot should consider not using the autopilot when any ice is visible on the airplane.

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

NOTE 9: This supersedes any relief provided by the Master Minimum Equipment List (MMEL)."

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

WARNING

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

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

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

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

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

- Report these weather conditions to air traffic control.

CAUTION

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(8) Report these weather conditions to ATC.

NOTE 10: An alternate means of providing this information in the AFM may be approved by the certifying agency.