U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
ARC Charter

Effective Date: 2/19/2010

SUBJ: Part 23 Icing Aviation Rulemaking Committee

1. Purpose of this Charter. This charter creates the Part 23 Icing Certification Aviation Rulemaking Committee (ARC) according to the Administrator's authority under Title 49 of the United States Code (49 U.S.C.) § 106(p)(5). This charter also outlines the committee's organization, responsibilities, and tasks.

2. Audience. We have written this charter for employees within the Office of the Associate Administrator for Aviation Safety. The audience for this charter also includes employees of the Office of the General Counsel and the Office of Aviation Policy and Plans.

3. Background. On October 31, 1994, an accident involving an Aerospatiale Model ATR72 series airplane occurred in which icing conditions, believed to include freezing drizzle drops, were reported in the area. The FAA and others conducted an extensive investigation of this accident. This investigation led to the conclusion that freezing drizzle conditions created a ridge of ice on the wing's upper surface aft of the deicing boots and forward of the ailerons. The NTSB concluded that the ridge of ice resulted in uncommanded roll of the airplane. The atmospheric conditions (freezing drizzle) that may have contributed to the accident are outside the icing envelope specified in Appendix C of part 25 of the Federal Aviation Regulations (14 CFR part 25) for certification of the airplane. Freezing rain is another atmospheric condition that also is outside the icing envelope. These conditions constitute an icing environment known as supercooled large drops (SLD). Appendix C of part 25 is also used for certification of part 23 airplanes for icing. The effects of SLD on part 23 airplanes are more significant than they are on part 25 airplanes. The smaller size of part 23 airplanes results in a larger collection efficiency, aerodynamic penalties are higher due to their smaller scale, they typically have reversible flight controls, and their power thrust margins are smaller. Accident reviews have shown most SLD events belonged to small airplanes (14 CFR part 23).

a. The NTSB issued various safety recommendations to the FAA following the Model ATR72 accident. One of the recommendations, A-96-56, states in part that:

> If the manufacturer cannot demonstrate safe operations in certain icing conditions, operational limitations should be imposed to prohibit flight in such conditions. Flightcrews should also be provided with the means to determine positively when they are in icing conditions that exceed the limits for aircraft certification.

b. Another recommendation, A-96-54, states:

> Revise the icing criteria published in 14 Code of Federal Regulations (CFR), parts 23 and 25, in light of both recent research into aircraft ice accretion under varying conditions of liquid water content, drop size distribution, and temperature, and recent developments in both the design and use of aircraft. Also, expand the appendix C icing certification

Distribution: A-W (VS)-2, A-X (VS)-2 Initiated By: ACE-111 envelope to include freezing drizzle/freezing rain and mixed water/ice crystal conditions, as necessary.

c. In response to these NTSB safety recommendations, the FAA tasked the Aviation Rulemaking Advisory Committee (ARAC) on December 8, 1997 (62 FR 64621). Their task was to define an icing environment that includes supercooled large drops (SLD) and devise requirements to assess the ability of aircraft to safely operate either for the time to exit or to operate without restriction in SLD conditions. The ARAC was asked to consider the need to define a mixed phase icing environment (supercooled liquid and ice crystals). They were also tasked to study the effects icing requirement changes could have on pilot compartment view, airspeed indicating system, static pressure systems, and angle-of-attack systems. The task was revised in June 2000 to address 14 CFR part 25 only.

d. In December 2005, the Aviation Rulemaking Advisory Committee's (ARAC) Ice Protection Harmonization Working Group (HWG) completed their final report on recommended rulemaking and advisory material related to supercooled large drop (SLD) conditions and ice crystal/mixed phase conditions. The committee's work had the support of the Flight Test HWG, the Powerplant Installation HWG, and the Engine HWG. The report included recommendations for a new appendix to 14 CFR part 25, defining an SLD environment, and a new 14 CFR part 33, Appendix D to address ice crystal/mixed phase conditions. Included in the report are recommendations addressing 14 CFR part 25 aircraft performance and handling qualities, engine installation effects, ice protection system requirements, and 14 CFR part 33 engine requirements. ARAC approved the report and sent it to the FAA in March 2006.

4. Organization and Administration of the Part 23 Icing Certification ARC. We will set up a committee of members of the aviation community, including airplane icing specialists representing diverse viewpoints. FAA participation and support will come from all affected lines-of-business. Where necessary, the committee may set up specialized work groups that include at least one committee member and invited subject matter experts from industry and government.

The charter is set up as follows:

a. The committee sponsor is the Manager, Small Airplane Directorate, who:

(1) Appoints members or organizations to the committee, at the manager's sole discretion;

(2) Receives all committee recommendations and reports;

(3) Selects industry and FAA co-chairpersons for the committee; and

(4) Provides administrative support for the committee, through the Aircraft Certification Service.

b. The co-chairpersons will:

(1) Determine (with other committee members) when a meeting is required (a quorum is desirable at committee meetings, but not required);

(2) Arrange notification to all members of the time and place of each meeting;

(3) Draft an agenda for each meeting and conduct the meeting;

(4) Keep meeting minutes; and

(5) Provide status updates to the Manager, Small Airplane Directorate, at 6 months and 12 months from the effective date of this charter.

5. Committee Membership

a. The committee will consist of members from the Federal Aviation Administration, Small Airplane Directorate and selected Aircraft Certification Offices. It will also consist of about 20 members, representing manufacturers of part 23 airplanes approved for known icing, consultant designated engineering representatives (DERs) who have certified part 23 airplanes for icing, operators of part 23 airplanes approved for icing, pilot unions, and aviation associations.

b. Each member or participant on the committee should represent an identified part of the aviation community and have the authority to speak for that community. Membership on the committee will be limited to promote discussions. Active participation and commitment by members will be essential for achieving the committee objectives and for continued membership on the committee. The committee may invite additional participants as subject matter experts to support specialized work groups.

6. Public Participation. Persons or organizations outside the committee who wish to attend a meeting must get approval in advance of the meeting from a committee co-chairperson or designated federal representative.

7. Committee Procedures and Tasks.

a. The committee advises and provides written recommendations to the Manager, Small Airplane Directorate, ACE-100.

b. Committee tasks include, but are not limited to, the following:

(1) Review the ARAC recommendations related to the proposed part 25 regulations and guidance for SLD, mixed phase, and ice crystals, and recommend how they need to be modified for part 23.

(2) Recommend part 23 regulations that will codify the guidance in Advisory Circular 23.1419-2D on activation and operation of ice protection systems, stall warning in icing conditions, and ice contaminated tailplane stall (ICTS).

(3) Recommend revisions to current § 23.1419 on airplane performance requirements in icing that require an exemption to the 61 knot stall speed requirement in icing.

(4) Determine applicable accidents and incidents that can be used for benefits in the economic analysis.

(5) Summarize certification and operating costs associated with the recommended regulations that can be used in the economic analysis.

(6) Identify compliance guidance that will be required to facilitate showing compliance with the recommendations above.

(7) Identify impact on operations in known and forecast icing and make recommendations for icing operations and training.

(8) Determine if using 1g stall speed criteria in icing is an option to reduce approach speeds and landing distances in icing conditions.

c. The committee may propose additional tasks as necessary to the Manager, Small Airplane Directorate, for approval.

d. The ARC will submit a report detailing recommendations for tasks (1) through (6) not later than 2 months from the effective date of this charter. The ARC will submit a report detailing recommendations for tasks (7) through (8) not later than 18 months from the effective date of this charter. The Manager, Small Airplane Directorate, may extend each deadline up to 6 months, if it is in the interest of the FAA to do so.

8. Cost and Compensation. The estimated cost to the Federal Government for the Part 23 Icing ARC is approximately $20,000 annually. All travel costs for government employees will be the responsibility of the government employee's organization. Non-government representatives, including the industry co-chair, serve without government compensation and bear all costs related to their participation on the committee.

9. Availability of Records. Subject to the conditions of the Freedom of Information Act, 5 U.S.C. 552, records, reports, agendas, working papers, and other documents made available to, prepared for, or prepared by the committee will be available for public inspection and copying at the FAA Small Airplane Directorate, 901 Locust, Kansas City, Missouri 64106. Fees will be charged for information furnished to the public according to the fee schedule published in 49 CFR part 7.

10. Committee Term. This committee becomes an entity on the effective date of this charter. The committee will remain in existence for a term of 24 months unless its term is ended sooner or extended by the Manager, Small Airplane Directorate.

11. Distribution. This charter is distributed to director-level management in the Office of the Associate Administrator for Aviation Safety; the Office of the Chief Counsel, the Office of Aviation Policy and Plans, and the Office of Rulemaking.

Administrator

10 February 2012

IN REPLY, REFER TO
L374-44-12-001

Mr. Earl Lawrence
Manager, Small Airplane Directorate
901 Locust St.
Kansas City, MO 64106

Dear Mr. Lawrence:

This letter submits Revision B of Part 23 Icing Aviation Rulemaking Committee (ARC) report which includes recommendations for Task 9 – “Determine if implementation of NTSB Safety Recommendation A-10-12 is feasible for part 23 airplanes for operations in icing conditions”.

HARMONIZATION STATUS

Foreign airworthiness authorities are not permitted to be “voting” members of an Aviation Rulemaking Committee but can participate as “observers” to allow them to share their experiences and perspectives. Transport Canada, Agência Nacional de Aviação Civil (ANAC), and the European Aviation Safety Agency (EASA) were invited to participate. Relative to the Task 9 discussions, the ARC had participation from ANAC, but not EASA. A Transport Canada representative provided comments on the ARC report based on a limited review and without the benefit of participation in the ARC discussions. The comments addressed Task 9 and additionally, tasking recommendations already completed by the ARC. As such, it is recommended that the FAA take the comments under consideration outside of the ARC process.

CONSENSUS

Consensus was achieved on the concepts recommended, however, agreement was not reached on which specific rule should be revised. Discussion on the options is included in the report revision.

CONCLUSION

In conclusion, the transmittal of the report revision concludes the assigned tasking for the Part 23 Icing Aviation Rulemaking Committee (ARC). On behalf of the members of the ARC, we appreciate the opportunity to participate in the rulemaking process.

Sincerely,

Jim R. Hoppins
Principal Engr., Ice Protection Systems, Cessna Aircraft
Industry Co-Chair, Part 23 Icing Aviation Rulemaking Committee

cc: John Colomy
Pat Mullen
Paul Pellicano

PART 23 ICING AVIATION RULEMAKING COMMITTEE REPORT

Revision B – February 2012

REVISION TRACKING

Revision - n/c (Jan 2011)

Location of change	Description
n/a	Original Release

Revision – A (April 2011)

Location of change	Description
Table 1	Added red font color under “Part 23” column – omitted by error. Added tables notes in the “Legend and Notes” section – omitted by error.
Section 1	Updated summary progress table
Section 7	Added Section 7 “Certification Cost Input” to provide cost estimates to the FAA economist for the proposed rulemaking per Task 5
Section 8	Added Section 8 “Operating Cost” to address Task 5 and Task 7.
Section 9	Added Section 9 “Benefit Summary” to discuss applicable safety events applicable to the proposed rulemaking per Task 4.
Section 10	Added Section 10 “Training Recommendations” to Task 7.
Appendix E	Added Appendix E – Operations Cost Survey
Appendix F	Added Appendix F – GAMA Icing Accident Survey
Misc	Updated table of contents, table of tables, table of appendices as required Updated abbreviations and acronyms as required Minor typographical edits

Revision – B (Feb 2012)

Location of change	Description
Section 1	Changed status of Task 9 to completed
Section 2 last paragraph on Task 9 status	Was “This task will be completed after recommendations are submitted for SLD and ice crystals, but prior to development of an NPRM so that any proposed rules can be bundled with the SLD and ice crystal rules.”
Section 11	Added Section 11 to address Task 9

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ABBREVIATIONS & ACRONYMS

Item	Description
µm	Micron (one millionth of a meter)
2EI	Two engines inoperative
3D	Three Dimensional
AEO	All Engines Operating
AFM	Aircraft Flight Manual
AIA	Aerospace Industries Association
AIM	Aeronautical Information Manual
AOA	Angle of Attack
APO	FAA Office of Aviation Policy and Plans
Appendix C	14 CFR 25, Appendix C
Appendix O	Proposed 14 CFR 25 new appendix
ARAC	Aviation Rulemaking Advisory Committee
ARC	Aviation Rulemaking Committee
ASOS / AWOS	Automated Surface or Weather Observing System
ASRS	Aviation Safety Reporting System
ATC	Air Traffic Control
ATP	Airline Transport Pilot
CFD	Computational Fluid Dynamics
CG	Center of Gravity
CS	Certification Standard
EHWG	Engine Harmonization Working Group
ELOS	Equivalent Level of Safety
FAA AIDS	FAA Accident/Incident Database
FAAST	FAA Safety Team
FADEC	Full Authority Digital Engine Control
FCS	Flight Control System
FIKI	Industry abbreviation used generically for aircraft certified for flight in icing
FITS	FAA Industry Training Standard
FTHWG	Flight Test Harmonization Working Group
FZDZ	Freezing Drizzle
FZRA	Freezing Rain
GA	Go Around
GAMA	General Aviation Manufacturers Association
GD / GU	Gear Down or Gear Up (landing gear)
GW	Gross Weight
ICTS	Ice Contaminated Tailplane Stall
IDS	Ice Detection System
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IPHWG	Ice Protection Harmonization Working Group
IPS	Ice Protection System
LWC	Liquid Water Content
MD	Minor Damage
MSL	Mean sea level
MVD	Median Volume Diameter
NATA	National Air Transportation Association
NOAA	National Oceanic and Atmospheric Administration
NPRM	Notice of Proposed Rulemaking
NPRM	Notice of Proposed Rulemaking
NTSB	National Transportation Safety Board
OEI	One Engine Inoperative

ABBREVIATIONS & ACRONYMS

Item	Description
PIDS	Primary Ice Detection System
PIREP	Pilot Report
POH	Pilot Operating Handbook
PTS	Pilot Test Standards
RACCA	Regional Air Cargo Carriers Association
S&C	Stability and Control
SD	Substantial Damage
SLD	Supercooled large drops
STC	Supplemental Type Certificate
SW	Stall Warning
TKS	Industry abbreviation used generically for fluid depressant ice protection systems
TO	Takeoff
Type II, III or IV	Type of Ground Deicing/Anti-Icing Fluids (reference SAE AMS 1428)
X-Wind	Crosswind
ZL	Freezing Drizzle
ZR	Freezing Rain

1. SUMMARY

The Part 23 Icing Aviation Rulemaking Committee was formed in early 2010 by FAA charter to consider the following tasking. The specific tasking requested of the ARC was and status is as follows:

No.	Task and Status
1	Review the ARAC recommendations related to the proposed part 25 regulations and guidance for SLD, mixed phase, and ice crystals, and recommend how they need to be modified for part 23.
	Completed
2	Recommend part 23 regulations that will codify the guidance in Advisory Circular 23.1419-2D on activation and operation of ice protection systems, stall warning in icing conditions, and ice contaminated tailplane stall (ICTS).
	Completed
3	Recommend revision to current § 23.1419 on airplane performance requirements in icing that require an exemption to the 61 knot stall speed requirement in icing.
	Completed
4	Determine applicable accidents and incidents that can be used for benefits in the economic analysis.
	Completed by Revision A
5	Summarize certification and operating costs associated with the recommended regulations that can be used in the economic analysis.
	Completed by Revision A
6	Identify compliance guidance that will be required to facilitate showing compliance with the recommendations above.
	Completed
7	Identify impact on operations in known and forecast icing and make recommendations for icing operations and training.
	Completed by Revision A
8	Determine if using 1g stall speed criteria in icing is an option to reduce approach speeds and landing distances in icing conditions.
	Completed
9	Determine if implementation of NTSB Safety Recommendation A-10-12 is feasible for part 23 airplanes for operations in icing conditions (tasking added Q3 2010).
	Completed

2. BACKGROUND

On October 31, 1994, an accident involving an Aerospatiale Model ATR72 series airplane occurred in which icing conditions, believed to include freezing drizzle drops, were reported in the area. The FAA and others have conducted an extensive investigation of this accident. This investigation led to the conclusion that freezing drizzle conditions created a ridge of ice on the wing's upper surface aft of the deicing boots and forward of the ailerons. The NTSB concluded that the ridge of ice resulted in uncommanded roll of the airplane. The atmospheric conditions (freezing drizzle) that may have contributed to the accident are outside the icing envelope specified in Appendix C of part 25 of the Federal Aviation Regulations (14 CFR part 25) for certification of the airplane. Freezing rain is another atmospheric condition that also is outside the icing envelope. These conditions constitute an icing environment known as supercooled large drops (SLD). Appendix C of part 25 is also used for certification of part 23 airplanes for icing. The effects of SLD on part 23 airplanes are more significant than they are on part 25 airplanes. The smaller size of part 23 airplanes results in a larger collection efficiency, aerodynamic penalties are higher due to their smaller scale, they typically have reversible flight controls, and their power thrust margins are smaller. Accident reviews have shown the majority of SLD events belonged to small aircraft (14 CFR part 23). The operating rules do not prohibit operations in supercooled large drop conditions.

The NTSB issued various safety recommendations to the FAA following the Model ATR72 accident. One of the recommendations, A-96-56, states in part that:

> If the manufacturer cannot demonstrate safe operations in certain icing conditions, operational limitations should be imposed to prohibit flight in such conditions. Flightcrews should also be provided with the means to positively determine when they are in icing conditions that exceed the limits for aircraft certification.

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> Revise the icing criteria published in 14 Code of Federal Regulations (CFR), parts 23 and 25, in light of both recent research into aircraft ice accretion under varying conditions of liquid water content, drop size distribution, and temperature, and recent developments in both the design and use of aircraft. Also, expand the appendix C icing certification envelope to include freezing drizzle/freezing rain and mixed water/ice crystal conditions, as necessary.

The FAA tasked the Aviation Rulemaking Advisory Committee (ARAC) on December 8, 1997 (62 FR 64621) in response to the NTSB safety recommendations. Their task was to define an icing environment that includes supercooled large drops (SLD) and devise requirements to assess the ability of aircraft to safely operate either for the time to exit or to operate without restriction in SLD conditions. The ARAC was tasked to consider the need to define a mixed phase icing environment (supercooled liquid and ice crystals). They were also asked to study the effects icing requirement changes could have on pilot compartment view, airspeed indicating system, static pressure systems, and angle-of-attack systems. The task was revised in June 2000 to address 14 CFR part 25 only.

In December 2005, the Aviation Rulemaking Advisory Committee's (ARAC) Ice Protection Harmonization Working Group (HWG) completed their final report on recommended rulemaking and advisory material related to supercooled large drop (SLD) conditions and ice crystal/mixed phase conditions. The committee's work had the support of the Flight Test HWG, the Powerplant Installation HWG, and the Engine HWG. The report included recommendations for a new appendix to 14 CFR part 25, defining an SLD environment, and a new 14 CFR part 33, Appendix D to address ice crystal/mixed phase conditions. Included in the report are recommendations addressing 14 CFR part 25 aircraft performance and handling qualities, engine installation effects, ice protection system requirements, and 14 CFR part 33 engine requirements. ARAC approved the report and sent it to the FAA in March 2006. The Ice Protection Harmonization Working Group has recently completed a review of available tools for compliance and revised the recommended guidance material. The ARAC report can be found at:

http://www.faa.gov/regulations_policies/rulemaking/committees/arac/media/tae/TAE_IP_T2.pdf

A Notice of Proposed Rulemaking (Docket No. FAA–2010–0636) was published in the Federal Register on June 29, 2010.

An Aviation Rulemaking Committee (ARC) was chartered to review the proposed part 25 regulations and guidance for SLD, mixed phase, and ice crystals, that have been recommended by ARAC, and to recommend how they need to be modified for part 23. The charter is in Appendix A.

The ARC task was not to produce an SLD rule from scratch, but to review the proposed part 25 rule and compliance guidance already recommended by an ARAC Issue Group (Transport Airplane and Engine, TAEIG) for applicability to part 23. An ARC was requested, rather than an ARAC tasking, to limit membership to airplane manufacturers that have certificated part 23 airplanes for flight in icing, Designated Engineering Representatives (DER) that have certified ice protection systems more common on part 23 airplanes, such as pneumatic, fluid, and electro-thermal, operators of those part 23 airplanes or groups that represent operators, and organizations who participated in the TAEIG working group, such as Transport Canada and EASA. The ARC still allowed subject matter experts to be brought in to provide background information. ARC membership is in Appendix B.

The FAA has already taken action on part 23 airplanes, equipped with pneumatic boots and reversible lateral control, related to SLD. The FAA issued 25 Airworthiness Directives from 1996 to 1998 requiring incorporation of AFM Limitations and procedures to recognize SLD and immediately exit severe icing. A list of the ADs is in Appendix C.

The FAA also issued a generic issue paper "Roll Control in Supercooled Large Droplet Conditions" in July 1997 that has been applied for new certifications on aircraft equipped with reversible roll axis controls and pneumatic de-icing boots. The issue paper provided some protection against loss of control by providing for means to evaluate susceptibility to roll control in SLD conditions. However, it was not intended to certify an airplane for unrestricted flight in supercooled large drops or any other conditions which are outside of the Appendix C icing envelope. The guidance in the issue paper was added to Advisory Circular 23.1419-2D and application expanded to any part 23 airplane without a fully evaporative wing anti-ice system. The issue paper can be found in the ARAC reports at the following link:

http://www.faa.gov/regulations_policies/rulemaking/committees/arac/media/tae/TAE_IP_T2.pdf

The scope of these actions is limited because they do not address the underlying safety concern of the unknown performance and handling safety margins for airplanes operating in freezing drizzle or freezing rain or a mixed phase. Any requirements resulting from these actions would not be comparable to those established by the current § 23.1419, which defines safe performance and handling qualities for flight in part 25, Appendix C icing conditions. The current rules do not address stall warning in SLD conditions, and they do not require an AFM limitation on intentionally flying into SLD.

As documented in the ARAC report, ice crystal conditions can affect engine operation and pitot probes. On part 23 airplanes, documented events of ice crystals affecting engine total temperature probes have been reported. Current certification addresses these effects on engine operation and critical systems through the issue paper process.

After the part 23 icing ARC charter was signed, an additional task was assigned to address NTSB safety recommendation A-10-12 for part 23 airplanes in icing conditions which states:

> For all airplanes engaged in commercial operations under 14 Code of Federal Regulations Parts 121, 135, and 91K, require the installation of low-airspeed alert systems that provide pilots with redundant aural and visual warnings of an impending hazardous low-speed condition.

This task was completed and Revision B of this report incorporates the ARC recommendations.

3. PREAMBLE DISCUSSION

A) SUBPART B ASPECTS (INCLUDING AUTOPILOT)

The proposed part 23 regulation for showing safe flight in Appendix O conditions is similar to the proposed part 25 regulation. The same three options are provided. The only difference is "capable of operating safely" is defined by reference to the applicable 23.21(c) paragraph. Section 23.21 is amended by the addition of paragraph (c). This paragraph defines the Subpart B regulations for which compliance must be shown with Appendix C and Appendix O ice accretions. As a result, the definition of "capable of operating safely" currently in § 23.1419(a) is deleted.

The ARAC proposal for compliance to part 25 Subpart B regulations with Appendix O ice accretions was reviewed. The part 23 ARC agreed with the ARAC recommendation that the regulations required for Appendix C be also applicable for Appendix O, for those airplanes that are approved for Appendix O. This includes the addition of takeoff requirements with gear down, where it may not be accurate to assume ice accretion may be negligible. The ARC identified a requirement for a separate part II of Appendix O, due to differences in the scenarios for ice accretion based on operations for part 23 aircraft. Also, the proposed part 25, Appendix O, part II directly references part 25 regulations which are not appropriate for part 23. The part 23 definitions for ice shapes are recommended to be incorporated into a new part 23 Appendix TBD, with Part I of the proposed Appendix defining ice shapes that may occur in 14 CFR Part 25, Appendix C icing conditions and Part II of the proposed Appendix ice shapes that may occur in 14 CFR Part 25, Appendix O icing conditions. Reference section 4B of this report for details on the recommended ice shape definitions.

The part 23 ARC agreed with the ARAC recommendation that allow an option to certify an airplane to a portion of Appendix O. The Subpart B regulations required to show safe operation in the approved portion of Appendix O are the same as those for Appendix C. The part 23 icing ARC also agrees that certifying to a portion of Appendix O in-flight will be difficult with current technology. Applicable guidance was added to the proposed advisory circular to address the concerns.

The part 25 proposed guidance has detailed information on the limitations to accomplish such a certification. The material was included as Appendix 7 of the proposed advisory circular. The part 23 ARC recommends that this material eventually be moved to AC 20-73 since it is applicable to both part 23 and part 25 airplanes.

The part 23 icing ARC agrees with ARAC that certifying an airplane to a certain phase of flight in Appendix O conditions is achievable. The ARC believes certifying to takeoff in Appendix O conditions would be the most common phases of flight certified because one, operators surveyed stated such an airplane is desirable to minimize impact on operations, and two, it may be easier to certify compared to the holding phase. The guidance for takeoff in Appendix O conditions assumes the airplane will not hold in Appendix O conditions, but for landing, certification must consider a detect and exit holding ice shape. Guidance is included in the draft part 23 advisory material.

The part 23 icing ARC discussed whether certification for takeoff (and/or landing) can be done to either freezing drizzle or freezing rain. The majority and minority positions on ARAC were reviewed, as well as current weather reporting technology. The ARC acknowledged the ARAC minority position on the percentage of freezing rain events being misreported as freezing drizzle, and believes this may be common since FAA experience is that snow intensities (currently based on visibility) are misreported half the time. The ARC also considered that part 23 airplanes operate at many airports with no weather observers. Although the airports with no human observers may have AWOS or ASOS, the current technologies of these systems prevent them from reporting freezing drizzle. The ARC believes the average pilot of a part 23 airplane will not be able to consistently distinguish drizzle from rain. The part 25 majority acknowledged that misdiagnosis can occur in discriminating between freezing drizzle and rain, and supports improvements in practices and technology to improve reporting accuracy. However, the IPHWG judged that the conservatism inherent in the certification practices would result in safe operations. This conservatism includes assuming a 12,000 foot vertical extent, 99% LWC and an engine out during the climb (per § 25.111 requirements).

Another issue is after takeoff, one must assume that FZDZ conditions can change to FZRA conditions, or vice versa. When this occurs, an in-flight cue for exceedance of certified conditions is mandatory. Technology may be available in 5-7 years to determine the drop sizes aloft in terminal areas, but that would only apply to larger, commercial airports. It may also be possible in the future for aircraft to develop in-flight cues for these types of exceedance, due to advances in weather reporting technology and experience with certification of various ice accretions. For now, operational issues preclude certifying a part 23 airplane to takeoff (and/or land) in FZDZ or FZRA alone, and no guidance is provided at this time. However, the ARC believes the regulation should allow the option to certify an aircraft for either condition in anticipation of future technologies and advancements.

The part 23 icing ARC recognized that Type II and IV ground deicing fluids have not been approved for many part 23 airplanes, not because it is not possible but because airplane manufacturers have not sought the approval. The part 23 icing ARC recognized that an airplane approved for takeoff in freezing drizzle and light freezing rain will accrete ice before lift-off if not treated with these fluids (The short hold-over times provided by Type I in these conditions make takeoff prior to hold-over time expiration difficult). Therefore, any aircraft that sought approval for takeoff in FZDZ or FZRA conditions would require that the aircraft meet published AFM/POH limitations and procedures. This may require prior manufacturer approval of Type II, III and IV ground deicing/anti-icing fluids.

The part 23 icing ARC took a slightly different approach than the part 25 ARAC group for “detect and exit”. For "operating safely after encountering Appendix O conditions" and "operating safely while exiting all icing conditions", the part 25 ARAC considered that these are not failure cases and the temptation to link this text with the phrase "continued safe flight and landing", commonly used in association with system failure conditions, should be resisted. The part 25 ARAC considered "detect and exit" cases as normal flight conditions arising from an inadvertent encounter with Appendix O icing conditions. Hence, the ARAC considered it appropriate to make "detect and exit" for Appendix O an integral part of any icing certification for Appendix C icing conditions i.e. if an Appendix C icing certification is sought, then "detect and exit" for Appendix O must also be addressed. The part 23 icing ARC agreed that detect and exit of Appendix O must be considered for a known icing approved airplane, but considered it conservative for part 23 airplanes. The part 23 ARC recognized that part 23 airplanes have more flexibility in divert options, and continued flight after an SLD encounter may occur less frequently. The part 25 ARAC considered all Subpart B regulations applicable to Appendix C should be applicable to “detect and exit”, with some exceptions. The part 23 icing ARC compared the inadvertent Appendix O encounter with an inadvertent icing encounter of an airplane not approved for icing. In the latter case, no Subpart B tests are required. However, the encounter with Appendix O is different in that pilot recognition of Appendix O versus Appendix C is not as black and white as ice/no ice. The ARC also considered that Appendix O ice accretions may be more critical than Appendix C, and an airplane certified for Appendix C should be shown to be safe following an encounter with Appendix O. In reviewing the Subpart B requirements for detect and exit, the ARC tried to avoid requirements that could dictate design for an environmental condition for which the airplane is not certified. The ARC decided that the regulations should address the safety issues that have been learned in Appendix O accidents. These are addressed in the following paragraphs.

PERFORMANCE AND HANDLING QUALITIES FOR "DETECT AND EXIT"

Regarding specifically handling qualities and performance, the discussions in the FTHWG addressed the following issues:

- Performance – The part 25 ARAC assumed that the take-off case need not be considered for a "detect and exit" airplane. Hence, with the exception of stall speeds, landing speeds and distances and landing climb performance, the part 25 ARAC considered that performance need not be specifically addressed for "detect and exit" certification. The part 23 icing ARC agreed, with the exception of a quantitative requirement for landing climb performance. The part 23 icing ARC decided that the airplane should be able to go-around following an encounter with SLD, particularly since most part 23 events occurred near an airport during approach or landing. However, the ARC felt a demonstration of the ability to go-around was sufficient. The ARC did not want a quantitative requirement in an environment the airplane is not approved for to possibly dictate design. Another factor was that the number of SLD events in a go-around was small. Some ARC members raised the issue that the commuter category approach climb rule be required. The majority of the ARC decided that engine out need not be considered for detect and exit because of the limited probability of occurrence and prior history. No combinations of engine failures in SLD are noted in the event database.

Various members of the ARC also questioned why enroute climb performance was not considered for the SLD “detect and exit” airplane. The subpart B group considered this question and agreed that considering enroute ice was not necessary for the “detect and exit” scenario. For flight planning purposes, flight into any SLD conditions for a ”detect and exit” airplane would not be considered. However, enroute performance provided for an appendix C approved airplane would normally include the worst case ice shape tested. At a minimum, the enroute ice shape would be used to provide performance in icing conditions. The conclusion was that the detect and exit shapes would not provide enough of a difference in performance from that tested for appendix C approval to require investigation with the specific SLD shape.

- Handling qualities – The part 25 ARAC proposed, with one exception, that the same handling qualities as for flight in Appendix C icing conditions are retained. That exception was a take-off case, CS/FAR 25.143(c)(1), addressing controllability following engine failure at V_2. No justification for a relaxed standard of other handling qualities requirements could be identified, bearing in mind that "detect and exit" is not a failure case and that the airplane, once clear of all icing conditions but retaining the ice accretion, may continue in clear air for some time. The part 23 ARC did not recommend that all Subpart B controllability tests be accomplished for detect and exit, but did recommend tests that address service history of airplanes in icing. These include susceptibility to roll control anomalies and ice contaminated tailplane stall.

- Lateral controllability - The part 25 ARAC reviewed the JAA Interim Policy and the FAA ADs published to address roll controllability issues. Several manufacturers gave presentations of their experiences in addressing the FAA ADs during the part 25 rulemaking effort. The part 25 ARAC concluded that the existing requirement is adequate to address roll control but there is a need for additional advisory material. This has been added to AC 25-25. The part 23 icing ARC reviewed the similar guidance in AC 23.1419-2D and thought it should be made more clear. Part 23 differs from part 25 in that the 23 rule has a quantitative roll rate requirement. The ARC decided that lateral control evaluation should be conducted on a detect and exit airplane, but the roll rate should be qualitatively, not quantitatively, evaluated. Therefore the lateral control evaluation was added to Section 23.143. The ARC reviewed additional tests that were proposed by Transport Canada during the part 25 ARAC group work. These included lateral control during 10° bank to bank rolls at airspeeds down to stall warning, and lateral control during sideslips. The bank to bank tests were added as advisory material to 23.201. The ARC decided that lateral control can be evaluated during the sideslips conducted to evaluate susceptibility to ice contaminated tailplane stall.

- Stall warning – The ARC believed stall warning, provided by the same means as in non-icing, must be provided with critical detect and exit ice shapes. The ARC adopted the three second after stall warning margin requirement proposed for part 25, in lieu of the five knot margin required in Appendix C for part 23 airplanes. The rationale was to avoid designs in which a second icing stall warning schedule was required for SLD, the issue being workload and training. The ARC believed a stall warning system designed for five knot margin in Appendix C could also provide a three second margin in Appendix O. The ARC believed a three second margin provided sufficient time to prevent stall, especially in the approach and landing phases of flight where the majority of part 23 events occurred. Since detect and exit ice includes pre-detection ice, such a design would also provide stall warning with pre-detection ice, which the ARC believes is necessary. A separate rule for pre-detection was therefore not required. This follows the philosophy of the proposed part 25 rule published in the NPRM. Similar to part 25 as explained in the NPRM preamble, if a design with two icing stall warning schedules were proposed, special conditions would be required.

- Approach speed – It is likely that stall speeds could increase with detect and exit ice compared to Appendix C ice. The approach speed with Appendix C must be at least 1.3 times the stall speed with Appendix C icing. Approach speeds in icing are usually increased because the increase in stall speed with Appendix C ice is usually above the 3 knot/3% threshold proposed. The ARC was concerned with additional increases in approach speed and resulting increases in landing distances, and the possibility of overruns. The ARC proposed that the approach speed determined for Appendix C may be used for detect and exit if adequate maneuver margin is demonstrated at that speed with detect and exit ice accretions.

- Pre-activation ice – Stall warning and susceptibility to ice contaminated tailplane stall are evaluated with pre-activation ice in Appendix C icing conditions, under current part 23 guidance and part 25 regulations. Part 25 requires a one second margin after stall warning if the means of stall warning is the same as non-icing. If the means are different, part 25 allows three second margin and acceptable stall characteristics. Current part 23 guidance for Appendix C ice accretion does not have the three second option. The ARC did not adopt the ARAC recommendation to apply the Appendix C pre-activation ice stall warning requirements to Appendix O conditions. The ARC was concerned that applying the same requirements to Appendix O pre-activation ice may have an overall adverse affect on safety by increasing non-icing takeoff and landing speeds.

  Current Part 23 advisory material (AC 23.1419-2D) specifies that stall warning margin with Appendix C pre-activation ice be “positive…and adequate.” Compliance with this requirement is typically shown by decelerating the airplane at 1 kt/sec and demonstrating that a stall can be prevented when recovery is initiated one second after stall warning, similar to the test defined in 25.207(h). Since, by definition, this test must be conducted with the airplane configured as it is prior to IPS activation, any adjustment to the stall warning schedule implemented for icing conditions is not active. As a result, the airplane must meet this requirement with the non-icing stall warning schedule. Recent industry experience is that this requirement can drive the stall warning setting to a lower angle of attack (more stall warning margin) than would otherwise be selected. A low stall warning AOA can result in insufficient maneuver margin for takeoff and landing which potentially drives artificially high takeoff and landing speeds for all non-icing takeoffs and landings, which constitute the vast majority of operations. Higher takeoff and landing speeds are not desirable from safety (runway overruns) or airplane utility perspectives.

The ice shape roughness associated with Appendix O pre-activation conditions may be more critical for stall warning than for Appendix C pre-activation conditions which could in turn drive an even lower stall warning AOA setting which would further impact non-icing takeoff and landing speeds.

Testing ICTS susceptibility with pre-activation ice in Appendix O conditions may result in reduced flap deflections in non-icing conditions, increasing landing speeds further.

Examination of the Part 23 accident history does not show that accidents occurred because the pilot was unaware that the airplane was in icing conditions. Furthermore, the proposed requirements for IPS activation based on 1) operation in conditions conducive to icing (temperature and visible moisture), 2) first indication of ice accretion or 3) input from a primary ice detector are effective at minimizing unprotected exposure times in icing conditions. To further minimize risk of an event with pre-activation ice in Appendix O conditions, the ARC decided to require an Advisory or Primary Ice Detector for commuter category airplanes that would otherwise rely solely on visual cues (proposed § 23.1419(e)(2), which is what was proposed for part 25 airplanes. The ARC concluded that since airplanes will continue to be required to meet existing Appendix C pre-activation ice stall warning requirements and due to the potential negative effect on non-icing takeoff and landing speeds, an additional requirement to demonstrate stall warning with ice accretions representing the very small exposure time associated with pre-activation Appendix O conditions is unwarranted. Another potential mitigating feature is installation of a Low Airspeed Alert, which will activate at airspeeds higher than stall warning speed, but lower than operating speeds to prevent nuisance warnings. Low airspeed alert aspects are to be addressed under ARC task 9 which will be addressed as a follow-up recommendation to this report. For reliability requirements of ice detection systems see the discussion under systems aspects, reference § 23.1419.

- Pre-detection ice - The ARC adopted the same philosophy that stall warning and susceptibility to ICTS be evaluated with pre-detection ice. However, since detect and exit ice includes pre-detection ice, in most cases there would not be a requirement to test pre-detection ice. Exceptions may be if design of the stall warning system includes a unique schedule for SLD conditions (as discussed above in the "Stall Warning" paragraph), or there is an autopilot limitation against operation after detection of SLD conditions.

AUTOPILOT ASPECTS

No regulation changes were proposed, for part 25 to address autopilot operation in icing conditions. Icing is not referenced in § 25.1329, but there is detailed guidance in Advisory Circular 25.1329 on autopilot operation in part 25, Appendix C icing conditions. Change 1 to Advisory Circular 25.1329 was proposed and it adds "applicable" Appendix O conditions to the current Appendix C conditions listed as "normal conditions" for which the flight guidance system should be designed. Similarly, the ARC believes the current guidance on testing autopilots in Appendix C conditions is applicable to Appendix O conditions. The current guidance in AC 23.1419-2D, combined with the current part 23 regulations, have proved sufficient for evaluating the autopilot in Appendix C icing conditions. However, the ARC proposes a regulation for an autopilot disconnect indication as discussed later.

There is guidance in Advisory Circular 23.1419-2D on flight testing autopilots in icing conditions for which the airplane is certified. For severe icing conditions, current part 23 certification practice is similar to airworthiness action that was taken on most pneumatic boot equipped airplanes, with reversible lateral flight controls, in 1996-1997. The following was added to the Airplane Flight manual:

> Limitations section:
>
> "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: 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."
>
> Procedures section:
>
> "WARNING: 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."
>
> "Do not engage the autopilot. The autopilot may mask unusual control system forces."
>
> "If the autopilot is engaged, hold the control wheel firmly and disengage the autopilot."

The ARC decided that the autopilot should not have to be prohibited for flight in Appendix O conditions, particularly in the single pilot, IMC environment, if adequate testing was accomplished. The current part 25 guidance and proposed guidance in Change 1 of AC 25.1329 were used as starting points for proposed part 23 guidance. There is existing guidance in AC 23.1419-2D for evaluating the autopilot in icing conditions. The ARC proposes to consolidate the autopilot guidance for all icing conditions, Appendix C and Appendix O, into one section of the guidance for new type certificates. Appendix 3 of AC 23.1419-2D contains guidance on modified or new autopilots STC's on airplanes approved for flight in icing conditions.

Testing will be required with applicable Appendix O ice shapes (e.g. detect and exit) if autopilot use will be approved. An applicant still has the option to prohibit autopilot use for detect and exit aircraft in Appendix O icing conditions. However, since the autopilot may be engaged prior to pilot recognition of Appendix O conditions, autopilot flight testing has to include "pre-detection ice". If an autopilot is installed and approved for flight in non-icing conditions, or required in non-icing flight for compliance to § 23.1523, it will be required for flight in icing conditions based on operational requirements. Similarly, if an autopilot equipped airplane is approved for any portion or phase of flight in Appendix O conditions, the autopilot will be required to operate in those Appendix O conditions.

The guidance contains requirements for flight testing of ice shapes simulating critical Appendix C, detect and exit (or pre-detection), and the approved portions of Appendix O. The guidance material retains the requirements to test the autopilot in natural Appendix C icing conditions. It is expected that the autopilot will be flight tested in natural Appendix O conditions for which the airplane is approved. The ARC also recommends that the guidance in AC 23-17B on autopilot systems as a minimum reference the autopilot guidance in AC 23.1419-2D.

When choosing critical simulated ice for flight testing, the effect on autopilot performance and operation should be considered.

The proposed guidance includes flight testing symmetrical ice shapes, there is no proposal to flight test asymmetric ice shapes. However, the ARC believed that if autopilot use in Appendix O conditions was to be approved, unusual operating condition for which the autopilot is compensating must be addressed. This could include asymmetric lift due asymmetric wing ice shedding, or possibly the autopilot operating near its authority limit due to ice accretion effect on control power or hinge moment. The ATR Roselawn accident is one example in which automatic autopilot disconnect after reaching authority limit resulted in a loss of control. Although there are no such documented events in the part 23 fleet, this could be because of current practice of prohibiting autopilot use in severe icing, or it could be these events have occurred but not documented due to the lack of flight data recorders in the part 23 fleet The proposed change to AC 25.1329 adds asymmetric icing as a "Rare Normal" condition that should be addressed, and the ARC believes it should be addressed for part 23 airplanes. The ARC proposes a requirement for a "bark before bite" to permit the crew to manually disengage the autopilot and take control prior to any automatic autopilot disengagement that would result in a hazardous flight condition. A paragraph (i) is proposed to be added to Section 23.1329. This requirement would apply only if the autopilot is to be approved for use in Appendix O conditions, including detect and exit. The rule specifies an indication rather than an annunciation. There may be designs in which control position or bank angle would be an acceptable indication. Associated guidance is added to the draft AC 23.1419-2D revision.

B) SUMMARY TABLE OF SUBPART B PART 23 PROPOSALS VERSUS PART 25 PROPOSALS

The table below summarizes each Subpart B paragraph and the requirements proposed for part 23 detect and exit airplanes by the ARC versus proposed for part 25 by ARAC.

Table 1 - Comparison of Part 25 versus Part 23 Recommendations

Section	Title	Proposed Part 25	Part 23	Proposed Part 23 ARC
		Detect & Exit		Detect & Exit
25.21	Proof of compliance		23.21	
25.23	Load distribution limits		23.23	
25.25	Weight limits		23.25	
25.29	Empty weight and corresponding CG		23.29	
25.31	Removable ballast		23.31	
25.33	Propeller speed and pitch limits		23.33	
25.101	General (performance)		23.45	
25.103	Stall speed		23.49	(a) and (b) only. Stall speed must be defined to determine operating speeds and stall warning margin.

Section	Title	Proposed Part 25	Part 23	Proposed Part 23 ARC
25.105	Takeoff		23.53	NOTE 1
25.107	Takeoff speeds		23.51	NOTE 1
25.109	Accelerate-stop distance		23.55	NOTE 1
25.111	Takeoff path		23.57	NOTE 1
25.113	Takeoff distance and takeoff run		23.59	NOTE 1
25.115	Takeoff flight path		23.61	NOTE 1
25.117	Climb: general		23.63	NOTE 1
	Climb: AEO		23.65	NOTE 1
	Takeoff climb: OEI		23.66	NOTE 1
25.119	Landing climb AEO		23.77	Except in lieu of quantitative criteria climb must be measurably positive.
	Climb OEI GW<6000 Normal		23.67(a)	NOTE 2
	Climb OEI GW>6000 Normal		23.67(b)	NOTE 2
25.121(a)	Climb OEI TO GD Commuter		23.67(c)(1)	NOTE 2
25.121(b)	Climb OEI TO GU Commuter		23.67(c)(2)	NOTE 2

Section	Title	Proposed Part 25	Part 23	Proposed Part 23 ARC
25.121(c)	Climb OEI Final TO Commuter		23.67(c)(3)	NOTE 2
25.121(d)	Climb OEI Approach Commuter		23.67(c)(4)	NOTE 2
25.123(a)	Enroute flight path OEI		23.69	NOTE 2
25.123(b)	Enroute flight path OEI		23.69	NOTE 2
25.123(c)	Enroute flight path 3-4 engine		NA	NOTE 2
	Glide: Single engine airplanes		23.71	NOTE 2
25.125	Landing		23.73 Vref	Applicable. 1.3Vs or use App. C Vref as long as maneuver margin tests OK Intent is to not bump SLD approach and landing speed (runway overrun?) if App C speed is adequate.
25.125	Landing		23.75 Dist.	Applicable if Vref defined for Appendix O detect and exit greater than Appendix C Vref. May be determined by analysis.
	Flight characteristics: General		23.141	

Section	Title	Proposed Part 25	Part 23	Proposed Part 23 ARC
25.143(a)	Controllability and Maneuverability		23.143(a)	Applicable for appropriate flight phases
			23.143(b)	It must be possible to make a smooth transition from one flight condition to another (including turns and slips) without danger of exceeding the limit load factor, under any probable operating condition. AEO only. May be evaluated concurrently with other flight tests.
25.143(b)(1)	Sudden failure of engine		23.143(b)	
25.143(b)(2)	Sudden failure of second engine			
25.143(b)(3)	Configuration changes			
25.143(c)(1)	Control with OEI in icing TO			NOTE 2
25.143(c)(2)	Control with OEI in icing Appr. & land			NOTE 2
25.143(c)(3)	Control with OEI in icing Appr. & GA			NOTE 2
25.143(d)	Control force limits		23.143(c)	Applicable
25.143(e)-(g)				

Section	Title	Proposed Part 25	Part 23	Proposed Part 23 ARC
25.143(h)	Maneuver margin			
25.143(i)	ICTS		23.143(d)	Not applicable.
25.143(j)	Control – pre-activation ice		23.143(e)	Applicable. Evaluated with 0.5g to 1.5g, low and high airspeed, idle and GA thrust/power.
25.143(k)	Control – pre-detection ice			
	Control – detect & exit		23.143(f)	Applicable. Evaluated with 0.5g to 1.5g, low and high airspeed, idle and GA thrust/power. Longitudinal and lateral control evaluated with sideslips expected during operations.
	Lateral control evaluation		23.143(g)	Specific tests added to regulation.
25.145(a)	Pitch down capability		23.145(a)	NOTE 3
25.145(b)	Configuration changes		23.145(b)	NOTE 3
25.145(c)&(d)	GA w/complete flap retract– no loss of altitude		23.145(b)(3)	NOTE 3
	1.5g capability above Vmo/Mmo		23.145(c)	NOTE 3

Section	Title	Proposed Part 25	Part 23	Proposed Part 23 ARC
	Power off glide gear and flap extended		23.145(d)	NOTE 3
	Landing with primary FCS failure		23.145(e)	NOTE 4
25.145	Longitudinal control		23.145	NOTE 3
25.147(a)	Directional control – OEI		23.147(a)	NOTE 2
25.147(b)	Directional control – 2EI			
25.147(c)	Lateral control – OEI			
25.147(d)	Lateral control - 2EI			
25.147(e)	Lateral control margin – AEO			
	Sudden engine failure – 2 sec delay		23.147(b)	NOTE 2
	Control with primary lateral FCS failure		23.147(c)	NOTE 4
25.149	Minimum control speed		23.149	NOTE 2
	Acrobatic maneuvers		23.151	NOTE 5
	Control during landings		23.153	NOTE 3

Section	Title	Proposed Part 25	Part 23	Proposed Part 23 ARC
	Elevator control force in maneuvers		23.155	NOTE 3
	Rate of roll		23.157	Rate of roll evaluated qualitatively during compliance to 23.143(g).
25.161	Trim		23.161	NOTE 3
25.171	General (stability)		23.171	NOTE 3
25.173	Static longitudinal stability		23.173	NOTE 3
25.175	Demonstration of Static Long. Stab.		23.175	NOTE 3
25.177	Static lateral-directional stability		23.177	Evaluated during sideslips conducted for ICTS evaluation.
25.181	Dynamic stability		23.181	NOTE 3
25.201(a) (b)(d)(c)(1)			23.201 & 23.203	Applicable. Use pass/fail criteria in AC 23.1419-2D: Roll may slightly exceed 15 degrees if characteristics qualitatively determined to be safe.
25.201(c)(2)	Turning stall 3 kt/sec		23.203(a)(2)	NOTE 5

Section	Title	Proposed Part 25	Part 23	Proposed Part 23 ARC
25.203	Stall characteristics		23.201 & 23.203	Applicable except use pass/fail criteria from AC 23.1419-2D. One kt/sec wings level and turning stalls only. No accelerated turning stall.
25.207(a)	Stall warning		23.207(a)	Applicable.
	Means of stall warning		23.207(b)	Applicable.
25.207(b)	Means of stall warning same in icing		23.207(i)	Applicable plus means of stall warning same as non-icing and Appendix C.
25.207(c)	5 knot/5% margin to stall		23.207(c)	
25.207(d)	3 knot/3% margin to Vsr		23.207(c)	
See 25.143(h)	Maneuver margin		23.207(d)	See 23.73

Section	Title	Proposed Part 25	Part 23	Proposed Part 23 ARC
25.207(e)	3 sec margin to stall in icing		23.207(h)	Adopt part 25 3 sec in lieu of part 23 five knot in icing. Reasons: 3 sec is adequate time, particularly in approach and landing phase where most events occur Relaxing margin in SLD may result in only one SW schedule for icing. How would a separate SLD SW schedule be implemented? A switch? We want to avoid that – workload issue or possible intentional non-compliance.
25.207(f)	Stall warning 1.5g turns 2 kt/sec		23.207(e)	Shouldn't be required to be consistent with current part 23 practice
25.207(g)	Abnormal configuration of high lift			
25.207(h)	Stall warning pre-activation ice		23.207(g)	
25.207(i)	Stall warning pre-detection ice			Not included in part 25 NPRM. NPRM pre-amble explains should be covered by detect and exit ice shape.
	Acrobatic airplane stall warning		23.207(f)	
	Spinning		23.221	

Section	Title	Proposed Part 25	Part 23	Proposed Part 23 ARC
25.231	Ground and water Longitudinal S&C		23.231	Applicable – no dedicated tests
25.233	Ground and water Directional S&C		23.233	Applicable – no dedicated tests. Add guidance similar to App C to analyze sideslip data for x-wind capability
25.235	Taxiing conditions		23.235	Not applicable
25.237	Wind velocities		23.233	
	Operation on water		23.237	Applicable – no dedicated tests
25.239	Spray characteristics		23.239	
25.251(a)	Vibration & buffeting		23.251	Applicable . Evaluation limited to 250, Vne, airspeed shown to have no ice accretion, reduced speed limit published in the AFM for SLD exit./*
25.251(b) – (e)	Vibration & buffeting		23.251	
25.253(a)	High speed characteristics & recovery		23.253	
25.253(b)	Maximum speed for S&C non-icing			
25.253(c)	Maximum speed for S&C icing			

Section	Title	Proposed Part 25	Part 23	Proposed Part 23 ARC
25.255	Out-of-trim characteristics			
Legend and Notes:				
	Not required			
	Required – specific language added			
	Required – referenced in § 25.21(g)			
Red text	Not required in 23.1419 Amdt. 23-43			
NOTE 1: Airplane is assumed to takeoff clean and not takeoff into SLD conditions. NOTE 2: Service history shows part 23 SLD accidents not due to engine failure. NOTE 3: No dedicated tests required. Controllability, trim and stability evaluated concurrently with other tests. NOTE 4: Service history shows part 23 SLD accidents not due to flight control failure. NOTE 5: Not required or typically evaluated currently for Appendix C icing conditions.				

C) Subpart B - Means of Compliance Appendix O

The proposed part 23 guidance material for Appendix O was derived from the proposed part 25 proposed guidance. A description of the simulation tool limitations for Appendix O and guidance for airplane components in the different Appendix O distributions are provided. Some of the details are omitted and the part 25 guidance is provided as reference. As in part 25, as the tools mature, the part 23 guidance will be revised.

APPENDIX O ICING ENVELOPE

The ARC adopted the proposed freezing drizzle and freezing rain definitions in the proposed part I of Appendix O of part 25. The ARC proposes that part 23 regulations reference part I of Appendix O of part 25. The ARC charter did not intend to change the part I definitions, and there is no reason to, since the ARC cannot rationalize why it should be different, since the environment is not changed by the category of airplane flying in it. The ARC did, however, question the proposed liquid water content at the cold freezing drizzle conditions as discussed below.

APPENDIX O ICE ACCRETIONS

The ARC reviewed the proposed ice accretions in proposed part 25, Appendix O, part II. The ARC decided that part 23 should adopt a part 23 appendix to define ice accretions in part 25, Appendix O, part I conditions, and not reference part 25, Appendix O, part II, for the following reasons:

- Part 25, Appendix O, part II references part 25 sections; and
- The ARC modified the detect and exit ice accretions.

The ARC agreed with the part 25 proposal that takeoff and failure ice shapes would not be required for a detect and exit airplane. The ARC proposed initial modifications for detect and exit ice accretions as follows:

- Enroute ice accretion was limited to airplanes with an altitude capability below 30,000 feet, since airplanes with capability above 30,000 would cruise above that altitude. This rationale and the 30,000 ft. number is the same rationale for the guidance in AC 23.1419-2D on fluid capacity for fluid ice protection systems. Enroute ice was also limited to 55 nm. This distance is in guidance in AC 23.1419-2D for runback ice and covers 90% of status clouds according to data in ADS-4. The ARC was looking for means to limit the requirement to calculate enroute ice, since the ice accretion amount is usually addressed by the 45 minute hold, and some manufacturers address the 45 minute hold and not enroute.
- Pre-activation ice was deleted. See discussion earlier in this report.

- Landing ice was re-defined. Since it was expected most part 23 airplanes would land if Appendix O was encountered during approach and landing, a go-around was deleted. It was replaced with a 17.4 nm exposure, initially with approach flaps and the last 6 nm (outside marker distance) in either Appendix C or O, whichever was more critical.

Two additional revisions were made for “detect and exit” after a review of alternatives:

- The phases of flight required for analysis was reduced to holding and approach; and

- The ambient temperature that must be analyzed for “detect and exit” ice accretions in Appendix O was limited to -13°C and above.

One of the alternatives considered by the ARC was simplification of detect and exit ice accretions. The ARC recognized that four different Appendix O distributions combined with four different flight phases would require much tunnel test and analyses. As a result, the ARC eliminated enroute phase and landing phase for detect and exit, so only holding and approach phases remained. The rationale was that the ice accretion determined during these phases could account for the remaining phases.

The ARC did an initial review of part 23 icing events in suspected SLD conditions and determined that most events, 39%, occurred during the approach phase. So the ARC determined that ice accreted during the holding phase, which may have preceded the events, and the approach phase, should be evaluated. The landing phase had the next highest amount of events, 31%. Even though the majority of these events were hard landings and non-fatal, the ARC believes the ice accretion determined during the approach phase would be sufficient. The proposed landing phase profile differed from the approach in that the last 6 nm was at landing flaps versus approach flaps. If the design did develop substantial ice accretion behind the protected area during the approach, it most likely would serve as an accretion site at the lower angle of attack with landing flaps, and shadow the upper wing surface. Flight testing would still include landing and go-around demonstrations (3% of events), and the ARC believes a stall protection system and AFM procedures developed with approach ice shapes would be sufficient for these phases. Also, the ARC proposed approach phase included transiting 17.4 nm in Appendix C after an SLD exposure (which could be critical since the SLD ice accretions would serve as a new accretion site for Appendix C drops), much higher than the ARC proposed landing phase. The remaining part 23 SLD events occurred in climb, cruise, and descent (26% of events). The ARC believes the holding phase adequately addresses these. A descent may be critical due to low bleed and low angle of attack, but the only proposed part 25 profile which includes a descent is the approach definition, which is included in the ARC recommendations.

Another alternative considered was evaluating the need to consider freezing drizzle conditions at very cold conditions. Some members of the ARC reviewed the FAA technical report on the data and analysis used for development of the 14 CFR part 25 Appendix O definitions (DOT/FAA/AR-09/10) and noted that most of the data used in the analysis was collected at ambient temperatures above -10°C which suggests a reduced probability of occurrence with decreasing ambient temperatures similar to Appendix C. An evaluation was presented to the ARC of the effects of the larger drops on a fluid based ice protection system is used on many part 23 aircraft. The cold temperature prolonged holding conditions become the design driver for these types of systems due to the increased water catch of the large drops. The ARC also considered that many part 23 aircraft have limits on the available energy for thermal ice protection systems and reconsidered the need to use the same hold criterion as used in part 25. The consensus of the ARC was that the need to consider this long of a hold in freezing drizzle and freezing rain was reduced both by the reduced probability of holding, combined with the reduced probability of the SLD conditions at the cold extremes. As such, it is recommended that the holding criterion in SLD, be limited to ambient temperatures above -13°C. The ARC was also concerned that an assumption of a hold in SLD icing conditions at the cold extreme could be a driver for the stall speed setpoints, which could increase landing speeds. This increase in landing speeds could have an unintended adverse effect on safety. The review of the event history indicates that most in-flight events occur at a total temperature near 0°C, with no evidence of issues due to prolonged holds at cold extremes. Suspected SLD events for which flight data recorder data on temperature is listed in Table 2.

Table 2 - Suspected SLD Events

Model	Flight	Altitude (ft)	OAT (ºF)	KCAS	Distance (nm)	Time (min)	KTAS	T_{TOT} (ºF)
ATR-72	4184	10000	24.7	175	54.1	16	203	34.5
ATR-72	GE 791	18000	14.0	195	78.3	18	261	30.1
EMB-120	3272	7000	17.0	180	8.2	2.5	196	26.0
		4000	24.0	166	7.2	2.5	172	31.0
EMB-120	5054	17000	24.8	150	10.0	3	200	34.3
EMB-120	7233	10000	15.8	170		NA	196	24.9
C-560	Pueblo	7000	17.6	155	8.5	3	169	24.4
C-560	Eagle River	1000	29.0	NA				
SF-340	3008	8000	24.8	180	3.4	1	201	34.4
		9000	23.0	180	3.4	1	205	33.0
		10000	21.2	165	3.2	1	191	29.8

In addition, the reported temperature at the destination airport was reviewed for part 23 suspected SLD events on approach and landing. For 21 such events, the average ambient temperature was 29.2°F, the median was 32°F, and the coldest was 12°F (-11.1°C). This recommendation provides a balance of safety, yet provides less design penalties (weight, energy, etc.) for part 23 designs. Advisory material is recommended to clarify this change.

For Appendix O conditions for which approval is sought, the ARC recommends the same ice accretion definitions as proposed for part 25 with three modifications:

The proposed part 23 regulation definition for hold will not include 45 minutes. The draft guidance will define 45 minutes for Appendix C conditions. For Appendix O, 45 minutes for hold will be defined for OAT at and above minus 13°C. Below minus 13°C, the hold duration and the enroute phase can be limited the time required to transit 17.4 nm. See the discussion above for rationale on not considering the coldest temperatures.

The landing phase definition will include a go-around in accordance with AFM procedures versus a climb at the minimum balked landing climb gradient. The ARC proposes that the go-around may be accomplished with flaps other than landing flaps if the applicant demonstrates the procedure to be safe. Takeoff approval in freezing drizzle or light freezing rain must include the climb through a freezing drizzle or freezing rain layer which may extend higher than the 1,500 feet AGL takeoff phase. The ARC believed the maximum vertical extents defined in proposed Appendix O were too conservative (12.000 feet and 7,000 feet, respectively for FZDZ and FZRA). The ARC analyzed data from “An Inferred Climatology of Icing Conditions Aloft, Including Supercooled Large Drops. Part I: Canada and the Continental United States,” published in the November 2007 publication of the Journal of Applied Meteorology and Climatology. For FZDZ and FZRA, 90% of vertical extents were less than 6,000 feet and 3,500 feet, respectively. A value of 90% has been used previously in horizontal extent for runback ice accretion. A definition of climb with these vertical extents was added to be used for takeoff approval.

To summarize, part 23 regulations will reference the following:

Supercooled Water Icing Conditions	Definition of Icing Conditions	Airframe Ice Accretions for Showing Compliance to Subpart B
Stratus and Cumulus clouds	Part 25, Appendix C, Part I	Part 23, Appendix TBD, Part I
Freezing Drizzle and Freezing Rain	Part 25, Appendix O, Part I	Part 23, Appendix TBD, Part II

There are concerns that this structure may lead to confusion. The ARC recommends that the FAA consider establishing a new part 23 Appendix (or Appendices) that incorporates all the part 23 icing conditions and ice accretion definitions, negating the need to reference part 25 appendices or a portion of them.

The ARC reviewed a comment in the part 25 SLD rulemaking docket pertaining to an icing parameter developed by researchers based on their icing flight tests on a University of Wyoming King Air 200T (comment 11.1 in docket FAA-2010-0636). This parameter is the mathematical product of 80VD (drop size in microns for which 80% of the liquid water content is in drop sizes smaller) and LWC (liquid water content in g/m^3). Icing conditions were encountered that resulted in rapid increases in drag and stall speed beyond stall warning. The ice accretion which led to these severe encounters were described as sharp edges ice formations, 0.08 to 0.16 inch in height, that do not touch each other. The ARC could not gain access to any documentation such as photographs. The severe icing encounters correlated to an 80VD*LWC range of approximately 22 to 68 at an ambient temperature of around -8°C.

The ARC reviewed ice accretion photograph from several icing tunnel projects as follows (80VD calculated using calibration data from the NASA IRT):

1. Two minute inadvertent encounter at an 80VD=65, OAT= -10°C from a runback research project (DOT/FAA/AR-07/16)
2. SLD runs in the NASA IRT to support the ARAC IPHWG in which 80VD ranged from 96 to 164, OAT= -9.9 to -6.5°C
3. Intercycle/residual icing research at an 80VD=20, OAT= -9.8°C (DOT/FAA/AR-06/48)
4. Intercycle/residual icing research at an 80VD=39, OAT= -9.6°C (DOT/FAA/AR-06/48)
5. Certification project (proprietary data reviewed by FAA only) at an 80VD=52, OAT= -6.7°C

The roughness levels reviewed are associated with a range of temperatures, airspeeds, freezing fractions as well as the drop size and liquid water content parameters. Many of the cases reviewed were well outside the proposed Dow/Marwitz criteria, but significant roughness effects are apparent. By inspection, it can be concluded that these cases outside the proposed criteria could produce adverse drag effects. Although an exhaustive research effort was not performed, the roughness levels for point 4 are among the most benign of those reviewed even though it lies in the center of the proposed "adverse" icing region. Roughness levels for points 1 and 5 also lie in the “adverse” 80VD region and do not appear different than roughness documented outside the adverse region. Roughness densities were varied and there were cases where roughness elements did not touch each other. The review suggests that the proposed "adverse" icing criteria is an over-simplification of the complex icing physics that occur. In addition, the proposed criteria suggests that one type of icing conditions would be severe for all aircraft, regardless of the type of ice protection system used, or the protected area extents. This simplistic approach cannot be justified given the differences in the accident rates between differing types of aircraft and systems.

The rulemaking approach proposed for both part 25 and part 23 considers the complex icing physics through a combination of icing tunnel testing of representative aircraft models which capture variations in icing physics, and actually does include icing conditions in the “adverse” region. The Appendix O freezing drizzle (MVD>40) MVD is 110 µm. Using the NASA IRT calibration data, this corresponds to an 80VD of 249 µm. At -8°C, the Appendix O LWC for this distribution is 0.24 g/m^3 (it was erroneously high in the NPRM published on June 29 2010). This results in an

80VD*LWC = 59 which is in the adverse region. Therefore, certification testing to Appendix O will include conditions in the adverse region. The ARC does recognize that the certification tunnel runs should document the details of roughness elements for simulated ice shape flight testing, and an appropriate note is added to the guidance material.

NATURAL SLD FLIGHT TEST

The part 23 ARC adopted the part 25 proposal regarding the requirement to flight test in measured, natural icing conditions, which is required for Appendix C icing conditions in §§ 23.1419 and 25.1419. For compliance to §§ 23.1420 and 25.1420, flight test in measured, natural Appendix O conditions is listed as one of the means of compliance. The language “as found necessary” was removed by the ARC. The ARC believed the part 25 language was too vague as to who decided whether natural icing flight tests were required. The ARC also decided to write guidance that was specific on whether flight testing in natural Appendix O would be required. The ARC believed that if flight in any portion of Appendix O was to be approved, (e.g. § 23.1420(a)(2) or (a)(3)) flight test in those portions should be conducted. The ARC believed that Appendix O conditions for which an airplane is approved should not be treated differently than Appendix C, particularly if there is less experience with the simulation tools in Appendix O compared to Appendix C. The ARC recognized that flight test safety was one of the issues raised during IPHWG deliberations, but the ARC believed the fleet pilot should not be the first pilot exposed to these conditions if the airplane is allowed to operate indefinitely in these conditions. Carrying the instrumentation needed to measure Appendix O drop sizes is also an issue with part 23 airplanes. The ARC decided that there may be some phases of flight, such as takeoff, where freezing drizzle or rain conditions will be reported. For these phases, which may be a common phase applicants seek approval for, instrumentation would not be required.

For a detect and exit airplane, the ARC wanted to make it clear that flight test in natural Appendix O conditions would not be required for a part 23 airplane if certain conditions were met. The conditions are as follows:

1. For the Appendix O distributions where the capability exists[1], icing tunnel tests or icing tanker tests and analytical codes are used to determine critical ice shapes on lifting surfaces.
2. The simulated, critical ice shapes are flight tested to show compliance with applicable Subpart B regulations.

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[1] Current icing tanker or icing tunnel simulation techniques are limited to FZDZ. For FZRA techniques see Appendix 7 of the recommended AC materials.

3. Appendix O detection method(s) are certified as described in the Advisory Circular.
4. Subsequent designs may be able to use similarity to past certifications.

D) Subpart B - Appendix C Ice Accretions

Task 2 & 3 - The part 23 icing ARC reviewed the current requirements for Appendix C which requires compliance to Subpart B performance, stability, controllability, and maneuverability regulations with Appendix C ice accretions. The part 23 icing ARC proposes the following changes, which provides relief from the current rule:

Stall speed (Task 3):

Section 23.1419, amendment 23-43, required "…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. 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 certificated single engine airplane 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 did not meet the 61-knot stall speed requirement with critical ice accretions, guidance was added to Advisory Circular 23.1419-2C, published July 21, 2004. This guidance discussed compensating features to be considered for an exemption to the stall speed requirement of § 23.1419(a), amendment 23-43. The rationale was that an exemption with these 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. Stall warning means with ice accretion should be the same as in non-icing.

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

4. 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.

A total of four exemptions were granted from 2008 to 2010. No exemption requests were denied. The initial requests were published in the Federal Register and no comments were received. In an effort to reduce FAA and industry workload, the FAA tasked the Part 23 Icing Aviation Rulemaking Committee to recommend a rule amendment to exempt compliance to paragraphs (c) and (d) of Sec. 23.49 for flight in icing conditions. The ARC recommended rule changes to exempt these specific paragraphs. Since the certification basis of a new airplane model that would include the new Sec. 23.1419 amendment would most likely incorporate the regulations listed in the compensating features, the ARC determined it was not necessary to incorporate the compensating features in the regulations. The ARC recommended to keep a history of the issue in Advisory Circular 23.1419.

TAKEOFF ICE ACCRETION

The AC 23.1419-2D guidance on the performance thresholds for when takeoff ice accretion must be considered, and when takeoff speeds and approach speeds must be increased, are codified. Consideration was given to accomplish this by only amending 23.1419, or possibly the proposed 23.21(c), but the ARC determined it was cleaner to amend each affected rule, similar to part 25.

The part 23 icing ARC was tasked with recommendations on codifying certain guidance in AC 23.1419-2D. Recommendations were made in the following areas:

STALL WARNING

The ARC proposed amendments to 23.207 that would codify the AC 23.1419-2D guidance. These proposals would require the means of stall warning and stall warning margin to be the same for ice protection system operation as in non-icing operation. It also proposes to codify the guidance on pre-activation ice.

ICE CONTAMINATED TAILPLANE STALL

The requirement to evaluate susceptibility with zero load factor push-overs and sideslips is codified.

LATERAL CONTROL EVALUATION

The guidance in AC 23.1419-2D regarding lateral control evaluation was codified. The pass/fail criteria have been missing in the AC and are added to the proposed regulation. The IPHWG recommended lateral control evaluations in sideslips and in 10 deg bank to bank rolls down to stall warning. The 10 deg bank to bank rolls were added to the advisory material for 23.201. These tests would be applicable to Appendix C and O conditions.

ACTIVATION OF ICE PROTECTION SYSTEM

The ARC adopted the proposed part 25 requirements, with the exception that the proposed part 23 rule would provide an option for immediate activation based on visual observation of first sign of ice accretion, for normal, utility and acrobatic airplanes approved for flight in icing. The earlier discussion on stall warning and ICTS testing with pre-activation ice explains why the part 25 proposal was adopted for commuter category airplanes. The ARC believes the smaller scale of the part 23 non-commuter category airplanes allows easier observation of ice accretion, and the part 23 icing accident database shows that failure to recognize ice accretion is not a safety issue. In addition, delays in recognizing visual cues are addressed in the definition of pre-activation ice used in stall warning and ICTS evaluations. The proposed part 25 rule requires either an ice detection system, whose cost is relatively large compared to the airframe for a part 23 airplane, or icing system operation based on visible moisture and temperature. The latter may result in unnecessary icing system operation which is common on part 23 airplanes, and can lead to a shorter system life.

DEFINITION OF PRE-ACTIVATION ICE

As in part 25, current part 23 guidance addresses stall warning and susceptibility to ICTS with pre-activation ice. Pre-activation ice for part 23 airplanes is currently two minutes if activation is based on visual cues, and 30 seconds if it based on visible moisture and outside air temperature. Part 23 is poorly harmonized with Part 25. Large Part 25 aircraft have moved toward Primary Ice Detection Systems (PIDS or IDS), which is not a realistic option for much of Part 23 due to equipment cost. This has resulted in certification programs with very large pre-activation ice shapes and system operating needlessly in non-icing conditions. However, both part 25 and part 23 guidance have not given credit for an advisory ice detection system.

The NTSB recommendation is to activate ice protection as icing starts. This is one of the primary tenants on the NTSB “Most Wanted List”. Since the flight crew can only detect icing by visual observation of ice accretions and ice detectors can potentially detect ice below the human visual threshold, it is a given the ice detector could reduce preactivation ice shapes. The following chart provides an option that gives credit for an Advisory IDS and increases harmonization with Part 25. This guidance gives an airplane manufacturer incentive to install an ice detection system with a reduction in the time used for defining the preactivation ice shapes. In order to get credit, the system cannot be optional equipment, and this must be recognized in the minimum equipment list.

Table 3 - Pre-Activation Ice Accretions - Appendix C Continuous Maximum Conditions

IPS Activation	**AC 25 Pre-activation Ice Accretion**	**Part 23 Pre-activation Ice Accretion**	
		The left and right columns provide two approaches that may be used. The right column provides typical values that may be used in lieu of system specific data.	
Visual of First Indication of Accretion on Reference Surface	Time to detect [(1)] +30 seconds [(2)] +IPS response time	Time to detect [(1)] +30 seconds [(2)] +IPS response time	2 minutes [(2)]
Potential Icing Conditions (OAT and Visible Moisture)	+30 seconds [(2)] +IPS response time	+30 seconds [(2)] +IPS response time	30 seconds [(5)]
Primary IDS and Manual IPS Activation	IDS response time +10 seconds [(2)] +IPS response time	IDS response time[(3)] +10 seconds +IPS response time	30 seconds [(3)(5)]
Primary IDS and Automatic IPS Activation	IDS response time +IPS response time	IDS response time[(3)] +IPS response time	20 seconds [(3)(5)]
Advisory IDS	No Credit	IDS response time [(4)] +10 seconds [(2)] +IPS response time	60 seconds [(4)(5)]

Notes:
(1) Total time not to exceed 2 minutes
(2) Easily recognizable by the flight crew in all foreseeable conditions (e.g., at night in clouds)
(3) Applicant should show that the response time of the ice detector at freezing fractions of one is less than stated time.
(4) In low freezing fractions conditions, applicant should show that detector will annunciate prior to ice accretion on critical surfaces. This may be accomplished by comparing icing tunnel tests to response times provided by the detector manufacturer.
(5) Add delay time due to any IPS activation logic

Advisory IDS have seen limited use in the past; this has not been a result of concern over detector effectiveness but of system reliability. The concern is the possibility of a flight crew that has become dependent on the IDS that has failed (without annunciation of the failure), entering icing conditions and waiting for the now failed IDS to detect ice. The ARC believes this concern can be mitigated by requiring a reasonable level of operational performance from the Advisory IDS and proposes the SAE AS5498 Minimum Operational Performance Specification for Inflight Icing Detection System as possible specification to allow credit for the Advisory IDS. One issue with the common vibrating probe ice detection system is the response time at temperature near freezing. Guidance material was added to the advisory material to address these issues.

The ARC also investigated the possibility of reducing the two minute time for visual ice detection for an airplane with a two man flightcrew. The ARC determined that any time reduction would be subjective and difficult to demonstrate.

Task 8 - The ARC was tasked to determine if using 1-g stall speed criteria in icing is an option to reduce approach speeds and landing distances in icing conditions. Part 25 already uses the 1-g stall speed requirement, introduced at amendment 25-108 in 2002). An equivalent safety finding for the use of 1-g stall speeds, instead of the minimum speeds obtained in the stalling maneuver, as the basis for showing compliance with certain 14 CFR part 23 performance, and 14 CFR part 36 noise requirements, was established for several past part 23 type certification projects. Pilot objectivity on stall identification has become a key factor in decisions on flying technique, especially where deterrent buffet or excessively low load factors are developed during stalls to V_{SMIN}. This can be especially true with ice accretion on protected surfaces (e.g., intercycle), in which the lift curve can flatten considerably as CL_{MAX} is approached. For a stick pusher equipped airplane where stall would be defined by stick pusher speed, operating speeds using the 1-g stall speed criteria would be several knots lower than using V_{SMIN}. The ARC recognized there could be an advantage. Stall speed would have to be determined in icing the same means as in non-icing, which would require re-writing the 23.207 for non-icing conditions, which is outside the ARC tasking. Since the option is already available to part 23 applicants, the ARC determined no additional guidance is needed for icing conditions.

E) POWERPLANT ASPECTS

SEC. 23.901 INSTALLATION

This section was reviewed with respect to the reference of icing in (d)(2) which states "Ensure that the capability of the installed engine to withstand the ingestion of rain, hail, ice, and birds into the engine inlet is not less than the capability established for the engine itself under Sec. 23.903(a)(2)".

It was determined that the consideration of large drops or mixed phase/ice crystals did not have an effect on this section as long as it was not interpreted to mean that all ice shapes that may form on an airframe in front of an engine are required to be less than that tested during the part 33 certification. The recommendation for § 23.1093 includes picking up the specific language that includes consideration of ice on "airframe components" similar to the part 25 proposal. As such, per the requirements of § 23.901, no design feature of the installation should degrade the basic capability of the engine with respect to ice ingestion, but the ingestion of airframe ice should be addressed under the more specific requirements of § 23.1093.

SEC. 23.903 ENGINES

This language recommended for part 25 was reviewed and it was determined that it was appropriate as drafted and should be recommended for incorporation into part 23. However, the ARC recommended advisory material on how to determine acceptable service history.

SEC. 23.905 PROPELLERS

This section was reviewed with respect to the reference of icing in (e) which states "All areas of the airplane forward of the pusher propeller that are likely to accumulate and shed ice into the propeller disc during any operating condition must be suitably protected to prevent ice formation, or it must be shown that any ice shed into the propeller disc will not create a hazardous condition". It was determined that this requirement would not be affected by the addition of large drop conditions. However, the ARC recommends advisory material to clarify the requirements with respect to large drop conditions and aircraft approved for flight into icing conditions.

SEC. 23.929 ENGINE INSTALLATION ICE PROTECTION

Modifications to the requirement are recommended to incorporate reference to the large drop environment as well as clarify that this requirement is related to flight in icing approvals. Also, recommend modification of the criterion used for thrust loss from "appreciable loss" to capture the effect on aircraft performance as defined in proposed 23.21(c). Since this requirement encompasses the propeller and the engine installation, consideration of any applicable systems requirements from sub part E and sub part F are also recommended.

It addition, it is recommended to delete the reference to "wooden propellers". The consensus of the ARC is that the requirements should be based on whether the aircraft is seeking approval for flight into known icing, not on the construction method of the propeller.

There was consideration given to changing the scope of § 23.929 to propellers similar to part 25 and allowing § 23.1093 to be the focus for engine installation effects due to the current overlap for engine installation effects between the two paragraphs. The ARC elected not to make this change, as it is not required due to the large drop icing and there is adequate guidance material published in AC 23-16A to differentiate between the engine installation effects of the two paragraphs.

The review of the event data does not indicate any safety issues related to engine installation effects while exiting severe icing conditions. There are events with documented speed losses which could be partially attributed to propeller icing. As such, the rule language was modified such that the icing environment to be considered for propeller icing includes the SLD conditions while exiting the environment, but for engine installations consideration of only the approved icing environments is acceptable.

SEC. 23.1093 INDUCTION SYSTEM ICING PROTECTION

The icing aspects of § 23.1093(a) Reciprocating engines were reviewed and it was determined that the current rule language was acceptable without changes.

The ARAC recommended changes for § 25.1093(b) were reviewed and determined to be appropriate for near direct incorporation. As part of this incorporation, the consideration of airframe components that could affect engine operation through accumulation of icing becomes a specific requirement of this section, rather than the more generic prior requirements of § 23.901(d) as discussed in AC 23-16A.

The recommended ARAC Part 25 language provides for showing compliance with the defined icing conditions (Part 25 Appendices C & O, Appendix D of part 33, and in falling and blowing snow) within the limitations established for the airplane for such operations. This relationship between the aircraft limitations and compliance requirements was further clarified with recommended guidance material (for inclusion in AC 23-16A) with respect to aircraft that are not certified for icing conditions, and for aircraft that show compliance with the requirements of § 23.1420(a)(1) or § 23.1420(a)(2).

In response to the part 25 NPRM, the Aerospace Industries Association (AIA) submitted public comments that would modify the ARAC proposed § 25.1093(b). The intent of the ARC is to keep the requirements of § 23.1093(b) and § 25.1093(b) the same, due to similar installation requirements between the two parts. However, since the part 25 final rulemaking will not be available during the ARC timeframe, this cannot be assured. As such, the AIA recommendations were incorporated into the ARC recommendations for part 23 as follows:

1) Recommend changes to idle speed language in § 23.1093(b)(1) to be consistent with the engine requirement of § 33.68(a) & (b).
2) The insertion of the "if any" clause in § 23.1093(b)(2) was added to allow that a temperature limitation may not be necessary. The choice of ambient temperature for the ground freezing fog rime icing demonstration should be driven by critical point analysis as required by § 33.68 (b)(1). This analysis should also be used to show that at colder temperatures below the § 33.68 Table 1, Condition 2 test temperatures, a more critical point does not exist. The applicant should be permitted to use analysis to demonstrate safe operation of the engine at temperatures below the required test demonstration. If appropriate, no limitation would then be required for the Airplane Flight Manual.

3) The AIA recommended deletion of Appendix O from the 23.1093 requirements. There are no known part 25 events that support a safety concern due to engine induction system icing in SLD conditions aloft. In particular, the Part 25 ARAC EHWG evaluated all of the known icing-related events since 1988 and found no events in SLD conditions aloft. As such, the compliance efforts required for engine inlets with respect to large drop conditions will provide no benefit in the regulatory analysis. The ARC considered this recommendation in light of part 23 aircraft. Given that many part 23 aircraft already have limitations on flight in SLD through FAA issued severe icing airworthiness directives, the service history likely does not include sustained flights in FZDZ and FZRA. As such, the successful service history can be applied to aircraft certified under 23.1420(a)(1). However, for aircraft approved for unrestricted flights in portions or all of Appendix O (§ 23.1420(a)(2) or (a)(3)), the exposures to such conditions are expected to increase. As such, consideration of Appendix O exposures for approved portions per 23.1420(a)(2) or (a)(2) is recommended.

4) Deletion of the ARAC proposed § 25.1093(b)(1)(iii) to be consistent with AIA recommendations for § 33.68. The words "stall, surge, or flameout or loss of engine controllability (for example, rollback)" are redundant to the requirement for no unacceptable loss of power or thrust. The inclusion of "stall, surge, or flameout or loss of engine controllability (for example, rollback)" causes confusion. For example, as written, a rotating stall, which can cause no noticeable impact to engine operation and would only be detectable by special instrumentation could be found unacceptable. Therefore, deletion of the stall, surge or flameout language is recommended.

SEC. 23.1521 POWERPLANT LIMITATIONS

The proposed § 25.1251(f) would require limitations to be established for the minimum temperature as well as the duration, as discussed in item 2 above for § 25.1093(b)(2). Same rationale applies, and the requirements were deleted from the recommendations for part 23.

F) SYSTEMS AND RELATED ASPECTS

SEC. 23.629 FLUTTER.

This section was reviewed with respect to changes that might be required due to unique aspects of SLD ice shapes. It was determined that no changes are required. It is recommended that ice shapes for the approved portions of Appendix shall be developed using the ice shape scenarios and evaluated by analysis similar to current Appendix C methods.

SEC. 23.775 WINDSHIELD AND WINDOWS..

This section was reviewed with respect to changes that might be required due to unique aspects of SLD icing. Rule sections (a), (b), (c), (d), (e), (g) and (h) remain unchanged. It is recommended that section (f) to be modified to reference the large drop environment.

SEC. 23.1323 AIRSPEED INDICATING SYSTEM.

Due to the wide operating range of aircraft certified under Part 23, it was determined appropriate to modify the recommended §25.1323 language in a way more applicable to Part 23 aircraft. It is recommended not to modify the regulation or require flight testing in natural icing conditions for aircraft certified for IFR only (not approved for flight into icing conditions). AC20-73A already provides guidance on using Appendix C as the definition of icing conditions for probes on IFR aircraft, which is equivalent to the current standards. For aircraft certified for flight in icing conditions, the regulation should be changed to require Appendix C and O conditions be met in accordance with §23.1420(a). The mixed phase and ice crystal conditions should be required for probes on aircraft that operate at altitudes and airspeeds where ice crystal induced airspeed anomaly events have occurred in the past and on aircraft where the airspeed indicating system serves a critical function as defined in AC 23.1309-1D. It is intended that this section reference the same mixed phase/ice crystal conditions as §25.1323, which is expected to be Appendix D of Part 33 but has not been finalized at the time of this draft. A review of the incident history revealed that issues involving ice crystals occurred at high true airspeeds and at altitudes typically above 29,000 ft. Although some incidents were reported at lower altitudes they all involved aircraft capable of high cruise speeds above 29,000 ft. The 29,000 ft threshold was selected because of the typical performance and system complexity increase associated with aircraft capable of meeting the RVSM requirements. Mach 0.75 was selected as a result of the incident history.

Guidance is suggested to clarify the policy on the operation of pitot probes under emergency battery conditions. A requirement to provide protection for all mixed phase conditions under emergency battery operations commonly used on Part 23 aircraft is impractical due to the high power requirements at the low voltages of emergency bus operation. In addition, the probability of encountering critical mixed phase or ice crystal conditions was considered sufficiently low that it should be considered remote (based on engineering judgment). Aircraft will still be protected against Appendix C icing conditions under the emergency power scenarios. As such, an appropriate level of safety is provided without undue burden on the aircraft design.

NPRM 10-10 suggest that additional freezing rain conditions beyond those in the proposed 14 CFR Part 25 Appendix O and 14 CFR Part 33 Appendix D may be added to Part 25 after a review of comments and malfunctions. The ARC review determined that there is a lack of historical incidents in part 23 aircraft involving pitot probes and these types of conditions. This is most likely due to scale effects, such as boundary layer concentration factors, and lower true airspeed effects. In addition the requirements of operation in the meteorological conditions described by 14 CFR Part 25 Appendix O and 14 CFR Part 33 Appendix D provide for testing in freezing rain beyond conditions currently evaluated. It is recommended that these additional freezing rain test conditions not be adopted, if later added to the Part 25 proposal.

SEC. 23.1324 ANGLE OF ATTACK SYSTEMS

The new Part 25 proposed rule requiring ice protection for angle of attack system sensors was reviewed for applicability to Part 23 aircraft. It was determined to be appropriate to require this new regulation for Part 23, if applied similarly to the proposed §23.1323 (with respect to aircraft performance and system criticality). It is acknowledged that the standard, trailing-vane-style angle of attack sensor should not be susceptible to mixed phase or ice crystal accretions by design. However, the angle of attack probe designs that sense dynamic pressure for angle of attack (similar to pitot probes) can be expected to be susceptible to these conditions. Therefore, it is intended that this section uses the same icing conditions and applicability criteria as those proposed for §23.1323.

NPRM 10-10 suggest that additional freezing rain conditions beyond those in the proposed 14 CFR Part 25 Appendix O and 14 CFR Part 33 Appendix D may be added to Part 25 after a review of comments and malfunctions. The ARC review indicated that with respect to AOA detectors the phenomena of concern has been water entering mechanical parts that require free movement to operate correctly, then freezing and preventing free movement. This can be a result of direct impingement or runback. This has been effectively addressed in the past as a Part §23.1309 issue under subpart (b)(1) - It must perform its intended function under any foreseeable operating condition. No regulatory changes are recommended. Suggested guidance material referencing issues to be considered have been added to AC 23.1419. In addition the requirements of operation in the meteorological conditions described by 14 CFR Part 25 Appendix O and 14 CFR Part 33 Appendix D provide for testing in freezing rain beyond conditions currently evaluated. It is recommended that these additional freezing rain test conditions not be adopted, if later added to the Part 25 proposal.

SEC. 23.1325 STATIC PRESSURE SYSTEM.

Section §23.1325(b)(3) was reviewed with respect to the wording “icing conditions.” It is recommended that the rule remain unchanged for aircraft certified for IFR only (not approved for flight in icing). AC20-73A already provides guidance on using Appendix C as the definition of icing conditions for ports on IFR aircraft. It is recommended that wording be added to require the icing conditions of Appendix C and the SLD conditions of Appendix O in accordance with §23.1420(a) for aircraft certified for flight in icing conditions.

The ARC has determined that static ports are not high efficiency collectors of ice crystals by their installation or design. As such the philosophy and guidance of the proposed §25.1325 rule to not include requirements for mixed phase or ice crystal conditions was upheld here.

SEC. 23.1326 PITOT HEAT INDICATION SYSTEMS

As part of the mixed phase icing requirements of §23.1323, higher heat probes will likely be required to compensate for the energy required to melt ice crystals. Current pitot probes have such high heat levels that many manufacturers provide systems that minimize or turn-off pitot heat on the ground prior to takeoff to protect the equipment or composite structures. Since accurate airspeed information is only required for safe flight, there is no safety benefit to indicating the pitot heat system is OFF for ground operations. These types of systems have typically required an ELOS to be compliant with the requirements of the current §23.1326. Also, §23.1326(b)(1) conflicts with the dark cockpit philosophy employed by many manufacturers by requiring an amber indication (typically indicative of a failure caution) for what could be a pilot commanded state. Therefore, it is recommend that the rule language be modified so that the safety objective of ensuring the pitot heat system is operating as intended during flight be retained but also allow alternate methods of compliance on the ground without requiring an ELOS.

SECTION 23.1329 AUTOMATIC PILOT SYSTEM

See discussion under sub part B.

SEC. 23.1403 ICING INSPECTION LIGHTS.

The current requirement for illumination of ice accumulations is provided by §23.1419(d). To address illumination requirements for both appendix C ice accretions and appendix O, a new icing requirement is proposed similar to §25.1403. This requirement would address critical ice shapes as well as ice accumulations used for operation of the ice protection systems, or initiation of aircraft procedures such as exiting severe icing conditions. The proposed rule language was drafted to eliminate the need for an Equivalent Level of Safety if other, non-visual means were used to determine ice formation (e.g. a primary ice detection system for system activation). The rule language was drafted to only require icing inspection lights if they are necessary and not to require wing inspection lights for aircraft where the wing cannot be viewed from the cockpit.

SEC. 23.1416 PNEUMATIC DE-ICER BOOT SYSTEM.

The requirements of §23.1416 are largely obsolete with the increased scope of §23.1309 and §23.1322. In addition, the requirement of §23.1416 (c) for an indication of normal operation is in conflict with the dark cockpit philosophy that is in use in many modern aircraft. As such, the recommendation is to delete the specific requirement for an indication and use the basis of §23.1309 and §23.1322 to provide cockpit indications. This will allow the use of both dark cockpit and non dark cockpit types of indications as is consistent with the proposed cockpit philosophy.

SEC. 23.1419 ICE PROTECTION

A review of the NPRM has resulted in recommended changes to the 14 CFR Part 23, §23.1419, and AC 23.1419.

Recommended Regulatory Changes:

Icing Inspection Lights – It is recommended that references to icing inspection lights be removed from this section and section §23.1403 be added. It is felt that this will reduce confusion regarding the means of determining icing conditions and operating the ice protections systems and the means of monitoring ice accumulations. The ice light requirements would be common to §23.1419 and §23.1420.

Ice Protection System Operation - The §23.1419 (d) references to the AFM have been moved to section h. New requirements were added as §23.1419(d)(e)(f)(g)(h) to include the ice protection system activation and ice detector requirements promulgated under amendment §25-129. These requirements are further referenced under the proposed §23.1420(c).

Recommended Guidance Changes:

Substantiated visual cue - two of the following methods are required, analysis, icing wind tunnel testing, icing tanker testing, natural icing flight testing to validate a visual cue. In the unique case of using two methods to validate visual cues on the windows of the cockpit, it is recommended that a combination of appendix C natural icing encounters validating 3D ice accretion (or impingement analysis) and 3D appendix O ice accretion analysis (or impingement analysis) satisfy the two method approach described above.

Ice Detector Reliability Requirements – With respect to ice detector reliability and software criticality requirements, for both primary and advisory systems, it is recommended that they be consistent with the hazard classification for ice detectors resulting from a §23.1309 hazard analysis. For ice detection primary and advisory aspects see discussion on pre-activation ice in the subpart B section of this report.

SEC. 23.1420 SUPERCOOLED LARGE DROP ICING CONDITION.

The requirements of §23.1420 are proposed to be similar to the §25.1420 requirements. The discriminator used in the part 25 rule is no longer applicable, as all aircraft certified under part 23 will have maximum takeoff weights of less than 60,000 lbs. The "approved portions" of 14 CFR Part 25, Appendix O as used in the proposed regulations and guidance material is intended to refer to aircraft that are certified against 23.1420(a)(2) or (a)(3). For aircraft certified against 23.1420(a)(1) the exposures in Appendix O are not approved and require exiting all icing conditions. The phrase "with exposures in accordance with 23.1420(a)(1), (a)(2) or (a)(3)" is intended to require consideration of the environmental conditions within the Appendix O environment, as well as the exposure durations as defined in 23.1420 and the ice accretions recommended in section 3B of this report.

4. RULEMAKING RECOMMENDATIONS

Rule language changes are denoted by a combination of **bold text** indicating added or changed language with ~~strikeouts~~ indicating deleted text.
The use of ellipsis "* * * * *" indicates that the omitted rule language is unchanged (same format used by the FAA for publication in the NPRM).

A) SUBPART B ASPECTS

Added new 23.21(c)(1) to define the requirements of "capable of operating safely" in part 25, Appendix C conditions.

Added new 23.21(c)(2) to define the requirements for "capable of operating safely following detection and exit of Appendix O icing conditions.

Added new 23.21(c)(3) to define the requirements to show an airplane can operate safely in Appendix C, detect and exit Appendix O, Appendix O or a portion of Appendix O.

Added new (c)(4) to define requirements in icing on weight and cg limits.

SEC. 23.21 PROOF OF COMPLIANCE

(c) The requirements of this subpart associated with icing conditions apply only if certification for flight in icing conditions is desired. If certification for flight in icing conditions is desired, the following requirements also apply.

(1) Compliance with each requirement of this subpart, except §§ 23.49(c), 23.67(c)(1), 23.77(d) and (e), the sudden engine failure requirements of § 23.143(b), 23.143(f), 23.145(c), (d), and (e), 23.147(c), 23.149(b) (d), and (f), 23.207(e) and (h), 23.221, 23.235, 23.239, and 23.253, must be met in the icing conditions specified in part I of appendix C of part 25. Compliance must be shown using the ice accretions defined in part I of appendix TBD of this part, assuming normal operation of the airplane and its ice protection system in accordance with the operating limitations and operating procedures established by the applicant and provided in the Airplane Flight Manual.

(2) If the applicant does not seek certification for flight in all icing conditions defined in Appendix O of part 25, compliance with §§ 23.49(a) and (b), 23.73(d)(1), 23.75, 23.77(d), and (e), 23.143(a) for appropriate flight phases, 23.143(b) except for sudden engine failure requirements, 23.143 (c) and (f), 23.201 (a), (b), (c) and (e), 23.203 (a)(1), (b)(1), (b)(2), (b)(3), (b)(6), and (c), 23.207(a), (b), (d) for appropriate flight phases, (h), and (i), 23.231, 23.233, 23.237,and 23.251, must be met in the Appendix O icing conditions for which certification is not sought in order to allow a safe exit from those conditions. Compliance is only required at ambient temperatures of -13 degrees Celsius and warmer in the icing conditions

defined in part I of Appendix O of part 25. Compliance must be shown using the ice accretions for holding and approach phase as defined in part II(b) of Appendix TBD of this part, assuming normal operation of the airplane and its ice protection system in accordance with the operating limitations and operating procedures provided in the Airplane Flight Manual.

(3) If the applicant seeks certification for flight in any portion of the icing conditions of Appendix O of part 25, each requirement of this subpart, except for §§ 23.49(c), 23.77(d) and (e), the sudden engine failure requirements of § 23.143(b), 23.143(f), 23.145(c), (d), and (e), 23.147(c), 23.149(b), unless the applicant seeks approval for takeoff in Appendix O conditions, 23.149(d), 23.203(a)(2), 23.207(e) and (h), 23.221, 23.235, 23.239, and 23.253, must be met in the Appendix O of part 25 icing conditions for which certification is sought. Compliance must be shown using the ice accretions defined in part II(c) of Appendix TBD of this part, assuming normal operation of the airplane and its ice protection system in accordance with the operating limitations and operating procedures provided in the Airplane Flight Manual.

(4) No changes in the load distribution limits of § 23.23 and the weight limits of § 23.25 (except where limited by performance requirements of this subpart), from those for non-icing conditions, are allowed for flight in icing conditions or with ice accretion."

Amend takeoff performance requirements for icing by codifying the guidance in AC 23.1419-2D, except the airplanes that may be required to comply are based on the light jet rule.

SEC. 23.45 GENERAL (PERFORMANCE).

* * * *

(i) If the applicant seeks certification for flight in icing conditions, performance must be determined with engine power losses associated with operating ice protection systems, except for takeoff performance if operation of an ice protection system is prohibited for takeoff by the Airplane Flight manual Limitations section.

SEC. 23.51 TAKEOFF SPEEDS.

* * * *

(d) For normal, utility, and acrobatic category turbojet powered airplanes without a wing leading edge high lift device and commuter category airplanes, if the applicant seeks certification for flight in icing conditions, the takeoff speeds specified in § 23.51 (a), (b), and (c), must be based on V_{S1} determined with the most critical of the takeoff ice accretions defined in Parts I and II of Appendix TBD of this part, as applicable in accordance with § 23.21(c), if the stall speed

with takeoff ice accretion at maximum takeoff weight with takeoff flaps, gear retracted exceeds that in non-icing conditions by more than the greater of three (3) knots CAS or three (3) percent V_{S1}.

(e) In determining the takeoff speeds for flight in icing conditions, the values of V_{MCG} and V_{MC} determined for non-icing conditions may be used.

SEC. 23.53 TAKEOFF [PERFORMANCE.]

(a) For normal, utility, and acrobatic category airplanes, the takeoff distance must be determined in accordance with paragraph (b) of this section, using speeds determined in accordance with Sec. 23.51(a), **[(b), (d) and (e)]**.

(b) For normal, utility, and acrobatic category airplanes, the distance required to takeoff and climb to a height of 50 feet above the takeoff surface must be determined for each weight, altitude, and temperature within the operational limits established for takeoff with—

(1) Takeoff power on each engine;
(2) Wing flaps in the takeoff position(s); and
(3) Landing gear extended.

(c) For commuter category airplanes, takeoff performance, as required by Secs. 23.55 through 23.59, must be determined with the operating engine(s) within approved operating limitations.

SEC. 23.57 TAKEOFF PATH.

* * * *

(c)

(1)

(2)

(3)

(4)

(5) If the takeoff speeds must be adjusted in accordance with Sec. 23.51 (d), or if the degradation of the gradient of climb determined in accordance with Sec. 23.67(c)(2) is greater than 0.4 percent, the airborne part of the takeoff must be based on the airplane drag;

(i) With the most critical of the takeoff ice accretions defined in Parts I and II of Appendix TBD of this part, as applicable in accordance with § 23.21(c), from a height of 35 feet above the takeoff surface up to the point where the airplane is 400 feet above the takeoff surface; and

(ii) With the most critical of the final takeoff ice accretions defined in Parts I and II of Appendix TBD of this part, as applicable in accordance with § 23.21(c), from the point where the airplane is 400 feet above the takeoff surface to the end of the takeoff path.

<u>SEC. 23.65 CLIMB: ALL ENGINES OPERATING.</u>

*   *   *   *

(c) **For normal, utility, and acrobatic category turbojet powered airplanes without a wing leading edge high lift device, if the applicant seeks certification for flight in icing conditions, the effect of takeoff ice accretion defined in Parts I and II of Appendix TBD of this part, as applicable in accordance with § 23.21(c), with must be determined if:**

(1) 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 (3) knots CAS or three (3) percent V_{S1}; and

(2) the degradation of the gradient of climb determined in accordance with Sec. 23.65(b) with "takeoff" ice is greater than 0.8 percent.

<u>SEC. 23.66 [TAKEOFF CLIMB: ONE ENGINE INOPERATIVE.]</u>

*   *   *   *

(g) For normal, utility, and acrobatic category turbojet powered airplanes, if the applicant seeks certification for flight in icing conditions, takeoff ice accretion defined in Parts I and II of Appendix TBD of this part, as applicable in accordance with § 23.21(c), must be accounted for if compliance to Sec 23.65(c) is required.

<u>SEC. 23.67 CLIMB: ONE ENGINE INOPERATIVE.</u>

*   *   *   *

(e) If the applicant is seeking certification for flight in icing conditions, the effect of ice accretion as defined in the following table, in accordance with applicable portions of § 23.21(c), must be determined if:

(1) V_{S1} with the appropriate ice accretion at maximum takeoff weight (maximum landing weight for approach) with takeoff or approach flaps as applicable, gear retracted, exceeds that in non-icing conditions by more than the greater of three knots CAS or three percent V_{S1}; and

(2) **If commuter category, the degradation of the gradient of climb determined in accordance with Sec. 23.67(c)(2) is greater than 0.4 percent.**

(3) **If turbojet powered normal, utility or aerobatic category, the degradation of the gradient of climb determined in accordance with Sec. 23.67 (a) or (b) ice is greater than 0.3 percent.**

Table 4 - Sec. 23.67 Applicable Ice Accretions

<table>
<tr><th></th><th></th><th colspan="2">Ice accretion</th></tr>
<tr><th>Applicable airplanes</th><th>Applicable regulation</th><th>Part I, Appendix TBD of part 23</th><th>Part II, Appendix TBD of part 23</th></tr>
<tr><td>Normal, utility, and acrobatic category reciprocating engine powered of less than 6,000 pounds maximum weight</td><td>§ 23.67(a)</td><td rowspan="4">Not required</td><td rowspan="4">Final takeoff</td></tr>
<tr><td>Normal, utility, and acrobatic category reciprocating engine powered of more than 6,000 pounds maximum weight</td><td rowspan="3">§ 23.67(b)</td></tr>
<tr><td>Normal, utility, and acrobatic category turbo-propeller powered</td></tr>
<tr><td>Normal, utility, and acrobatic category turbojet powered with a wing leading edge high lift device</td></tr>
<tr><td>Normal, utility, and acrobatic category turbojet powered without a wing leading edge high lift device</td><td>§ 23.67(b)</td><td colspan="2">Final takeoff</td></tr>
<tr><td rowspan="4">Commuter category</td><td>§ 23.67(c)(1)</td><td>Not required</td><td>Takeoff</td></tr>
<tr><td>§ 23.67(c)(2)</td><td colspan="2">Takeoff</td></tr>
<tr><td>§ 23.67(c)(3)</td><td colspan="2">Final takeoff</td></tr>
<tr><td>§ 23.67(c)(4)</td><td colspan="2">Approach</td></tr>
</table>

SEC. 23.69 [ENROUTE CLIMB/DESCENT.]

* * * *

(c) If the applicant is seeking certification for flight in icing conditions, the effect of "enroute" ice, as defined in Parts I and II of Appendix TBD of this part, as applicable in accordance with § 23.21(c), on climb performance must be determined if:

(1) the enroute climb speed selected in icing is more than the non-icing speed by the greater of three (3) knots CAS or three (3) percent V_{S1}; or
(2) if the service ceiling with "enroute" ice is less than 22,000 MSL.

SEC. 23.73 REFERENCE LANDING APPROACH SPEED.

* * * *

(d) If the applicant is seeking certification for flight in icing conditions, except as provided in paragraph (1), V_{REF} must be based on stall speed with the most critical of the landing ice accretions defined in Parts I and II of Appendix TBD of this part, as applicable in accordance with § 23.21(c), if the stall speed with critical ice at maximum landing weight with landing flaps, gear down exceeds that in non-icing conditions by more than the greater of three (3) knots CAS or three (3) percent V_{S0}.

(1) V_{REF} in the appendix O icing conditions for which certification is not sought may be the V_{REF} determined in Sec. 23.73(d) with critical Appendix C ice accretions, if the airplane at that V_{REF} complies with the maneuver margin requirements of Sec. 23.207(d) with the critical landing ice accretion defined in Part II, paragraph (b), of Appendix TBD of this part.

SEC. 23.77 BALKED LANDING.

(a) Each normal, utility, and acrobatic category reciprocating engine-powered airplane of 6,000 pounds or less maximum weight must be able to maintain a steady gradient of climb at sea level of at least 3.3 percent with—
(1)
(2)
(3)
(4) A climb speed equal to V_{REF}, as defined in Sec. 23.73(a) **and Sec. 23.73(d)**.
(b) Each normal, utility, and acrobatic category reciprocating engine-powered of more than 6,000 pounds maximum weight and each normal, utility, and acrobatic category turbine engine-powered airplane must be able to maintain a steady gradient of climb of at least 2.5 percent with—
(1)
(2)
(3)

(4) A climb speed equal to V_{REF}, as defined in Sec. 23.73(b) **and Sec. 23.73(d)**.

(c) Each commuter category airplane must be able to maintain a steady gradient of climb of at least 3.2 percent with—

(1)

(2)

(3)

(4) A climb speed equal to V_{REF}, as defined in Sec. 23.73(c) **and Sec. 23.73(d)**.

(d) For normal, utility, and acrobatic category reciprocating engine-powered airplanes of 6,000 pounds or less maximum weight, if the applicant seeks certification for flight in icing conditions, the steady gradient of climb at the landing field pressure altitude must be measurably positive with—

(1) Takeoff power on each engine;

(2) The landing gear extended;

(3) The wing flaps in the landing position approved for flight in icing, except that if the flaps may safely be retracted in two seconds or less without loss of altitude and without sudden changes of angle of attack, they may be retracted; and

(4) A climb speed equal to V_{REF} as defined in Sec. 23.73(d)

(5) The critical approach ice accretion defined in Part II, paragraph (b), of Appendix TBD of this part.

(e) For normal, utility, and acrobatic category reciprocating engine-powered airplanes of more than 6,000 pounds, turbine powered airplanes and commuter category airplanes, if the applicant seeks certification for flight in icing conditions, the steady gradient of climb at the landing field pressure altitude must be measurably positive with—

(1) Not more than the power that is available on each engine eight seconds after initiation of movement of the power controls from the minimum flight idle position;

(2) The landing gear extended;

(3) The wing flaps in the landing position approved for flight in icing; and

(4) A climb speed equal to V_{REF} as defined in Sec. 23.73(d)

(5) The critical approach ice accretion defined in Part II, paragraph (b), of Appendix TBD of this part.

SECTION 23.143 GENERAL (CONTROLLABILITY AND MANEUVERABILITY)

Amend 23.143 by adding the guidance in AC 23.1419-2D for Appendix C icing conditions, and the proposals by the Part 23 Icing ARC for Appendix O icing conditions:

* * * *

(d) When demonstrating compliance with §23.143 in icing conditions—

(1) Controllability must be demonstrated with the ice accretion defined in Parts I and II of Appendix TBD of this part, as applicable in accordance with § 23.21(c)(1) and (3) and appropriate to the phase of flight;

(2) It must be shown that a push force is required throughout a pushover maneuver down to a zero g load factor, or the lowest load factor obtainable if limited by elevator power or other design characteristic of the flight control system. It must be possible to promptly recover from the maneuver without exceeding a pull control force of 50 pounds; and

(3) Any changes in force that the pilot must apply to the pitch control to maintain speed with increasing sideslip angle must be steadily increasing with no force reversals, unless the change in control force is gradual and easily controllable by the pilot without using exceptional piloting skill, alertness, or strength.

(4) It must be possible to readily arrest and reverse roll rate using only lateral control input, and the lateral control force must not reverse with increase of control deflection.

(e) For flight in icing conditions before the ice protection system has been activated and is performing its intended function, it must be demonstrated in flight with the ice accretion defined in part I(e), of Appendix TBD of this part that:

(1) The airplane is controllable in a pull-up maneuver up to 1.5 g load factor; and

(2) There is no pitch control force reversal during a pushover maneuver down to 0.5 g load factor.

(f) For airplanes certified under 23.1420(a)(1) (detect and exit), it must be demonstrated with the ice accretion defined in Part II, (b) of Appendix TBD of this part as applicable in accordance with § 23.21(c)(2), that:

(1) The airplane is controllable in a pull-up maneuver up to 1.5 g load factor; and

(2) There is no pitch control force reversal during a pushover maneuver down to 0.5 g load factor.

(3) Any changes in force that the pilot must apply to the pitch control to maintain speed with increasing sideslip angle must be steadily increasing with no force reversals, unless the change in control force is gradual and easily controllable by the pilot without using exceptional piloting skill, alertness, or strength. Additionally, lateral control force must not reverse with increasing control deflection, as the angle of sideslip is increased up to the maximum appropriate to the type of airplane.

(4) It must be possible to readily arrest and reverse roll rate using only lateral control input, and the lateral control force must not reverse with increase of control deflection.

SECTION 23.207 STALL WARNING.

Amend 23.207 by adding the guidance in AC 23.1419-2D for Appendix C icing conditions, and the proposals by the Part 23 Icing ARC for Appendix O icing conditions:

*   *   *   *

(g) For flight in icing conditions before the ice protection system has been activated and is performing its intended function, with the ice accretions defined in part 23, Appendix TBD, part I(e) and part II(h), the stall warning margin in straight and turning flight must be sufficient to allow the pilot to prevent stalling without encountering any adverse flight characteristics when:
(1) The speed is reduced at rates not exceeding one knot per second;
(2) The pilot performs the recovery maneuver in the same way as for flight in non-icing conditions; and
(3) The recovery maneuver is started no earlier than one second after the onset of stall warning

(h) For airplanes certified under 23.1420(a)(1) (detect and exit), the stall warning margin in straight and turning flight must be sufficient to allow the pilot to prevent stalling (as defined in Sec. 23.201(b)) when the pilot starts a recovery maneuver not less than three seconds after the onset of stall warning. When demonstrating compliance with this paragraph, the pilot must perform the recovery maneuver in the same way as for the airplane in non-icing conditions. Compliance with this requirement must be demonstrated in flight with the speed reduced at rates not exceeding one knot per second, with the critical detect and exit ice defined in part II(b), Appendix TBD of this part.
(i) In showing compliance with paragraphs (c), (g), and (h) of this section, stall warning must be provided by the same means in icing conditions as for non-icing conditions.

SECTION 23.1329 AUTOMATIC PILOT SYSTEM

…

(i) If the applicant seeks certification for use of the autopilot for flight in applicable portions of 14 CFR 25 Appendix O, there must be an indication to permit the crew to manually disengage the autopilot and take control prior to any automatic autopilot disengagement that would result in a hazardous flight condition.

SECTION 23.1419 ICE PROTECTION

Amend 23.1419 by clarifying when compliance to 23.1419 is required. Amended rule would allow installation of ice protections systems, to facilitate exit from inadvertent icing encounters, without a requirement for compliance to 23.1419. Capable of operating safely is re-defined. The activation of ice protection system guidance in AC 23.1419-2D and operation of ice protection system regulations recommended by ARAC for part 25 are added.

~~If certification with ice protection provisions is desired~~ **If the applicant seeks certification for flight in icing conditions,** compliance with the requirements of this section and other applicable sections of this part must be shown**:**

(a) An analysis must be performed to establish, on the basis of the airplane's operational needs, the adequacy of the ice protection system for the various components of the airplane. In addition, tests of the ice protection system must be conducted to demonstrate that the airplane is capable of operating safely in continuous maximum and intermittent maximum icing conditions, as described in appendix C of part 25 of this chapter. As used in this section, “Capable of operating safely,” means that ~~airplane performance, controllability, maneuverability, and stability must not be less than that required in part 23, subpart B.~~ **the airplane complies with the requirements in § 23.21(c)(1).**

* * * *

~~(d) A means must be identified or provided for determining the formation of ice on the critical parts of the airplane. Adequate lighting must be provided for the use of this means during night operation. Also, when monitoring of the external surfaces of the airplane by the flight crew is required for operation of the ice protection equipment, external lighting must be provided that is adequate to enable the monitoring to be done at night. Any illumination that is used must be of a type that will not cause glare or reflection that would handicap crewmembers in the performance of their duties. 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.~~

(d) One of the following methods of icing detection and activation of the airframe ice protection system must be provided:

(1) A primary ice detection system that automatically activates or alerts the flightcrew to activate the airframe ice protection system; or

(2) A definition of visual cues for recognition of the first sign of ice accretion on a specified surface combined with an advisory ice detection system that alerts the flightcrew to activate the airframe ice protection system; or

(3) Identification of conditions conducive to airframe icing as defined by an appropriate static or total air temperature and visible moisture for use by the flightcrew to activate the airframe ice protection system; or

(4) For normal, utility and acrobatic category airplanes, a definition of visual cues for recognition of the first sign of ice accretion on a specified surface to alert the flightcrew to activate the airframe ice protection system~~.~~

(e) Unless the applicant shows that the airframe ice protection system need not be operated during specific phases of flight, the requirements of paragraph (d) of this section are applicable to all phases of flight.

(f) After the initial activation of the airframe ice protection system--

(1) The ice protection system must be designed to operate continuously; or

(2) The airplane must be equipped with a system that automatically cycles the ice protection system; or

(3) An ice detection system must be provided to alert the flightcrew each time the ice protection system must be cycled.

(g) Procedures for operation of the ice protection system, including activation and deactivation, must be established and documented in the Airplane Flight Manual.

23.1420 – SUPERCOOLED LARGE DROP ICING CONDITIONS.

The proposed 23.1420 rule is similar to the proposed 25.1420 rule. There is concern among some of the ARC members that the rule is vague on when natural icing in SLD is required.

(a) If certification for flight in icing conditions is sought, in addition to the requirements of § 23.1419, an airplane must be capable of operating in accordance with paragraphs (a)(1), (a)(2), or (a)(3), of this section.

(1) Operating safely after encountering the icing conditions defined in Appendix O of part 25:

(i) There must be a means provided to detect that the airplane is operating in Appendix O icing conditions; and

(ii) Following detection of Appendix O icing conditions, the airplane must be capable of operating safely while exiting all icing conditions. "Capable of operating safely," means that the airplane complies with the requirements in § 23.21(c)(2).

(2) Operating safely in a portion of the icing conditions defined in Appendix O of this part as selected by the applicant. "Capable of operating safely," means that the airplane complies with the requirements in § 23.21(c)(3).

(i) There must be a means provided to detect that the airplane is operating in conditions that exceed the selected portion of Appendix O icing conditions; and

(ii) Following detection, the airplane must be capable of operating safely while exiting all icing conditions. "Capable of operating safely," means that the airplane complies with the requirements in § 23.21(c)(2).

(3) Operating safely in the icing conditions defined in Appendix O of part 25. "Capable of operating safely," means that the airplane complies with the requirements in § 23.21(c)(3).

(b) To establish that the airplane can operate safely as required in paragraph (a) of this section, an analysis must be performed to establish that the ice protection for the various components of the airplane is adequate, taking into account the various airplane operational configurations. To verify the analyses, one, or more of the following methods must be used:

(1) Laboratory dry air or simulated icing tests, or a combination of both, of the components or models of the components.

(2) Laboratory dry air or simulated icing tests, or a combination of both, of models of the airplane.

(3) Flight tests of the airplane or its components in simulated icing conditions, measured as necessary to support the analysis.

(4) Flight tests of the airplane with simulated ice shapes.

(5) Flight tests of the airplane in natural icing conditions, measured as necessary to support the analysis.

(c) For an airplane certified in accordance with paragraph (a)(2) or (a)(3) of this section, the requirements of § 23.1419(e), (f) and (g) must be met for the icing conditions defined in Appendix O of part 25 in which the airplane is certified to operate.

B) ICE ACCRETIONS FOR SHOWING COMPLIANCE TO 14 CFR 23 SUBPART B

The following definitions of ice accretions are proposed to be added in an Appendix TBD to 14 CFR 23. The definitions are analogous to the 14 CFR 25 Appendix C, Part II and proposed 14 CFR 25 Appendix O, Part II. The definitions were modified to point to the appropriate part 23, subpart B references and other changes recommended by the ARC to accommodate part 23 aircraft. The Part I of the proposed Appendix corresponds to ice accretions as a result of exposure to 14 CFR 25, Appendix C icing conditions and Part II of the Appendix corresponds to the ice accretions that may result from exposure to 14 CFR 25, Appendix O icing conditions.

(1) 14 CFR 23 APPENDIX TBD - AIRFRAME ICE ACCRETIONS

(2) PART I - AIRFRAME ICE ACCRETIONS FOR SHOWING COMPLIANCE WITH 14 CFR 23 SUBPART B IN THE ICING CONDITIONS DEFINED IN 14 CFR 25 APPENDIX C PART I.

(a) Ice accretions--General.

The most critical ice accretion in terms of airplane performance and handling qualities for each flight phase must be used to show compliance with the applicable airplane performance and handling requirements in icing conditions of subpart B of this part. Applicants must demonstrate that the full range of atmospheric icing conditions specified in part I of this appendix have been considered, including the mean effective drop diameter, liquid water content, and temperature appropriate to the flight conditions (for example, configuration, speed, angle-of-attack, and altitude). The ice accretions for each flight phase are defined as follows:

(1) *Takeoff ice* is the most critical ice accretion on unprotected surfaces and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, occurring between liftoff and 400 feet above the takeoff surface, assuming accretion starts at liftoff in the takeoff maximum icing conditions of part I, paragraph (c) of 14 CFR 25, appendix C.

(2) *Final takeoff* ice is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, between 400 feet and either 1,500 feet above the takeoff surface, or the height at which the transition from the takeoff to the en route configuration is completed and enroute climb speed is reached, whichever is higher. Ice accretion is assumed to start at liftoff in the takeoff maximum icing conditions of part I, paragraph (c) of 14 CFR 25, appendix C.

(3) *En route ice* is the critical 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. Applicable only to airplanes that are not certified to operate above 30,000 feet.

() *Holding ice* is the critical ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, during the holding flight phase.

(5) *Approach ice* is the critical ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation following exit from the holding flight phase and transition to the most critical approach configuration.

(6) *Landing ice* is the critical ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation following exit from the approach flight phase and transition to the final landing configuration.

(b) In order to reduce the number of ice accretions to be considered when demonstrating compliance with the requirements of Sec. 23.21(c), any of the ice accretions defined in paragraph (a) of this section may be used for any other flight phase if it is shown to be more critical than the specific ice accretion defined for that flight phase. Configuration differences and their effects on ice accretions must be taken into account.

(c) The ice accretion that has the most adverse effect on handling qualities may be used for airplane performance tests provided any difference in performance is conservatively taken into account.

(d) For both unprotected and protected parts, the ice accretion for the takeoff phase may be determined by calculation, assuming the takeoff maximum icing conditions defined in appendix C, and assuming that:

(1) Airfoils, control surfaces and, if applicable, propellers are free from frost, snow, or ice at the start of the takeoff;

(2) The ice accretion starts at liftoff;

(3) The critical ratio of thrust/power-to-weight;

(4) Crew activation of the ice protection system is in accordance with a normal operating procedure provided in the Airplane Flight Manual, except that after beginning the takeoff roll, it must be assumed that the crew takes no action to activate the ice protection system until the airplane is at least 400 feet above the takeoff surface.

(e) The ice accretion before the ice protection system has been activated and is performing its intended function is the critical ice accretion formed on the unprotected and normally protected surfaces before activation and effective operation of the ice protection system in continuous maximum atmospheric icing conditions. This ice accretion only applies in showing compliance to Sec. 23.143(e) and 23.207(g),

(3) PART II - AIRFRAME ICE ACCRETIONS FOR SHOWING COMPLIANCE WITH 14 CFR 23 SUBPART B IN THE ICING CONDITIONS DEFINED IN 14 CFR 25 APPENDIX O PART I

(a) General.

The most critical ice accretion in terms of airplane performance and handling qualities for each flight phase must be used to show compliance with the applicable airplane performance and handling qualities requirements for icing conditions as defined in § 23.21(c)(2) and (c)(3). Applicants must demonstrate that the full range of atmospheric icing conditions specified in part I of 14 CFR 25, Appendix O have been considered, including drop diameter distributions, liquid water content, and temperature appropriate to the flight conditions (for example, configuration, speed, angle-of-attack, and altitude).

(1) For an airplane certified in accordance with § 23.1420(a)(1), the ice accretions for each flight phase are defined in part II, paragraph (b) of this appendix.

(2) For an airplane certified in accordance with § 23.1420(a)(2), the most critical ice accretion for each flight phase defined in part II, paragraphs (b) and (c) of this appendix, must be used. For the ice accretions defined in part II, paragraph (c) of this appendix, only the portion of part I of 14 CFR 25, Appendix O in which the airplane is capable of operating safely must be considered.

(3) For an airplane certified in accordance with § 23.1420(a)(3), the ice accretions for each flight phase are defined in part II, paragraph (c) of this appendix.

(b) Ice accretions for airplanes certified in accordance with § 23.1420(a)(1) or (a)(2).

(1) *Holding ice* is the holding ice defined by part II, paragraph (c)(4), of this appendix, for an airplane certified in accordance with § 23.1420(a)(2), or defined by part I, paragraph (a)(4) of this appendix, for an airplane certified in accordance with § 23.1420(a)(1), plus:

(i) *Pre-detection ice* as defined by part II, paragraph (b)(3) of this appendix; and

(ii) The ice accumulated during the transit of one cloud with a 17.4 nautical miles horizontal extent in the most critical of the icing conditions defined in part I of 14 CFR 25, appendix O and one cloud with a horizontal extent of 17.4 nautical miles in the continuous maximum icing conditions defined in part I of 14 CFR 25, appendix C. The total exposure to the icing conditions need not exceed 45 minutes.

(2) *Approach ice* is the more critical of the holding ice defined by part II, paragraph (b)(1) of this appendix, or the ice calculated in the applicable paragraph (b)(2)(i) or (ii) of part II of this appendix:

(i) For an airplane certified in accordance with § 23.1420(a)(2), the ice accumulated during descent from the maximum vertical extent of the icing conditions defined in part I of 14 CFR 25, appendix O to 2,000 feet above the landing surface in the cruise configuration, plus transition to the approach configuration, plus:

(A) *Pre-detection ice*, as defined by part II, paragraph (b)(3) of this appendix; and

(B) The ice accumulated during the transit at 2,000 feet above the landing surface of one cloud with a horizontal extent of 17.4 nautical miles in the most critical of the icing conditions defined in part I of 14 CFR 25, appendix O and one cloud with a horizontal extent of 17.4 nautical miles in the continuous maximum icing conditions defined in part I of 14 CFR 25, appendix C.

(ii) For an airplane certified in accordance with § 23.1420(a)(1), the ice accumulated during descent from the maximum vertical extent of the maximum continuous icing conditions defined in part I of 14 CFR 25 appendix C to 2,000 feet above the landing surface in the cruise configuration, plus transition to the approach configuration, plus:

(A) *Pre-detection ice*, as defined by part II, paragraph (b)(3) of this appendix; and

(B) The ice accumulated during the transit at 2,000 feet above the landing surface of one cloud with a horizontal extent of 17.4 nautical miles in the most critical of the icing conditions defined in part I of 14 CFR 25, appendix O and one cloud with a horizontal extent of 17.4 nautical miles in the continuous maximum icing conditions defined in part I of 14 CFR 25 appendix C.

(3) *Pre-detection ice* is the ice accretion before detection of 14 CFR 25, appendix O conditions that require exiting per § 23.1420(a)(1) and (a)(2). It is the ice accumulated during the time needed to detect the icing conditions, followed by two minutes of further ice accumulation to take into account the time for the flight crew to take action to exit the icing conditions, including coordination with air traffic control.

(c) Ice accretions for airplanes certified in accordance with §§ 23.1420(a)(2) or 23.1420(a)(3). For an airplane certified in accordance with § 23.1420(a)(2), only the portion of the icing conditions of part I of 14 CFR 25 appendix O in which the airplane is capable of operating safely must be considered.

(1) *Takeoff ice* is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, occurring between liftoff and 400 feet above the takeoff surface, assuming accretion starts at liftoff in the icing conditions defined in part I of 14 CFR 25 appendix O.

(2) *Final takeoff ice* is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, between 400 feet and either 1,500 feet above the takeoff surface, or the height at which the transition from the takeoff to the en route configuration is completed and enroute climb speed is reached, whichever is higher. Ice accretion is assumed to start at liftoff in the icing conditions defined in part I of 14 CFR 25, appendix O.

(3) **Climb ice is the critical ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, during the climb after takeoff. Ice accretion includes ice accreted**

during takeoff phase plus the most critical of climb through 6,000 feet in freezing drizzle, or climb through 3,500 feet in freezing rain.

(4) *En route ice* is a**pplicable only to airplanes that are not certified to operate above 30,000 feet.** *En route ice* is the most critical 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 flight phase in the icing conditions defined in part I of 14 CFR 25, appendix O.

(5) *Holding ice* is the most critical ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, during the holding phase of flight.

(6) *Approach ice* is the ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, resulting from the more critical of the:

(i) Ice accumulated in the icing conditions defined in part I of 14 CFR 25, appendix O during a descent from the maximum vertical extent of the icing conditions defined in part I of this 14 CFR 25, appendix O, to 2,000 feet above the landing surface in the cruise configuration, plus transition to the approach configuration and flying for 15 minutes at 2,000 feet above the landing surface; or

(ii) *Holding ice* as defined by part II, paragraph (c)(4) of this appendix.

(7) *Landing ice* is the ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, resulting from the more critical of the:

(i) Ice accretion defined by part II, paragraph (c)(5)(i), of this appendix, plus ice accumulated in the icing conditions defined in part I of 14 CFR 25 appendix O during a descent from 2,000 feet above the landing surface to a height of 200 feet above the landing surface with a transition to the landing configuration, followed by a go-around conducted in accordance with Airplane Flight Manual procedures, from a height of 200 feet above the landing surface to 2,000 feet above the landing surface, flying for 15 minutes at 2,000 feet above the landing surface in the maximum flap configuration approved for holding, and a descent to the landing surface (touchdown) in the landing configuration; or

(ii) *Holding ice* as defined by part II paragraph (c)(4) of this appendix.

(8) For both unprotected and protected parts, the ice accretion for the takeoff phase must be determined for the icing conditions defined in part I of 14 CFR 25 appendix O, using the following assumptions:

(i) The airfoils, control surfaces, and, if applicable, propellers are free from frost, snow, or ice at the start of takeoff;

(ii) The ice accretion begins at liftoff;

(iii) The critical ratio of thrust/power-to weight; and

(iv) Crew activation of the ice protection system is in accordance with a normal operating procedure provided in the Airplane Flight Manual, except that after beginning the takeoff roll, it must be assumed that the crew takes no action to activate the ice protection system until the airplane is at least 400 feet above the takeoff surface.

(d) The ice accretion before the ice protection system has been activated and is performing its intended function is the critical ice accretion formed on the unprotected and normally protected surfaces before activation and effective operation of the ice protection system in the icing conditions defined in part I of 14 CFR 25 appendix O. This ice accretion only applies in showing compliance to §§ 23.143(e) and 23.207(g).

(e) In order to reduce the number of ice accretions to be considered when demonstrating compliance with the requirements of § 23.21(c), any of the ice accretions defined in this appendix may be used for any other flight phase if it is shown to be more critical than the specific ice accretion defined for that flight phase. Configuration differences and their effects on ice accretions must be taken into account.

(f) The ice accretion that has the most adverse effect on handling qualities may be used for airplane performance tests provided any difference in performance is conservatively taken into account.

C) POWERPLANT ASPECTS

SEC. 23.903 ENGINES

Add new 23.903(a)(3) to allow for approving new aircraft type certification programs with engines certificated to earlier amendment levels.

(a) Engine type certificate

* * * * *

(3) Each turbine engine must comply with one of the following paragraphs:
(i) Section 33.68 of this chapter in effect on [insert effective date of final rule], or as subsequently amended; or
(ii) Section 33.68 of this chapter in effect on February 23, 1984, or as subsequently amended before [effective date of final rule], unless that engine's ice accumulation service history has resulted in an unsafe condition; or
(iii) Section 33.68 of this chapter in effect on October 1, 1974, or as subsequently amended prior to February 23, 1984, unless that engine's ice accumulation service history has resulted in an unsafe condition; or
(iv) Be shown to have an ice accumulation service history in similar installation locations which has not resulted in any unsafe conditions.

* * * * *

SEC. 23.929 ENGINE INSTALLATION ICE PROTECTION

~~Propellers (except wooden propellers) and other components of complete 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.~~

If certification for flight in icing is requested:
(a) Propellers must be protected against the accumulation of ice as necessary to **comply with the requirements of § 23.21(c)(1), (c)(2), or (c)(3)** when operated in the icing conditions for which certification is requested, and after **encountering the icing conditions defined in Appendix O of part 25**
(b) Other components of the complete engine installations must be protected against the accumulation of ice as necessary to **comply with the applicable requirements of sub part E and F within 14 CFR 25 Appendix C and the approved portions of 14 CFR 25 Appendix O.**

SEC. 23.1093 INDUCTION SYSTEM ICING PROTECTION

*   *   *   *   *

(b) Turbine engines. Each engine, with all icing protection systems operating, must:
(1) Operate throughout its flight power range, including the minimum descent idle speeds, in the icing conditions defined in appendix C of part 25 of this chapter, approved portions of Appendix O of part 25 of this chapter, appendix D of part 33 of this chapter, and in falling and blowing snow within the limitations established for the airplane for such operation, without the accumulation of ice on the engine, inlet system components or airframe components that would do any of the following:
(i) Adversely affect installed engine operation or cause a sustained loss of power or thrust; or an unacceptable increase in gas path operating temperature; or an airframe/engine incompatibility; or
(ii) Result in unacceptable temporary power or thrust loss or unacceptable engine damage
(2) Idle for a minimum of 30 minutes on the ground in the following icing conditions shown in Table 1, unless replaced by similar test conditions that are more critical. These conditions must be demonstrated with the available air bleed for icing protection at its critical condition, without adverse effect, followed by an acceleration to takeoff power or thrust. During the idle operation the engine may be run up periodically to a moderate power or thrust setting in a manner acceptable to the Administrator. The applicant must document the engine run-up procedure (including the maximum time interval between run-ups from idle, run-up power setting, and duration at power) and associated minimum ambient temperature, if any, the maximum time interval, if any, and these conditions must be used in the analysis which establishes the airplane operating limitations in accordance with § 23.1521.

Table 5 - "Sec. 23.1093 -Table 1" - Icing Conditions for Ground Tests

Condition	Static Air Temperature	Water Concentration (minimum)	Mean Effective Particle Diameter	Demonstration
1. Rime ice condition	0 to 15°F (-18 to -9°C)	Liquid – 0.3 g/m3	15-25 microns	By test, analysis or combination of the two
2. Glaze ice condition	20 to 30°F (-7 to -1°C)	Liquid – 0.3 g/m3	15-25 microns	By test, analysis or combination of the two
3. Large droplet condition	15 to 30°F (-9 to -1°C)	Liquid – 0.3 g/m3	100 microns (minimum)	By test, analysis or combination of the two

~~(1) Each turbine engine and its air inlet system must operate throughout the flight power range of the engine (including idling), without the accumulation of ice on engine or inlet system components that would adversely affect engine operation or cause a serious loss of power or thrust--~~

~~(i) Under the icing conditions specified in appendix C of part 25 of this chapter; and~~
~~(ii) In snow, both falling and blowing, within the limitations established for the airplane for such operation.~~
~~(2) Each turbine engine must idle for 30 minutes on the ground, with the air bleed available for engine icing protection at its critical condition, without adverse effect, in an atmosphere that is at a temperature between 15° F and 30° F (between -9° and -1°C) and has a liquid water content not less than 0.3 grams per cubic meter in the form of drops having a mean effective diameter not less than 20 microns, followed by momentary operation at takeoff power or thrust. During the 30 minutes of idle operation, the engine may be run up periodically to a moderate power or thrust setting in a manner acceptable to the Administrator.~~

*   *   *   *   *

SEC. 23.1521 POWERPLANT LIMITATIONS.

*   *   *   *   *

(f) Maximum time interval between engine run-ups from idle, run-up power setting, duration at power and the associated minimum ambient temperature, if any, for ground operations in icing conditions, as defined in § 23.1093(b)(2).

D) SYSTEMS ASPECTS

SEC. 23.629 FLUTTER.

Unchanged.

SEC. 23.775 WINDSHIELD AND WINDOWS.

(f) Unless operation in known or forecast icing conditions is prohibited by operating limitations, ~~a means must be provide to prevent or to clear accumulations of ice from the windshield so that the pilot has adequate view for taxi, takeoff, approach, landing, and to perform any maneuvers within the operating limitations of the airplane.~~ **the following apply:**

> **(i) The aircraft must have a means to prevent or clear accumulations of ice from the windshield so that the pilot has sufficient view along the flight path in normal flight attitudes of the aircraft. This includes taxi, takeoff, approach, landing and to perform any maneuvers within the operating limitations. This means must be designed to function in ---**
>
> **(ii) The icing conditions specified in 14 CFR 25 Appendix C and approved portions of 14 CFR 25 Appendix O.**

SEC. 23.1323 AIRSPEED INDICATING SYSTEM.

(d) If certification for instrument flight rules is requested, ~~or flight in icing conditions is requested,~~ each airspeed system must have a heated pitot tube or an equivalent means of preventing malfunction due to icing. **In addition, if certification for flight in icing conditions is requested, the icing conditions specified below must be addressed:**

> **(1) Appendix C of Part 25, and Appendix O of Part 25, with exposures in accordance with 23.1420(a)(1), (a)(2) or (a)(3), and**
>
> **(2) The mixed phase and ice crystal conditions of Part 33, Appendix D, if the airspeed indicating system serves a critical function or the maximum certified ceiling is greater than 29,000 ft MSL and the M_{MO} is greater than Mach 0.75.**

SEC. 23.1324 ANGLE OF ATTACK SYSTEMS.

If an angle of attack system is provided for any instrument, device, or system required by the operating rules of this chapter, and certification for flight in icing conditions is desired, each angle of attack sensor must have a means of preventing malfunction due to icing. The icing conditions specified below must be addressed:

> **(1) Appendix C of Part 25 and Appendix O of Part 25 with exposures in accordance with 23.1420(a)(1), (a)(2) or (a)(3), and**
>
> **(2) The mixed phase and ice crystal conditions of Appendix D of Part 33, if the angle of attack system serves a critical function or the maximum certified ceiling is greater than 29,000 ft MSL and the M_{MO} is greater than Mach 0.75.**

SEC. 23.1325 STATIC PRESSURE SYSTEM.

(b)(3) If a static pressure system is provided for any instrument, device, or system required by the operating rules of this chapter, each static pressure port must be designed or located in such manner that the correlation between air pressure in the static pressure system and true ambient atmospheric static pressure is not altered when the aircraft encounters icing conditions**. If certification for flight in icing conditions is requested, the icing conditions described in Part 25 Appendix C and Appendix O, with exposures in accordance with §23.1420(a)(1), (a)(2) or (a)(3) must be addressed.** An anti-icing means or an alternate source of static pressure may be used in showing compliance with this requirement. If the reading of the altimeter, when on the alternate static pressure system differs from the reading of the altimeter when on the primary static system by more than 50 feet, a correction card must be provided for the alternate static system

SEC. 23.1326 PITOT HEAT INDICATION SYSTEMS

If a flight instrument pitot heating system is installed to meet the requirements specified in Sec. 23.1323(d), an indication system must be provided to indicate to the flight crew when that pitot heating system is not operating. The indication system must comply with the following requirements:
(a) The indication provided must incorporate an amber light that is in clear view of a flightcrew member~~.~~**, and**
(b) The indication provided must be designed to alert the flight crew if either of the following conditions exist:
(1) The pitot heating system is switched "off~~.~~" **during takeoff or in flight, except when the outside air temperature is greater than 5° C.**
(2) The pitot heating system is switched "on" and any pitot tube heating element is inoperative.

SEC. 23.1403 ICING INSPECTION LIGHTS.

If certification for flight in icing conditions is desired and aircraft procedures are dependent on visual observations of airframe ice accretion, a means must be provided for illuminating the formation of ice. Any illumination that is used must be of a type that will not cause glare or reflection that would handicap crewmembers in the performance of their duties.

SEC. 23.1416 PNEUMATIC DE-ICER BOOT SYSTEM.

Delete this section.

SEC. 23.1419 AND 23.1420

Systems aspects integrated with sub part B aspects; see the sub part B section above.

5. ADVISORY MATERIALS

A) Sub-Part B Aspects

See Appendix D for recommended revisions to AC 23.1419-2D

B) Powerplant Aspects

Note: The format of AC 23-16A has questions in a bold font. For clarity in denoting revisions from existing text, the bold font on the questions is not reproduced. To clearly separate questions from responses, indentation on the responses is used.

Sec. 23.901 Installation

AC 23-16A, reference Paragraph 23.901(d) - (revised material)

What are some other examples of issues not addressed by engine certification that need to be addressed for installation compliance with § 23.901(d)?

Amendment 25-53 added requirements for ice, hail, and birds similar to those in part 33. Examples of installation issues normally not addressed by engine certification, but that should be addressed for installation compliance, include the following:

1. Ice build-up on areas where ice shed may be ingested by the engines (for example, ice shed from wings and airframe sources into aft mounted engines) **should be addressed under the more specific requirements of § 23.1093 (b);** and

2. Consideration of items such as inlet splitters, acoustic liners, and so forth, that may be damaged by impact with ice, hail, and birds.

Sec. 23.903 Engines

AC 23-16A, reference Paragraph 23.903 - (added material)

What are some examples of how to show that "an ice accumulation service history in similar installation locations … has not resulted in any unsafe conditions"?

The intent of this regulation is to ensure that any unsafe conditions from prior designs are not carried forward onto new designs. One method of compliance would be to review the accident and incident history, any airworthiness directives on similar (or derivative) engines installed in similar locations and to coordinate with the engine manufacturer on any

prior service history issues. Any prior unsafe conditions must be addressed as part of the aircraft installation certification.

SEC. 23.905 ENGINES

AC 23-16A, reference Paragraph 23.905 - (added material)

What is required to show compliance for § 23.905(e) with respect to 14 CFR Part 25 Appendix O (SLD) conditions?

For aircraft without approval for flight in icing conditions, compliance for § 23.905(e) for inadvertent encounters with 14 CFR 25 Appendix O may be found by similarity to the 14 CFR 25 Appendix C conditions due to the similarity of ice volumes over the short durations during exit from all icing conditions. For aircraft that will be approved for flight in icing conditions, the icing exposures within Appendix O should be consistent with the durations used for developing the ice shapes used for demonstrating sub part B compliance (reference AC 23.1419-2E).

When showing compliance to § 23.905(e), can breakup of the ice shape be assumed prior to striking the blade?

There are no standard analytical methods for predicting break of ice shapes in flight. AC 20-147A contains some information on break-up as applicable to ice shapes used during part 33 testing of turbofan engines. For shapes that have similar aspect ratios, similar breakup characteristics may be assumed.

SEC. 23.929 ENGINE INSTALLATION ICE PROTECTION

AC 23-16A, reference Paragraph 23.929 - (added material)

Have the requirements of § 23.929 been applied to aircraft that are not certificated for flight in icing per § 23.1419?

For an airplane not certificated for flight in icing, compliance to § 23.929 is not required.

For an aircraft certified for flight in icing (§ 23.1419, § 23.1420), what icing environments and exposures should be used in showing compliance to this requirement?

The icing exposures should be consistent with the kinds of operation authorized under § 23.1525 and the certification option selected under § 23.1420. For aircraft certified under § 23.1420(a)(1), the propeller aspects should consider both operations in part 25, Appendix C as well as an exit from part 25, Appendix O. For the engine installation aspects, only Appendix C icing conditions must be considered. For aircraft certified to § 23.1420(a)(2) or (a)(3), consideration of extended operations in the

approved portions of part 25, Appendix O must be considered with respect to both the propeller and engine installation aspects. The exposure times should be consistent with the methods used to develop airframe shapes (reference AC 23.1419-2E).

If ice is determined 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, or evaluate the performance of such systems with tanker or natural icing tests. Tests should consider the critical operating temperatures and altitudes within Appendix C icing conditions. Tests of the generator cooling system with actual or simulated ice accumulation on the inlet should be performed with the maximum icing load on the electrical system at representative ambient temperatures. If data is analyzed in accordance with § 23.1043, the temperatures need to be corrected only to 32 degrees F, not a hot day.

Engine alternate induction air sources should remain functional in the required icing environments.

SEC. 23.1093 INDUCTION SYSTEM ICING PROTECTION

AC 23-16A, reference Paragraph 23.1093(b) - (revised/added material)

Is an airplane required to comply with § 23.1093 if it is not being certificated to fly in icing conditions?

Yes, compliance with § 23.1093(b) for induction system icing protection is required for all normal, utility, acrobatic, and commuter category airplanes certificated under part 23 even if the airplane is ***not*** being certificated for flight in icing conditions (§ 23.1419 compliance). Service experience has shown that airplanes can inadvertently encounter icing conditions even if the airplane is not approved for flight into icing conditions. This is particularly true for turbine engine powered airplanes, which typically have a greater operating flight envelope than reciprocating engine powered airplanes. These requirements are also those demonstrated during engine certification (reference 14 CFR part 33, subpart E, § 33.68, Induction system icing, for turbine aircraft engines).

The icing exposures considered should be consistent with the kinds of operation authorized under § 23.1525. The POH/AFM will have limitations prohibiting flight into known icing conditions, as such the icing exposures considered for compliance with § 23.1093 may be representative of an inadvertent encounter and subsequent exit from all icing conditions.

Delay of approval for flight into icing conditions should be addressed in a similar manner to an aircraft not intended for certification for flight into icing conditions. Some manufacturers choose to delay icing certification until after basic type certification is achieved due to marketing or contractual reasons. The aircraft may be fully equipped with airframe ice

protection systems that are certified from a equipment qualification and installation aspect, but have not been approved for flight into icing conditions. As such, limitations are required prohibiting flight into icing conditions.

Approvals for § 23.1093 for delayed or basic type certification should be based on the limited inadvertent exposure times that are possible for an aircraft prohibited from flight into icing conditions. In the event of an inadvertent encounter, the engines must operate without a sustained loss of power and there must not be a need to shutdown an engine in flight. Airframe ice protection systems may be considered part of the engine ice protection system if the possibility exists of airframe ice accretions shedding into the engine inlets. An example is ice accretion on the inboard wing of airplanes with aft fuselage mounted engines.

Applicants for basic (§ 23.1093) or delayed flight into icing certification (prior to §§ 23.1419, 23.1420) may show compliance to §23.1093 with the following methods:

> **(a) Flight testing in measured natural icing or flight testing behind an airborne icing tanker, supplemented by analysis as described in paragraph 16 of AC 23.1419-2E, 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.

Approval for the icing conditions of part 33, Appendix D should similarly be based on standard cloud extents and the altitude capabilities of the aircraft.

If the kinds of operation at the aircraft level change (for example flight into icing per § 23.1419 is sought), compliance with § 23.1093 will need to be readdressed considering the changes in icing exposures.

For an aircraft certified for flight in icing (§ 23.1419, § 23.1420), what icing environments and exposures should be used in showing compliance to § 23.1093?

The icing exposures should be consistent with the kinds of operation authorized under § 23.1525 and the certification option selected under § 23.1420. The requirements of § 23.1093(b)(1)(i) establish the requirements to show operation of the installed engine throughout the defined environments, within the limitations established for the airplane. For aircraft that will be approved for all of Part 25, Appendix O, the icing exposures within Appendix O should be consistent with the exposures used for developing ice shapes used for demonstrating sub part B compliance. Similarly, for the requirements of § 23.1420 propeller/engine installation exposure times should be consistent with the methods used to develop airframe shapes reference AC 23.1419-2E.

For an aircraft certified for flight in icing (§§ 23.1419, 23.1420), what other considerations are necessary for compliance to §23.1093?

Turbine 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. 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.

For engine ice protection systems, which for aft fuselage mounted engines can include the inboard wing ice protection system, a delay of two minutes in the continuous maximum icing conditions of appendix C to part 25 is utilized to validate the ice shedding analyses and § 33.77 ice slab test

results. To minimize flight testing, an applicant has the option of conducting this evaluation after the tests in Table 3 are conducted, provided the tested ice accretion is conservative for both tests.

For amended TC's and STC's due to an engine change, the effects of ice shedding and the suitability of the ice protection power supply should be addressed.

(a) 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.

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

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

Compliance methods for the large drop environments are limited by the current development state of simulation methods. Reliance on available simulation methods combined with engineering judgment will be required for findings of compliance in the icing conditions of 14 CFR 25, Appendix O and 14 CFR 33, Appendix D. See AC 23.1419-2E and AC 20-147B for additional guidance on available interim methods and simulation tools.

What compliance methods are available for the icing conditions of part 33, Appendix D?

The analysis and compliance methods for ice crystal/mixed phase conditions are limited by currently available testing and analytical methods. The primary concern to be addressed is the potential for accumulation of ice crystals within inlet ducting (that can build and shed causing engine damage) and potentially the added heat required to melt trapped ice crystals.

Certification of ice crystals/mixed phase conditions for the air data sensors used for engine control may be accomplished under Part 33. Any engine installation/airframe use of such data should consider the results of the

qualification testing and ensure that it is applicable for the installation certification.

The FAA has conducted mixed phase icing tests, which indicated that for unheated airfoil surfaces, the potential ice accretion was the same or less than the same total water content of supercooled liquid water. The overall power required for running-wet ice protection was not significantly changed between all liquid and mixed-phase conditions. However, the local power density was higher around the stagnation area compared to purely liquid conditions due to the heat required to melt the impacting particles that either fully or partially stick to the surface. For internal flow areas with considerable changes in airflow direction, and potential for trapping ice particles, the latent heat effect of the ice crystals may be more prominent.

For inlets that have considerable changes in airflow direction, an assessment of the potential for areas of accumulation of mixed phase/ice crystal conditions within the inlet should be accomplished. Some icing tunnel facilities have limited ice crystal capabilities that may be suitable for evaluating potential accumulations and/or shedding trends in such designs.

Compliance for pitot-style inlets (without considerable changes in airflow direction) or for inlet designs using inertial separation, may be shown through qualitative analysis of the design and supported by similarity to previous designs that have shown successful service history.

For the ground icing requirements of § 23.1093(b)(2), what determines whether a limitation on maximum time interval is required?

The intent of the ground icing is to ensure that the aircraft can be safely operated in ground icing conditions for extended times, which may be in excess of 30 minutes. For aircraft that complete the 30-minute interval and exhibit consistent, repetitive build and shed cycles (with or without intermediate engine run ups), no maximum time interval would be required. For aircraft that complete a minimum of 30 minutes without any engine run-ups, a run-up should be performed to ensure that ice has not been accumulating, just prior to shed. If the run-up does not produce any adverse operating effects or engine damage, no maximum time interval would be required. If the run-up does produce adverse operating effects or damage to the engine, the test should be repeated to determine a shorter time interval in which the engine can operate and then complete an acceleration without adverse operating effects or damage to the engine. This shorter time interval would then become an operating limitation.

C) <u>SYSTEMS ASPECTS</u>

See Appendix D for recommended revisions to AC 23.1419-2D

D) <u>AC 23-17C</u>

Add additional materials for AC 23-17ABC at end of the pertinent sections:

…

23.1323 Airspeed indicating system

…

<u>Amendment 23-tbd and subsequent</u>

<u>This amendment added additional requirements to address supercooled large drops and mixed phase/ice crystal requirements. The regulation as applied to IFR aircraft is essentially unchanged from prior amendments. For aircraft certified for flight into icing conditions, see AC 23.1419-2E or subsequent revision.</u>

...

23.1326 Pitot heat indication systems

…

<u>Amendment 23-tbd and subsequent</u>

<u>This amendment modified the requirements of 23.1326 to alleviate the need for an ELOS for pitot systems that are not operated on the ground to protect equipment or composite structures or at high ambient temperatures in flight. For more discussion, see AC 23.1419-2E or subsequent revision.</u>

…

23.1329 Automatic pilot system

AC 23.1329 Section 3(d)

Note: Requirements for autopilots with respect to icing certification are addressed in AC 23.1419-2E.

…

To show compliance with part 23, § 23.1329, applicable to autopilot system installations in small airplanes, the following is acceptable.

1. RELATED REGULATIONS AND DOCUMENTS

…

b. Advisory Circulars

…

AC 23.1419-2E "Certification of Part 23 Airplanes for Flight in Icing Conditions", dated TBD.

6. ALTERNATIVES CONSIDERED

Before proposing new rulemaking, the FAA considers alternative ways to rulemaking to solve the safety issue under consideration. The first two alternatives were considered in detail by the Ice Protection Harmonization Working Group and included in the part 25 NPRM published on June 29, 2010. The part 23 ARC did not study these in detail but consider these alternatives valid for part 23. They are repeated here as published in the Federal Register on June 29, 2010.

ALTERNATIVE 1: TERMINAL AREA RADAR AND SENSORS

"The IPHWG considered the use of terminal area radar and ground-based sensors to identify areas of SLDs so they can be avoided, rather than require certification for operations in SLD. Equipment for detecting and characterizing icing conditions in holding areas is being developed. However, the equipment would have limited coverage area. For areas not covered by terminal area radar and ground-based sensors, airborne radars and sensors are being developed that would identify SLD conditions in sufficient time for avoidance. These ground-based and airborne systems are not mature enough to provide sufficient protection for all flight operations affected by SLD. Even if the equipment was mature, rulemaking would still be necessary to establish safety margins for inadvertent flight into such conditions and to provide an option for applicants to substantiate that the airplane is capable of safe operation in SLD conditions."

ALTERNATIVE 2: ICING DIAGNOSTIC AND PREDICTIVE WEATHER TOOLS

"The IPHWG considered the use of icing diagnostic and predictive weather tools to avoid SLD rather than certify an airplane to operate in SLD conditions. Tools have been developed that can provide information on icing and SLD potential, but may not report all occurrences of SLD. These experimental tools are available on the Internet and can be used to provide flight planning information guidance for avoidance of SLD conditions. However, rulemaking would still be necessary to establish safety margins for inadvertent flight into such conditions and to provide an option for applicants to substantiate that the airplane is capable of safe operation in SLD conditions."

ALTERNATIVE 3: MAINTAIN CURRENT CERTIFICATION MEANS OF COMPLIANCE

The ARC considered the option of continuing the current method of addressing SLD during certification of part 23 airplanes. One reason for considering this is the fact that there are no icing related accident of airplanes with the current part 23 icing regulation (introduced at Amendment 23-43) in its certification basis. Table 6 lists these airplanes. It was also recognized that the icing accident trend has been down, as illustrated in Figure 1.

Table 6 - Aircraft Certified to § 23.1419 Amdt. 23-43

Models Certified at Amendment 23-43	Year Certified	No. of U.S. Registered Airplanes as of November 1, 2010
Hawker Beech 390	2001	183
Extra 400	2002	11
Emivest SJ30-2	2007	5
Diamond DA-42	2007	*164 (tbd certified to 23.1419)*
Cessna 510	2007	190
Embraer 500	2008	87
Eclipse 500	2008	*267 (88 certified to 23.1419)*
Cirrus SR22	2009	281
Embraer 505	2009	7
Cessna 525C	2010	9

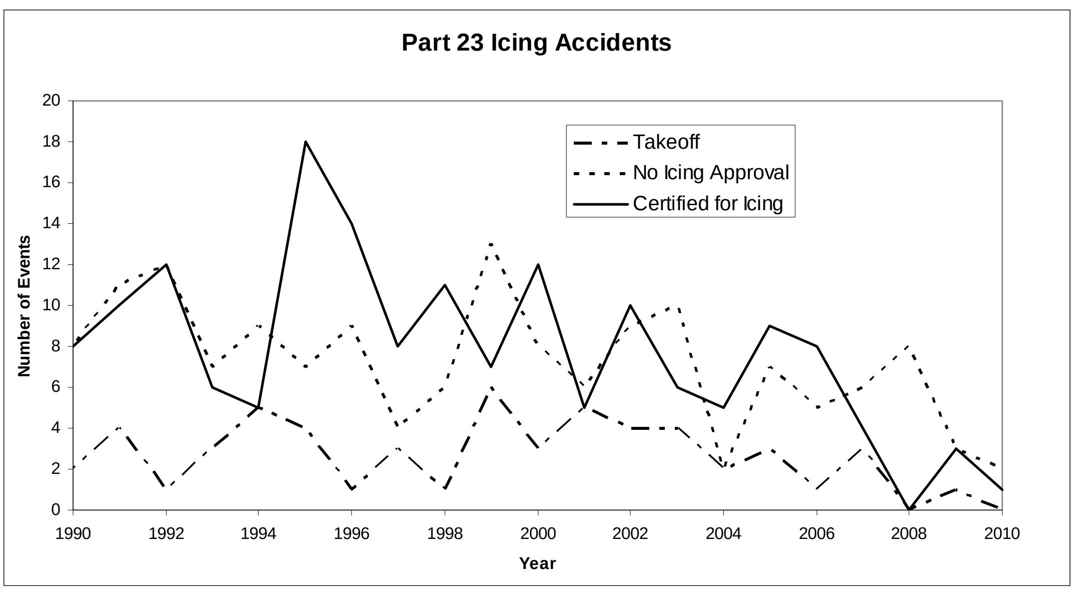

Figure 1 - Icing Accident Trend 1990-2010

A General Aviation Manufacturers Association (GAMA) review indicates that the proposed rule will not have a big impact on part 23 airplane safety because it will only be applicable to new airplanes. The estimated number of new aircraft manufactured and affected by the rulemaking will be small compared to the existing fleet. In addition, the number of accidents attributed to icing for part 23 aircraft that are certified for flight in icing is a small percentage compared to other causes. Most of the icing events reviewed are on aircraft not certified for flight in icing, which will not be corrected by this rulemaking proposal. As a result, the ARC would like to emphasize the importance of efforts to educate pilots who operate existing airplanes that are not certified for icing on the dangers of using those products in icing environments discussed in alternative #4.

SLD is currently addressed by evaluating susceptibility to roll control anomalies in SLD and providing generic SLD cues and exit procedures in the Airplane Flight Manuals (AFMs).

Adopting this alternative would obviously eliminate an increase in certification costs. However, the ARC did not recommend this alternative for the following reasons:

The scope of these actions are limited because they do not address the underlying safety concern of the unknown performance and handling safety margins for airplanes operating in freezing drizzle or freezing rain or a mixed phase. Any requirements resulting from these actions would not be comparable to those established by the current § 23.1419, which defines safe performance, stall warning and characteristics, and handling qualities for flight in part 25, Appendix C icing conditions.

The current accepted means of determining the SLD shape is either using an arbitrary shape and size, or determining it analytically. The result may be an ice shape that is not conservative enough, or too conservative, which may result in over design (cost) or a safety impact (unnecessarily high approach and landing speeds). Choosing this option would not result in an AFM requirement to prohibit flight in SLD conditions.

ALTERNATIVE 4: PILOT TRAINING

The ARC recognized that icing training for pilots can be improved. For example, part 61 requires logbook endorsements for tailwheel, high performance airplanes, and high altitude (pressurized) airplanes, but has no such requirements for an airplane approved for icing. The ARC looked at two examples (Mitsubishi MU-2 series and Cessna C-208 series) in which annual icing training is required by airworthiness directive (AD). The service history of these airplanes in icing improved dramatically after the ADs were issued, although other actions in addition to training were required. If training alone without the certification rulemaking described in this report were proposed, it would have to be made mandatory to be effective (with testing and recurring refresher training). There was not be a consensus in the ARC to propose a part 61 amendment to add icing training, and therefore this alternative was not chosen. However, the ARC will be proposing additional non-regulatory training to supplement the proposed rules as part of Task 7. These training recommendations will be added by revision of this report.

In addition to SLD, training for ground deicing/anti-icing and airplanes not approved for known icing (since these make up a large percentage of events) are recommended.

RULEMAKING ALTERNATIVES CONSIDERED OTHER THE ACTION PROPOSED

The following are rulemaking alternatives (additional, reduced, or modified rules) that were considered by the ARC.

ALTERNATIVE 5: SIMPLIFY PROPOSED SECTION 23.1420(A)(1)

The ARC considered simplifying proposed 23.1420(a)(1) for "detect and exit" airplanes by only requiring an AFM Limitation that prohibits flight in freezing drizzle and freezing rain. Proposed 23.1420(a)(2) and (a)(3) apply to airplane seeking approval in a portion of Appendix O or all of Appendix O and would still be proposed as is. Adopting this alternative would delete the requirement to analyze and test "detect and exit" ice shapes and would be a large decrease in certification costs. It also addresses one of the cons described in alternative no. 3 above. However, it would not address roll control anomalies in SLD, which is accomplished today in certification. It would also not address the underlying safety concern of the unknown performance and handling safety margins for airplanes operating in freezing drizzle or freezing rain, particularly stall warning, or a mixed phase, and therefore was rejected.

ALTERNATIVE 6: DELETE PROPOSED SECTIONS 23.1420(A)(2) AND (A)(3)

When alternative 5 was discussed, in addition to simplifying paragraph (a)(1) of the proposed rule, deleting (a)(2) and (a)(3) was considered. If an applicant wanted approval to operate in a portion or all of Appendix O, 25.1420(a)(2) or (a)(3) could be added into the certification basis. Adding specific part 23 sub-part B rules could be done since Subpart B requirements differ between part 23 and 25. The ARC recognized that the certification basis would be difficult to apply consistently (e.g. 1g stall speeds, additional administrative expenses- issue papers, FAA/Applicant coordination). It was recognized that in some areas, the proposed part 25 requirements would be more stringent (holding for 45 minutes at extreme cold OAT; ice protection activation requirements) and less stringent in others (certification for takeoff in freezing drizzle and not freezing rain, or vice versa). This alternative was not adopted for these reasons.

ALTERNATIVE 7: TAKEOFF IN EITHER FREEZING DRIZZLE OR LIGHT FREEZING RAIN

Operators of part 23 airplanes, particularly in commercial service, want the capability to takeoff and land in freezing drizzle and freezing rain. The ARC concurred with the part 25 ARAC IPHWG that certifying to a portion should be permitted. In addition to proposing 23.1420(a)(2), the ARC provides detailed guidance for certifying a part 23 airplane to takeoff in SLD conditions. The part 25 proposal allows certification for takeoff in freezing drizzle and not freezing rain, and vice versa. There are benefits if part 23 policy was the same. One, freezing drizzle and freezing rain could possibly result in very different ice accretions on a part 23 airplane, which would allow the one more critical to be certified and not the other. This would reduce certification cost as well as provide an operational capability that would otherwise not be available. The latter is important because one of the ARC surveys (Appendix TBD of this report) of operators showed a prohibition on freezing drizzle has a larger impact than freezing rain. As described in this report, the ARC believed that in the part 23 operating environment, with today's technology, it would not be uncommon to misidentify freezing drizzle and freezing rain. Because these ice accretions may have different effects on part 23 airplanes, the ARC decided that for now, takeoff certification in Appendix O would have to include all of Appendix O.

ALTERNATIVE 8: MODIFY THE PROPOSED PART 25, APPENDIX O ICING ENVIRONMENT

The ARC analyzed a common ice protection system on part 23 airplanes, the fluid anti-ice system, for compliance to the proposed part 25, Appendix O icing conditions. It was found that the freezing drizzle condition at -25°C OAT was the critical point, requiring a large increase in flow rate to maintain an anti-ice solution. This would result in a large increase in fluid capacity, resulting in a weight penalty. An increase in analyses and tests would also result depending on how the system was to be designed compared to the current certified system. Although not analyzed, it is theorized a thermal bleed air system may also find this to be its critical condition, requiring additional bleed air. The ARC reviewed the research data points that were used for development of the part 25 Appendix O and the documented icing conditions of icing events, and questioned why the liquid water content at -25°C could not be reduced (due to the lack of data in this region). The ARC decided it was not appropriate to propose SLD icing conditions different from that proposed for part 25. Alternatively, the ARC proposed rule language in 23.21(c)(2) to address the issue, and guidance for 23.21(c)(2)(3) for holding duration at cold freezing drizzle conditions. The ARC proposal targets the primary safety concern of warm Appendix O conditions without undue penalty to part 23 aircraft.

ALTERNATIVE 9: REDUCE NUMBER OF FLIGHT TESTS OR ANALYSES REQUIRED

The ARC asked itself, are we proposing requirements for D&E airplanes for which service history shows no safety issue? Eliminating tests that provide no safety benefit would reduce certification cost. The ARC could not justify any revisions to what was proposed for certification for flight in Appendix O or an approved portion of it. Any reduction would be a reduction of what is currently required for Appendix C icing conditions.

For a detect and exit airplane, the ARC decided at the beginning of their work to propose rules that address the safety concern and not have icing conditions for which the airplane is not approved to dictate design. Compliance to the following regulations are proposed with detect and exit encounters:

Section 23.77	Landing climb
Section 23.143	ICTS
Section 23.1323	SLD requirements for airspeed indicating systems
Section 23.1325	Static pressure system

There have been no documented fatal events due to SLD icing conditions related to any of these areas. The part 23 icing ARC decided to retain them as requirements because the lack of flight data recorders in the part 23 fleet could be one reason why, but also rationalized the following:

Section 23.77 - Icing research testing documented in FAA Technical Report DOT/FAA/06-60, “Propeller Icing Tunnel Tests on a Full-Scale Turboprop Engine,” March 2010 showed a significant difference in propeller ice accretion and performance between an Appendix O condition and several Appendix C conditions, and therefore propeller performance could affect climb capability in Appendix O. There are part 23 airplanes with documented events in which a forced landing resulted from flight in Appendix O conditions.

Section 23.143 - A ridge behind the protected area could form on the horizontal tail as well as the wing, and since an ICTS event has a high probability of being catastrophic, the ARC believes it should be tested.

Section 23.1323 - Pitot probes have high collection efficiency and therefore their performance does not change with drop size. Also consider the liquid water content of Appendix O is smaller than Appendix C, there should be no performance problem in Appendix O. However, ice accretions forward of the probe could affect the position error, and since Appendix O conditions could affect all probes at the same time, the possibility of misleading airspeed should be evaluated.

Section 23.1325 - Certification experience has shown some locations of static ports can result in ice accretion near them in Appendix O conditions.

Section 23.629 – The part 25 NPRM proposed that a flutter analysis is required for detect and exit shapes. This was a subject that the ARC debated. Flutter experts from some airframe manufacturers were consulted and recommended that anything that could form on the aircraft should be analyzed, and since applicants will be defining ice shapes to use for flight testing exit criteria, they would likely analyze them for flutter characteristics. On the other hand, service history shows no events due to flutter of SLD ice accretions. In addition, on unprotected surfaces such as wing tips, the mass of ice due to SLD is not expected to be higher than due to Appendix C. The ARC decided that a flutter analysis would not be required for detect and exit ice accretions.

Ice crystal Requirements - Ice crystal requirements for the airspeed indicating system are proposed in § 23.1323. There are no documented ice crystal events of pitot probes on part 23 airplanes. The documented events on part 25 airplanes show that high altitude and high true airspeed are factors. The ARC decided that part 23 airplanes which are capable of certain altitude and Mach number should show compliance.

ALTERNATIVE 10: REDUCE NUMBER OF REQUIRED ICE SHAPES

Similarly to alternative 9, the ARC asked itself if it could simplify the guidance on ice shapes to reduce the amount of analyses, icing tunnel tests, and possibly flight tests that would have to be accomplished. Could one ice shape, such as exposure at end of the hold, perhaps approach (eliminating landing, enroute, etc.) be used as a simplified approach that would provide most of the safety benefit? The ARC reviewed the service history and rationalized that analyses of ice accretions for “detect and exit” can be limited to the holding phase and approach phase. The ARC could not rationalize doing the same for the portions of Appendix O for which the airplane is approved, for the same reason as alternative 9.

ALTERNATIVE 11: ALLOW VISUAL CUE FOR ALL PART 23 AIRPLANES

Section 25.1419 was revised at Amendment 25-129 in 2009 to add requirements for activation of ice protection. A visual cue alone is not compliant to 25.1419, an advisory ice detection system is required to be installed. Adding an ice detection system increases certification cost as well as the cost of the airplane (by at least $TBD). In reviewing the service history of part 23 airplanes, pilots typically know when they’re in icing. The scale factor and pilot visibility of more accretion surfaces (such as wing leading edge) is one difference between part 23 airplanes and part 25 airplanes. The ARC, therefore, decided not to require an advisory ice detection system to supplement visual cues for normal, utility, and acrobatic category airplanes. However, the ARC chose to adopt the part 25 requirements for commuter category airplanes. The larger scale factor, and the fact that pre-activation ice in SLD would not be required were factors in the decision.

ALTERNATIVE 12: NECESSITY TO FLIGHT TEST IN NATURAL APPENDIX O CONDITIONS

The necessity to flight test in natural Appendix O conditions was debated during the IPHWG and the pros and cons are detailed in the IPHWG report which can be found in rulemaking docket F AA–2010–0636. A large con was the cost involved. The ARC adopted similar rule language as part 25, making natural icing one of the acceptable means of compliance, rather than an absolute requirement. The ARC added specific guidance for a path for detect and exit airplane in which natural icing flight tests in Appendix O would not be required as one of the means of compliance. The ARC did not adopt this for an airplane approved to fly in a portion or all of Appendix O. For example, to approve takeoff in Appendix O conditions, the guidance material states takeoff demonstrations in natural Appendix O should be accomplished. The majority of the ARC believed the airplane should be flight tested in the actual conditions for which it is approved, and not put the flying public in that position. The alternative, not adopted, would be to certify approved portions of Appendix O the same manner as detect and exit.

ALTERNATIVE 13: AERODYNAMIC PERFORMANCE MONITOR AS AN ALTERNATIVE TO § 23.1420

Similar to the first two alternatives, this alternative was not discussed in detail by the ARC but it is valid for part 23. The discussion in the IPHWG working group report is repeated here:

"The working group considered the use of aerodynamic performance monitors (APM's) to detect sources of boundary layer instabilities similar to those caused by ice accretions. The logic is that flightcrews would be alerted to take precautionary actions once the wing or a control surface's boundary layer conditions had reached a safety threshold, regardless of what caused the boundary layer disturbance. Several attempts have been made to investigate the feasibility of APMs on civil aircraft. Currently no APMs are used on commercial aircraft and there is little operational experience to establish confidence in the system's capabilities. The working group concluded that APM's are not sufficiently mature to support a rule based on its technology. However, the rule is written broadly enough to allow the use of an APM as a means of compliance should the APM's reach the maturity required to obtain approval for installation on a Part 25 (23) airplane."

7. CERTIFICATION COST INPUT

A) Assumptions

As part of the Task 2, ARC members provided input on the estimates on the cost of the proposed regulatory changes to assist the FAA in performing the regulatory analysis. Both the increase in costs and any potential for reduced costs were considered.

With the diverse range of aircraft within part 23 and the range of certification levels typically sought, some method of sub-dividing the fleet was required. The ARC elected to consider both aircraft size and the certification options available to applicants.

The assumptions used for the certification cost estimates are provided in Table *7* and Table 8.

Cost estimates were limited to the added costs related to the proposed rulemaking. The basic costs associated with certification within Appendix C icing are existing requirements and are not part of the cost basis.

Other assumptions used in the estimates were as follows:

- The costs for amended type certificates considered significant under § 21.101 will have a similar cost as a new type certification basis.
- ARC members were to use their anticipated compliance methods (icing tunnels, icing tankers, test methods) as the cost basis.
- For aircraft certified to detect and exit per § 23.1420(a)(1), no testing in natural large drop conditions would be required (applicant's discretion).
- For aircraft certified for takeoff and landing (approved portion) per § 23.1420(a)(2), flight testing in natural large drop conditions would be required.
- For aircraft certified without restrictions per § 23.1420(a)(3), flight testing in natural SLD would be required.
- Costs estimates were to include total costs, including both labor hours for direct engineering and supporting personnel. Direct non-recurring costs were considered all costs that are not direct labor (wind and/or icing tunnel rental, additional icing tunnel models, travel, chase aircraft rental, contract services such as meteorologist, tool making, etc.)
- Estimates were provided in labor hours assuming that the FAA economist would use the appropriate $/hour rate for such technical engineering activity.

Some of the rulemaking recommendations would alter compliance methods for basic compliance with § 23.1419. These changes were to be included in the estimates as differences due to the proposed rulemaking. As a part of this, there was some changes made that could reduce some of the existing certification costs within Appendix C certifications. ARC members were requested to provide an estimate of these costs to be considered in the overall economic balance.

Table *7* - Size Assumptions Used for Certification Cost Estimates

Aircraft Type	**Assumptions**
Small part 23 aircraft	Single reciprocating engine (under 6,000 lbs)
Large part 23 aircraft	Twin turbofan, commuter category (under 19,000 lbs)
Note: This is intended to capture the upper and lower bounds within part 23. If further sub-categories are required, the ARC can provide guidance based on aircraft and certification complexity .	

Table 8 - Certification Approval Options with Respect to Icing Conditions

Option	**Assumptions**
Basic Certification (not approved for flight into icing)	Required for all part 23 certifications • This option includes all icing considerations for certification of an aircraft that is prohibited from flight into icing conditions. • Includes any basic engine requirements such as § 23.1093 (does not include § 23.929). • Optionally, includes systems and equipment requirements such as pitot heat and static source heat requirements for aircraft certified for IFR/IMC operations. • Includes any ice protection equipment installed on a “non-hazard” basis as there are no additional icing rule requirements beyond those for a “basic” certification.
Approval for flight into icing per § 23.1419	Optional Requirement (applicants discretion) • Approval for flight into icing is optional within part 23. • Many small part 23 single engine aircraft are not approved for flight in icing. However, the industry trend is that icing approvals are becoming more common on smaller aircraft due to market demand. As such, the estimates were provided for both the “Small” as well as the “Large” part 23 aircraft as defined in Table 7. • Approval for flight into icing under § 23.1419 is limited to the environmental definitions in 14 CFR 25, Appendix C.
Approval to proposed § 23.1420	Required if aircraft if approved for flight into icing per § 23.1419.

B) <u>INCREASED COST CATEGORIES</u>

The increased costs were further divided to account for the different aspects of a typical certification. These divisions were as follows:

<u>Airframe Analysis</u>

The airframe analysis aspect was intended to address aspects of the certification related to the airframe ice protection systems and the effect of the airframe ice shapes on the performance and handling qualities of the aircraft (not including actual flight testing). This type of activity typically includes:

Table 9 - Regulatory Input - Airframe Analysis

Aspects	Activities
Ice Shapes/Impingement	• Includes any additional analysis required to show compliance to the proposed rules for development of unprotected ice shapes on areas such as wing tips/roots, stabilizers tips/roots, vertical stabilizer (if applicable), radomes, etc. • Development of the protected area limits on wing, propeller, etc. • Any potential ice shapes that may form behind the protected areas.
Aerodynamic Effects	• This category includes any CFD or other aerodynamic analysis required to look at the criticality of ice shapes, evaluate the potential performance effects at the airfoil and/or aircraft level, as well as SLD cue development (wind tunnel testing addressed separately).
Aeroelastic Stability	• Required for approved portions of Appendix O
Water Catch & Thermal Aspects	• This category includes any required analysis of the altered water catch effects due to the proposed rulemaking, examples include effect on evaporative or running wet anti-ice systems, effect on freezing point depressant systems, etc.

<u>Wind Tunnels</u>

The wind tunnel category includes items such as wind tunnel model rework, wind tunnel contract expenses, fabrication of the ice shapes, labor to develop the test plans, data analysis, test reports and conduct testing as well as any added costs for travel expenses. Model rework aspects limited to necessary modification necessary to perform the SLD testing. Does not include the basic cost of the model if it would have been build for Appendix C certification efforts.

Icing Wind Tunnels

This category was divided into airframe and engine installation aspects. Detail tasks/items are similar to the wind tunnel category above, again considering only the differences due to the large drop certification efforts.

Engine Installation

This category considers engine installation effects that would be required for certification to proposed §§ 23.903, 23.929 and 23.1093. Considers requirements for any analysis, review of service history, shedding aspects and compliance methods.

Miscellaneous Systems

This category considers the systems and equipment aspects such as §§ 23.775, 23.1323, 23.1324, 23.1325, 23.1326, 23.1403, 23.1419 and 23.1420. This would include any changes to system architecture and integration, system safety assessments, SLD ice detector qualification and installation certification, any modifications to windshield heat levels, angle of attack and pitot probe requirements, as well as any supporting analysis for the above.

Flight Testing

This category was subdivided into three areas, dry air shape testing, icing tanker testing and natural SLD testing.

Table 10 - Regulatory Input – Flight Testing

Dry air ice shape testing	• Includes test plans, conducting the testing including any necessary build-up of the ice shapes for safety mitigation, data analysis and test reports. • Ice shape definition (drawings, installation instructions), fabrication and installation. Analysis of the ice shapes was considered under the Airframe Analysis category.
Icing tanker Testing	• Includes icing tanker rental & fabrication if the applicant deems necessary for showing compliance. Not all manufacturers/applicants will have access to icing tankers, requiring alternate means of compliance. • Test plans, conducting the testing, data analysis and required documentation. • Includes cost and time to fly the aircraft to and from the test area, and chase aircraft rental as required to document tests • Flight crews and support personnel such as support engineering staff and maintenance personnel
Natural SLD Testing	• Test plans, conducting the testing, data analysis and required documentation. • Airplane preparation (install instrumentation, painting for visibility of ice shedding, cameras, etc.) • Includes cost and time to fly the aircraft to and from the SLD conditions, and chase aircraft rental as required to document tests. • Flight crews and support personnel such as support engineering staff and maintenance personnel to conduct natural ice tests in SLD • Icing meteorological support. • Specific icing instrumentation for SLD (rental if required)

C) INCREASED COST SUMMARY

The estimates reflect the increased costs for applicants for the different types of certification. The differences in bids reflect different approaches towards certification As an example, some applicants may use more analysis, and less icing and wind tunnel tests, not all applicants have access to icing tankers and consequently may have more effort expended in icing and/or flight tests. As such, the bid pairs (labor and non-recurring costs) should not be split between different estimates.

The bids reflect the best estimates available at this point in time, but did have considerable variance between the different estimates. This is likely a reflection of the uncertainties in the certification process (applicants won't know the full extent of work required until a full certification plan is completed and approved), as well as what facilities/simulation methods are available to the various applicants. As such, it is recommended to use a median approach to the regulatory analysis to more accurately reflect the true costs associated with the rule.

Table 11 provides a summary of the total labor hours and the non-recurring costs that would occur for each certification program. It is assumed that the APO will determine the appropriate engineering labor rate for use in the analysis.

For reference on detect and exit certification, most manufacturers assumed one Appendix O ice shape configuration for flight test evaluation, although one manufacturer assumed three ice shapes.

Table 11 - Summary of Increased Certification Costs for Proposed Rulemaking

Summary	Hours						Non-recurring costs					
	Basic		FIKI				Basic		FIKI			
	(non-FIKI)		Detect and Exit		Unrestricted		(non-FIKI)		Detect and Exit		Unrestricted	
	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large
Estimate A	none	none	2700 hrs	4890 hrs	6020 hrs	10465 hrs	none	none	$ 343,000	$ 427,500	$ 997,000	$ 1,740,500
Estimate B	none	none	no bid	15300 hrs	no bid	32300 hrs	none	none	no bid	$ 2,340,000	no bid	$ 3,620,000
Estimate C	none	none	1900 hrs	no bid	4440 hrs	no bid	none	none	$ 188,000	no bid	$ 453,000	no bid
Estimate D	none	100 hrs	4096 hrs	4106 hrs	10124 hrs	10074 hrs	none	$ 2,000	$ 233,500	$ 480,500	$ 542,000	$ 1,029,000
Estimate E	none	none	3324 hrs	5283 hrs	11214.5 hrs	15728 hrs	none	none	$ 108,231	$ 635,762	$ 520,154	$ 2,528,646
Summary Median	none	100 hrs	3012 hrs	5087 hrs	8072 hrs	13097 hrs	none	$ 2,000	$ 210,750	$ 558,131	$ 531,077	$ 2,134,573

Table 12 provides a summary of the total labor hours and the non-recurring costs that would occur for each aspect of certification considered. As discussed above, separation of the bid pairs (labor and non-recurring) is not recommended.

Table 12 – Detailed Medians for the Aspects of Certification

	Hours						Non-recurring costs					
	Basic		FIKI				Basic		FIKI			
	(non-FIKI)		Detect and Exit		Unrestricted		(non-FIKI)		Detect and Exit		Unrestricted	
	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large	Small	Large
Median of all bids received, by category:												
Airframe Analysis	none	0 hrs	810 hrs	1158 hrs	1847 hrs	2342 hrs	none	$ -	$ -	$ -	$ -	$ -
Wind Tunnels	none	0 hrs	80 hrs	614 hrs	160 hrs	1217 hrs	none	$ -	$ 27,500	$ 90,250	$ 90,500	$ 164,300
Icing Wind Tunnels - Airframe Aspects	none	0 hrs	208 hrs	296 hrs	434 hrs	768 hrs	none	$ -	$ 50,000	$ 137,994	$ 88,518	$ 384,982
Icing Wind Tunnels - Engine Aspects	none	0 hrs	89 hrs	258 hrs	147 hrs	574 hrs	none	$ -	$ 8,003	$ 83,997	$ 21,884	$ 247,741
Engine Installation	none	100 hrs	225 hrs	325 hrs	390 hrs	750 hrs	none	$ 2,000	$ 1,000	$ 1,000	$ 1,000	$ 6,000
Misc - Systems	none	0 hrs	364 hrs	740 hrs	804 hrs	1336 hrs	none	$ -	$ 7,500	$ 27,500	$ 7,500	$ 32,500
Flight Test - Dry Air Testing	none	0 hrs	463 hrs	1190 hrs	1416 hrs	4274 hrs	none	$ -	$ 23,500	$ 106,250	$ 62,500	$ 248,750
Flight Test - Tanker Testing	none	0 hrs	380 hrs	255 hrs	740 hrs	415 hrs	none	$ -	$ 48,000	$ 77,750	$ 113,825	$ 76,750
Flight Test - Natural SLD Testing	none	0 hrs	0 hrs	0 hrs	924 hrs	1752 hrs	none	$ -	$ -	$ -	$ 141,000	$ 346,500

D) COSTS FOR CERTIFICATION TO A PORTION

The guidance material recommendations provide guidance for certification to a portion of the large drop environment in the context of approving takeoff and landings in such conditions. The feedback from the operators within the ARC, indicated that this could become a significant operating restriction, and as such market demand may be sufficient for a manufacturer to seek such an approval.

The advisory material recommends additional ice shape scenarios that require consideration, and also advises that flight testing in natural large drop icing would be required. Additionally, since the certification would still be restricted during certain phases of flight, development of exit icing cues and ice shapes would be required.

The consensus opinion of the ARC was that the certification for approval for takeoff and landing is that the costs would be 70% of the difference between a detect and exit certification and a full unrestricted certification as noted below.

$$\textit{Portion Costs}_{\textit{Takeoff \& Landing}} =$$

$$\sum \textit{Detect \& Exit Costs} + 70\% * \left[\sum \textit{Unrestricted Costs} - \sum \textit{Detect \& Exit Costs} \right]$$

E) REDUCED COSTS CATEGORIES

An effort was made to identify the reduced costs in the same manner as for the increased costs as noted in Table *7* and Table 8. The sub-categories were similar to the cost evaluation (Analysis, Wind Tunnels, Icing Wind Tunnels and Flight Testing).

The effort was limited to the reduced costs related to the proposed rulemaking as compared to the requirements at 14 CFR 23, Amendment 43. The icing requirements of § 23.1419 at amendment 43 were altered to define “Capable of operating safety” as the airplane performance, controllability, maneuverability, and stability must not be less then that required in part 23, subpart B for Appendix C icing conditions. In addition to SLD rulemaking, the ARC proposed changes to § 23.1419 that eliminate certain Subpart B requirements. The estimate was intended to assist in determining how much of the costs of basic certification to § 23.1419 is reduced.

Examples of potential reduced costs were as follows:

23.49(c)	Stalling period - Tests would still be required to define stall speeds with critical ice accretions. However, the cost associated with writing and working on an exemption request is eliminated.
Takeoff	Determination of takeoff speeds or takeoff performance due to takeoff ice accretions is proposed not to be required for reciprocating or turboprop powered normal category airplanes. Therefore the cost to determine takeoff ice accretion (additional tunnel tests or analysis) and flight testing with takeoff ice accretion (stall and climb performance) would not be entered for the small airplane.
Roll Control in SLD	AC 23.1419-2D requested consideration of the potential for roll control anomalies in SLD conditions for aircraft with non-powered roll control surfaces.

The ARC members reviewed the request and could not identify a significant reduced cost. It was the opinion of the ARC members, that the magnitude of any reduced costs are well within the uncertainty of the increased cost estimates shown above. As such, it is recommended that the potential for reduced costs be acknowledged as a conservative factor in the regulatory analysis rather than an explicit calculation.

F) SUMMARY ARC POSITION ON COSTS

The ARC completed the assigned tasking which was to review the part 25 rulemaking and determine an appropriate response for part 23. However, the larger issue of how to improve icing safety for the part 23 fleet was not directly addressed by the new certification rules. The ARC has concerns over the relatively high certification costs associated with the rules proposed with respect to the overall safety benefit on icing safety for the part 23 fleet. The GAMA presentation included in Appendix F illustrates the limited effect on the current part 23 aircraft.

As discussed in Section 9 Benefit Summary, the majority of part 23 icing accidents occur on aircraft that are not certified for flight in icing. As flight in icing systems are optional equipment on many part 23 aircraft, this trend will not be altered by the introduction of new certification rules. Additionally, the large quantity of aircraft already in the field combined with the relatively low projected production rates will limit the overall effect of new certification rules on the part 23 fleet.

Additionally, all of the icing events have occurred on aircraft built prior to increased icing certification standards associated with § 23.1419, Amendment 43 which was introduced in 1993. This rule change only considers Appendix C icing conditions, but required the aircraft to meet the subpart B standards in icing conditions. This has typically been assessed in recent certifications with extensive ice shape testing, simulating preactivation, normal operation as well as system failure shapes. The guidance material also required severe icing language to be added to the AFMs with generic identification cues. The lack of safety events associated the amended icing rules, begs the question of whether increased standards of § 23.1419, Amendment 43 provides sufficient protection for exiting severe icing conditions, including exposures to part 25, Appendix O. Another unintended consequence of the rulemaking is a potential decrease in the safety level as more manufacturers/customers may opt for a no-hazard system due to the certification requirements and increased flight in known icing option costs.

Most part 23 aircraft will likely elect to comply with the detect and exit option of §23.1420(a)(1). The combination of small scale, limited power, and reversible flight controls makes it technically challenging to certified to a portion or unrestricted flight per § 23.1420(a)(2) or (a)(3). As a detect and exit aircraft, operations in freezing drizzle and freezing rain will be prohibited by AFM limitations which will limit the aircraft exposure to conditions when forecast or reported. Significant certification cost reduction could be realized by reducing the scope for detect and exit aircraft to determining and validating exit cues. The exit procedures for an inoperative ice protection system could be used to provide the safety margins desired for a safe return and landing. The system failure shapes typically require increased approach and landing speeds as well as potential flap limits. While the exact effect of the SLD shapes would not be assessed, a level of safety commensurate with the exposure risk could be achieved.

Alternately, it may be possible to reduce the certification requirements, while maintaining the level of safety, based on the accident history review with focus on the certification areas that are affected. Using this type of bottoms up approach would provide the maximum value for the certification costs.

While there is a desire to maintain an equivalent level of safety to part 25, the ARC recognizes that most part 23 aircraft are operated differently than the part 25 transport aircraft. Part 23 aircraft have more operational flexibility, and can operate out of much smaller airports. This ability to divert and land at a large number of airports provides more options than part 25 operations constrained to specific airports.

8. OPERATING COST

A) COST OF AVAILABLE CERTIFICATION OPTIONS

On the operators' side for non-recurring costs, a breakdown divided into three categories can be envisaged.

(1) AIRPLANES CERTIFIED TO § 23.1420(A)(1) "DETECT AND EXIT"

It is envisioned that most part 23 airplanes, particularly the airplanes marketed more for part 91 operations versus part 135 cargo[2] operations, will be certified to "detect and exit." These airplanes will be prohibited from operating in Appendix O conditions, for example taking off at an airport reporting freezing drizzle or freezing rain. Based on an AOPA survey, it can be assumed that 50% of part 91 operations would not be affected since they do not currently operate in these conditions. Based on NATA and RACCA surveys, it can be assumed that 50% of part 135 operations would not be affected since they do not currently operate in these conditions. This value was obtained by combining the 1/3 NATA number with 3/5 RACCA number for light freezing rain resulting in 4/8. The RACCA respondents who did not operate in freezing drizzle were higher, which is not quite understood. The lower number is used to be conservative. These airplanes will have costs associated with the following:

- Cancelled flight (due to Appendix O conditions at the departure airport)
- Cancelled flight (due to Appendix O conditions at the destination airport)
- Diversion by exiting (increased flown distance)
- Diversion to alternate

The impact due to diversion by exiting while enroute is small. Part 23 airplanes today are required to exit severe icing by an AFM Limitation. Appendix O conditions would cause severe icing on many part 23 airplanes.

(2) AIRPLANES CERTIFIED TO § 23.1420(A)(2) "APPROVED TO OPERATE IN A PORTION OF APPENDIX O"

Many of the part 23 airplanes expected to be operated in part 135 cargo operations most likely will be certified to takeoff in Appendix O conditions, and almost as much will be certified to takeoff and land in these conditions. There are additional certification costs for landing. The surveys showed the operators want these capabilities for new

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[2] The operating rules for cargo versus passenger operations are mostly the same for part 135 operations, however part 135 cargo operations typically have more pressures to dispatch into significant weather conditions than part 135 passenger operations.

airplanes. The only effect on takeoff and landing would possibly be a weight limit (resulting in payload decrease) to comply with takeoff, approach, or landing climb gradient requirements. These airplanes will have costs associated with the following:

- Impact on dispatch (performance limited take-offs or landings and payload decrease)
- Diversion by exiting (increased flown distance)
- Cancelled flight (due to Appendix O conditions enroute)

The impact due to diversion by exiting while enroute is small as discussed in § 23.1420(a)(1).

(3) AIRPLANES CERTIFIED TO § 23.1420(A)(3) "APPROVED TO OPERATE IN ALL OF APPENDIX O"

It is not anticipated that a part 23 airplane will be certified to this rule due to the small scale effects and capabilities of ice protection systems common on these airplanes. However, it should not be ruled out completely due to technology advances and/or market pressure. Therefore a small percentage of future part 23 airplanes certified to this rule should be assumed. The operating costs associated with this option are:

- Impact on dispatch (performance limited take-offs or landings and payload decrease)

B) TRAINING

Costs due to any increase in training should be considered for the part 135 operators. In part 91 operations, airplanes requiring a type rating should be considered. The Airline Transport Pilot Practical Test Standards (FAA-S-8081-5F) introduced the following special emphasis area at Change 2, July 2008 and therefore training for ATP ratings will be affected:

> "Added recognition of wing contamination to icing; adverse effects of wing contamination in icing conditions during takeoff, cruise, and landing phases of flight; and icing procedures of information published by the manufacturer, within the AFM, that is specific to the type of aircraft;.."

The increased cost would involve training the limitations, any procedure in Appendix O different than in Appendix C, and Appendix O recognition cues. Part 135 operators that employ dispatchers would also have an increase in cost.

Costs associated with the training of Air Traffic Control and weather system personnel also need to be considered, but it is assumed this was included in the part 25 rulemaking effort.

C) DESIGN IMPLICATIONS

Compliance to the new rules may result in design changes which will affect operators. Modifications in the ice protection systems such as an increased bleed and/or engine size or increased fluid capacity) will increase cost and/or weight. If engine size or bleed extraction remains unchanged, there may be payload reductions to meet climb requirements.

D) AIRPLANE MANUFACTURING INDUSTRY

The new rule will not affect the current fleet. New airplanes with a prohibition on taking off and landing in Appendix O will compete with the existing fleet. Except for some very recent certifications which adopted recommended language in AC 23.1419-2D, the current fleet has no such prohibition. This will lead to either more new certifications complying with proposed § 23.1420(a)(2) in lieu of § 23.1420(a)(1), or if the RACCA and AOPA surveys are an indication, will lead many to buy a used airplane rather than a new one. This would lead to lower sales of new airplanes, which would affect not only the airplane manufacturers but their suppliers. Regarding the RACCA survey, the question was “presuming you’re considering a new aircraft”. The NATA representative, a part 135 cargo operator, commented that they usually buy used airplanes anyway, so the impact due to these operators may not be large.

E) ACTUAL COST DATA

This discussion is meant to guide the FAA economist to the types of recurring costs that should be considered. The surveys in Appendix E of this report contain limited quantitative data which may be useful to the economist.

9. BENEFIT SUMMARY

A) ICING ACCIDENT DATABASE REVIEW

The ARC examined incidents and accidents to identify those which may be considered in the benefit analysis of the regulatory evaluation. The ARC would like to acknowledge the work of Steve Green, a consultant hired by the FAA to help assemble the part 23 icing database and identify applicable accidents. Much of the narrative in this section of the report was extracted from a draft of Mr. Green's report to the FAA.

Three data sources were used - NTSB data, the FAA Accident/Incident Data System, and the NASA Aviation Safety Reporting System. The original project that studied part 23 icing accidents was accomplished in 2007. A total of 187 part 23 icing events were considered in the original study. Of these 187 events, 38 of them took place prior to 1982 and were thus not originally considered, however several of these were re-examined to determine if SLD was present. Four events were rejected from the current work following additional examination of their relevance. An additional 7 events were determined to present inadequate data for evaluation. Although these 7 events had been evaluated for the previous study, it was determined after careful reconsideration that they did not have enough data available. Three events that had been deemed to present inadequate data in the earlier study were now included in the current evaluation. This resulted in 141 original events. An additional 84 events were added to this data - 54 events from the ASRS database, 1 from the FAA AIDS data, and 29 events from the NTSB data. These included events that occurred after the 2007 study, and events that were found after a more robust "scrubbing" of the databases. These events were then analyzed to determine their applicability to the proposed rules. An additional 12 events were removed as a further review indicated the aircraft were not approved for known icing.

The following table lists the accidents applicable to SLD. All aircraft were certified to § 23.1419 at Amendment 23-14 or earlier, including Civil Air Regulations (CAR) 3. No aircraft in the events database were certificated under. § 23.1419 Amendment 23-43 (latest amendment for part 23 icing certification). Since 1979 through 2010, there were 48 events with a total of 57 fatalities.

Table 13 – Events Applicable to SLD

DATE	AC TYPE	LOCATION	FATAL	INJURY	HULL LOSS
01/03/2009	BE-58	Brainerd, MN	0	0	SD
02/16/2007	CE-340A	Council Bluffs, IA	4	0	Yes
03/20/2006	PA-23-250	Emporia, KS	0	1	SD
01/25/2006	CE-421C	Carson, WA	1	0	Yes

Table 13 – Events Applicable to SLD

DATE	AC TYPE	LOCATION	FATAL	INJURY	HULL LOSS
01/11/2005	BE-65-E90	Rawlins, WY	3	1	Yes
12/10/2003	CE-441	Vestavia Hills, AL	2	0	Yes
11/04/2003	CE-208B	Bangor, ME	0	0	MD
12/26/2006	CE-414	Johnstown, PA	2	0	Yes
12/24/2002	BE-58	Egypt, AR	1	0	Yes
02/07/2001	BE-65-B80	Sioux Falls, SD	0	1	Yes
02/07/2001	BE-58	Ainsworth, NE	1	1	Yes
12/18/2000	BE-58	Huntingburg, IN	0	0	SD
05/31/2000	CE-414	Monarch, MT	3	0	Yes
01/24/1999	PA-46-350P	Rockford, IL	0	1	Yes
01/21/1999	BE-95-C55	Pellston , MI	3	0	Yes
01/08/1999	CE-310R	Allentown, PA	0	0	SD
04/07/1998	CE-208B	Bismarck, ND	1	0	Yes
03/05/1998	CE-208B	Clarksville, TN	1	0	Yes
01/20/1998	CE-208B	Grand Island, NE	0	0	SD
11/13/1997	BE-65-A90	Wheeling , WV	0	0	SD
11/02/1997	PA-34-200T	Lynn, IN	2	0	Yes
01/08/1997	BE-200	Dallas, TX	0	0	SD
12/28/1996	BE-65-C90	Rhinelander, WI	0	2	Yes
02/07/1996	BE-1900D	Bradford, PA	0	2	SD
01/15/1996	MU-2B-36	Malad City, ID	8	0	Yes
12/22/1995	B-58	Minneapolis, MN	0	0	SD
10/21/1995	CE-421C	Battle Creek, MI	1	0	Yes
03/05/1995	CE-421C	El Prado, NM	4	0	Yes
03/02/1995	CE-208B	Ardmore, OK	0	1	SD
02/15/1995	PA-23-250	Minneapolis, MN	0	0	SD
02/14/1995	CE-T310R	Grand Island, NE	0	0	SD
12/08/1994	BE-18	Kansas City, MO	1	0	Yes
11/25/1993	CE-303-T303	Rogers, AR	2	0	Yes
01/27/1992	CE-441	Green Bay, WI	0	0	MD

Table 13 – Events Applicable to SLD

DATE	AC TYPE	LOCATION	FATAL	INJURY	HULL LOSS
02/27/1990	CE-208B	Denver, CO	1	0	Yes
03/03/1989	CE-310R	Des Moines, IA	0	0	SD
03/05/1986	MU-2B-60	Eola, IL	5	0	Yes
02/26/1986	BE-18	Janesville, WI	0	1	Yes
02/18/1986	CE-402B	Rochester, MN	0	0	SD
11/25/1985	500 (Twin Commander)	Des Moines, IA	7	0	Yes
12/04/1984	CE-T310R	Lubbock, TX	0	0	SD
12/05/1983	BE-18-TC45J	Kansas City, KS	1	0	Yes
12/18/1982	CE-310R	Gaylord, MI	0	0	SD
01/06/1982	CE-340A	Rolla, MO	0	0	SD
12/18/1980	BE-60	Denver, CO	0	2	SD
02/15/1980	BE-18	Olathe, KS	1	0	Yes
12/04/1979	DHC-6-300	Steamboat Springs, CO	2	20	Yes
3/21/1984	CE-421C	Joliet, IL	0	0	SD

SD – substantial damage
MD- minor damage

The above events only include U.S. events. The following foreign events should be mentioned since SLD is suspected and they involve an aircraft type which has 6 events in the U.S. table. The first event is an incident in which airplane could not climb. The events in Russia and Canada were stall on approach. The Russian event is significant because the airplane was equipped with a flight data and voice recorder.

Table 14 – International Events Applicable to SLD

DATE	AC TYPE	LOCATION	FATAL	INJURY	HULL LOSS
01/19/2006	CE-208B	Florø, Norway	0	0	No
11/19/2005	CE-208B	Moscow, Russia	8	0	Yes
03/14/1997	CE-208B	Simcoe, ON, Canada	1	0	Yes

There exist 16 events known to the FAA of thrust rollback in certain turbojet engines of part 23 airplanes in suspected ice crystal conditions that do not appear in public records. All occurred in cruise at an altitude of 28,000 to 41,000 feet. Blockage of the heated total temperature probe causing erroneous data to the FADEC is suspected. These events are not available publicly and are not listed. There are 6 documented events on part 23 airplanes of possible ice crystals causing erroneous airspeed information to systems or the flightcrew. All occurred in cruise at altitudes above 35,000 ft and at speeds of Mach 0.75 or higher. All events cleared once the aircraft descended into warmer altitudes.

The proposed regulations promulgate guidance on ice contaminated tailplane stall (ICTS). The following events are suspected ICTS events that are not included in the SLD tables above:

Table 15 – Events Applicable to ICTS Rulemaking

DATE	AC TYPE	LOCATION	FATAL	INJURY	HULL LOSS
10/13/1978	DHC-6-200	Barrow, AK	1	1	SD
3/12/1985	DHC-6-300	Barter Is., AK	0	4	SD
12/14/1987	BAE-3101	Joplin, MO	0	7	SD
12/26/1989	BAE-3101	Pasco, WA	6	0	Yes
1/19/1996	PA-34-200T	Des Moines, IA	0	1	SD
Note: An ICTS accident involving a model BAE 3101 in Beckley, WV on January 30, 1991 is not included since the airframe ice protection system was inoperative.					

THE USE OF NTSB PUBLIC DOCKETS

The NTSB maintains a docket for each accident or incident that it investigates. Events which took place earlier than about 1992 are stored on microfiche. Those which took place after this point are stored digitally. Recently, the Board has started putting their full dockets on line.

In some dockets, only the NTSB Form 6120 is present, and in some of those cases, it is not complete. Some dockets are thorough, containing original written statements and police reports. They almost always contain a statement from the pilot-in command, should he/she have survived, as well as witness statements and ATC transcripts where appropriate. The docket also contains photographic evidence, although there is no standard for the photographic evidence.

FAA AIDS reports are not supported by retained documentation. Therefore, additional material such as inspector's notes and so forth are apparently only available in rare cases, and is not obtainable through a standardized records management system. Unfortunately, the lack of a narrative in many FAA reports renders them nearly unusable.

WAS AIRPLANE EQUIPPED WITH ICE PROTECTION SYSTEMS?

A common issue with the NTSB dockets for part 23 airplane events is the lack of documentation of the ice protection systems and certification, even when the accident clearly involves airframe icing. At one point, during the mid eighties, the Board used a field documentation form that contained check boxes for icing equipage and icing certification. In many cases, these checkboxes, even though present, were not used. Later Board field documentation forms have no provision for the indication of ice protection equipment or certification. In 80 analyzed part 23 events, the Board documentation, including docket materials, makes no reference to icing certification. Indeed, there are 7 cases in which the Board does specify that the airplane is icing certificated, but the TCDS certification data indicates that, for that airplane serial number, icing certification was not an option.

There were also a number of cases in which the Board documentation did not formally mention icing equipage. In some cases, the icing equipage could be determined through the wreckage documentation. In some events it was determined by obtaining a marketing photograph available of that particular registration number on the web. This was a last resort, as there is really no way to be sure that the ice protection equipment visible in the photo was the configuration in use at the time of the event.

AIRPLANE CERTIFICATION BASIS

There are 85 reports generated by the NTSB which make no reference to icing certification at all in either the factual reports or docket materials. Because of the wide irregularity in the NTSB data, certification has been assumed when the TCDS allows it and the aircraft is evidently equipped. If the serial number was available, either through the report or through a lookup of the registration, the Type Certificate Data Sheet information could be accessed to determine whether the serial number fell within the range of aircraft that were icing certificated if properly equipped.

All the aircraft in event database that were certificated for flight in icing were certificated under FAR 23.1419, Amendment 23-14, or earlier amendment. No aircraft in the events database were certificated under FAR 23.1419, Amendment 23-43. A subset of aircraft, such as the Beech King Air 200 and the Bae Jetstream 31, were certificated as Part 23 airplanes but used a FAR 25 icing certification basis.

Aircraft that are not certificated for icing account for 54% of the events. This is significant and suggests training on these airplanes is needed to impact the icing safety record.

There were two aircraft in the event database that were not certificated for icing, but were equipped on a “no-hazard” basis. Both of these events yielded no survivors. Both resulted from a stall followed by loss of control; icing was inferred due to ATC transmissions, in which both pilots discussed ice accretion. In one case, the TKS system was believed to be active; in the other, the operation of the TKS could not be determined. In one case, thunderstorms were in close proximity. No other recent “non-hazard” certifications were noted.

SUPERCOOLED LARGE DROPLET AND GLACIATED CONDITIONS ANALYSIS

Descriptors such as severe ice, freezing rain, freezing drizzle, side window icing, ice observed aft of the protected surfaces, heavy icing, large droplets, the presence of SLD in the official meteorological report, ice pellets on the ground. There were limited references to “SLD” since most of these accidents occurred prior to the 10/31/94 Roselawn accident and SLD is a term that was coined after that accident. For many of the part 23 events with no survivors, prior to 1994, the only indication of SLD were ground observations of freezing precipitation. If rain and drizzle were reported and the ambient temperature was below freezing, freezing rain and freezing drizzle, respectively, was inferred.

Table 16 – SLD Descriptor Distribution

Source of SLD	% of Total
Freezing Rain	33
Freezing Drizzle	29
Ice Aft of Protected Surfaces	23
Meteorological Analysis	6
Freezing Rain Inferred	3
Freezing Drizzle Inferred	3
Ice Pellets	3

Snow events appearing in approximately in 20% of the events, and suggests another training subject. In some circles, it was believed the presence of snow indicated all water was glaciated (therefore no airframe ice accretion), however the service history indicates snow can coexist with supercooled water.

The approach and landing events also show that the outside air temperature typically is near freezing. For 21 suspected SLD approach and landing events in which temperature was reported at the destination airport, the average ambient temperature was 29.2°F, the median was 32.0°F, and the lowest was 12.0°F.

WAS THE EVENT APPLICABLE TO THE PROPOSED SLD RULE?

The presence of SLD alone does not make the event applicable to the proposed SLD rule. There must also be evidence that the SLD was a factor in the accident. Examples include lift/drag degradation, stall and controllability. A lift/drag degradation appears in some form in nearly all of the reports for which detailed information is available, with the exception of ICTS events. It is likely that an early and aggressive response to these degradations may prevent more severe outcomes. During the analysis of the body of events, it was noted that certain types of aerodynamic events were often reported to precede the most severe events such as a stall. Generally, these were an airspeed decay, reduction in climb performance, inability to climb, inability to maintain altitude, inability to maintain a glide path, or a high sink rate. It has been hypothesized that all of these events are typical of a change in the lift/drag ratio for the configuration being employed at the time. This may be useful to understanding the nature of severe events. The most common result of lift/drag degradation in SLD is a hard landing as a result of the airplane sinking rapidly in the flare.

The following are examples in which SLD was present but the event not deemed applicable to the proposed rules (one occurrence in each case):

- Controllability problems on landing roll-out
- Failed or inoperative ice protection system
- Airplane took off with contamination
- Induction air iced over (reciprocating engine)
- Airplane significantly over gross weight limit

WINDSHIELD ICING

The presence of windshield icing was a disqualifying condition if no other aerodynamic event was found, since the detect and exit requirement will not address windshield icing. Windshield icing was exhibited in 29 of 214 part 23 airplane events; however windshield icing alone is typically a non-fatal event.

PILOT AWARENESS OF ICING

In most cases, the flight crew was aware of ice accretion. Only 3% of part 23 icing events had evidence in which the pilot was not aware of the icing conditions. There is a scale factor, since this number is 12% of part 25 airplane icing events.

ACTIVATION AND OPERATION OF ICE PROTECTION SYSTEM

A great deal of information about the operation of the IPS is not available from the reports, dockets or statements. Qualitatively, a substantial number of events are associated with a failure to operate the IPS. Since part 23 airplanes typically are not equipped with a flight data recorder or voice recorder, these events involve at least one survivor.

PHASE OF FLIGHT

Most part 23 SLD events occurred during approach and landing. Many of these events were non-fatal hard landings. Approximately two thirds of the SLD events on approach and missed approach were fatal. An SLD event on climb, cruise, or descent was typically fatal. For all flight phases, nearly all of the total hull losses and fatalities resulted from events that exhibited a stall.

Table 17 – Phase of Flight Distribution

Flight Phase	% of Part 23 Airplane SLD Events
Approach	38
Landing	34
Descent	9
Cruise	11
Climb	4
Missed Approach	4
Holding	0

OPERATING REGULATION

There does not appear to be a relationship between operating rule and number of events. Part 135 aircraft were just as likely to be involved in an icing event as Part 91 aircraft. Considering that Part 135 has a regulatory weather training requirement, and Part 91 does not, this point may speak to the effectiveness of that training.

RECOMMENDATIONS FOR ACCIDENT INVESTIGATION

The investigation of an accident that may involve icing could be greatly enhanced if the following steps were taken:

- Document the ice protection equipment
- Document the ice protection switch positions, if not destroyed
- Include the aircraft serial number (NTSB does; FAA does not)
- Document the status of the ice protection systems (switch positions, pilot statements, etc.)

- Determine if the airplane was certificated or approved for flight in known icing conditions, including any applicable placards
- If ice was found accreted on the aircraft, document the surfaces on which it was found, i.e., leading edge, aft of protected leading edge, antenna, landing gear, etc.
- In general, greater care with dates and registration numbers would be useful.

B) ICING INCIDENT DATABASE REVIEW

The three sources of data for this project represent three different thresholds of data reporting. The first, reported accidents, is a set of data that must meet a defined criteria. Because of the severity of these events, it is unlikely that any have been unreported. The second source of data, reported incidents, must likewise meet a defined criteria; however, since the severity is considerably lower, it is possible for a number of these events to have occurred without being reported. The final source, NASA ASRS data, has no defined threshold of reporting. Further, the collection of data from this source is dependent on pilot awareness of the program, which is not large in general aviation pilot community. An ASRS report is included if either an aerodynamic event or a procedural failure is reported. However, there is no way to know how many similar events have occurred and not been reported; the number is probably considerable.

Because of these factors, statistical evaluation is limited if not impossible. What is valuable is the identification of precursor characteristics. In many, if not most, Part 23 accidents there is almost no data available regarding pilot actions or decisions, simply due the absence of survivors or flight data recorders. The value in including the ASRS data lies with the study of those perceptions and actions. There are a number of patterns in the incidents which can also be seen in those accidents for which a pilot statement is available. This suggests a good likelihood that those accidents from which no survivor information can be obtained probably looked similar, at least initially.

The icing incidents support the proposed rulemaking to show adequate climb performance and an evaluation of ice contaminated tailplane stall in detect and exit SLD conditions. The incidents also show windshield icing over is a common occurrence in SLD encounters, but is non-fatal. Most of the indications of FZRA were of in-flight observations on the airplane, so it is possible FZDZ was misreported as FZRA. Limiting detect and exit encounters to outside air temperatures of -10°C and warmer is also supported. The following table contains a list of the incidents:

Table 18 – SLD Incidents

SOURCE	AC TYPE	LOCATION	REMARKS
ASRS 101079	Small transport	Utica, NY	Aircraft could not climb on attempted missed approach, windshield overwhelmed
ASRS 226123	Light transport	Beckley, WV	Performance problem in severe icing
ASRS 249506	Small transport	Yakutat, AK	Had to descend below 10,000 ft.MEA to avoid stalling in severe icing
ASRS 323820	PA-31	Covington, OH	FZRA encounter on approach, increased descent rate on landing, scraped obstruction during landing,
ASRS 325031	Commercial fixed wing	Springdale, AR	Encountered light FZDZ on approach, could not maintain glideslope with full power
ASRS 326243	Jetstream 31	Chicago/Rockford, IL	Encountered FZRA on approach, controls sloppy. Pilot speculated that extended time would have caused control problems
ASRS 416160	PA-46	Burlington, IL	Encountered severe icing at FL190, could not maintain altitude or airspeed
ASRS 456868	EMB-110	St. Louis, MO	Ice behind protected leading edge cause longitudinal control problem
ASRS 457893	BE-55	Port Huron, MI	Windshield iced over in FZRA
ASRS 597221	PA-34-200	Cleveland, OH	FZRA encounter overwhelmed all IPS, including pitot heat, could not arrest descent at 6,000 feet
ASRS 647858	CE-208A	Pocatello, ID	Could not climb at 10,200 ft., tail vibration
ASRS 82159	Small transport	Chicago/Rockford, IL	FZRA during descent starting at 8,000 feet, performance problem
ASRS 845030	MU-2	US	Airspeed loss and loss of control with no ice on wing leading edge
AIDS 19911107055879C	BE-18	Springfield, MO	Encountered severe icing on approach, landed short
AIDS 20011126038439C	CE-208B	North Platte, NE	Performance problem in heavy icing
NTSB Access Database 20001212X16303(A)	Jetstream 31	Dayton, OH	Noted ice aft of protected areas, uncommanded pitch down with full flap extension on approach

10. TRAINING RECOMENDATIONS

A) INTRODUCTION

The Part 23 icing ARC undertook a detailed evaluation of all Part 23 aircraft accidents in which icing was a causal factor. The accident review determined that icing accidents most often resulted from operational errors not related to aircraft certification. 53% of icing accidents 1990-2001 (257 total accidents) occurred in aircraft that are not even certified for flight into known icing or that have any ice protection equipment. In order to have the greatest impact on icing accident rate, the ARC recommends an integrated approach be taken that encompasses not only enhancements in the certification of Part 23 aircraft but also an educational initiative for all operators. This educational initiative needs to include all pilots, not only pilots of aircraft certificated for flight into known icing conditions.

The ARC is not recommending training mandated through regulation, but instead a focused training initiative / marketing campaign similar to the effective training initiative recently administered to improve runway safety. The FAA recently led an effort to improve runway safety in the United States (U.S.) by decreasing the number and severity of surface incidents and runway incursions. To achieve this end, the FAA's Office of Runway Safety launched a multi-pronged educational initiative with collaboration between the FAA and its stakeholders in the aviation community. Together with industry, the FAA developed and delivered updated advisory material, brochures and interactive programs to a broad audience of pilots and flight instructors. The results of this educational initiative are irrefutable. The runway incursion rate dropped 50% two years in a row. This achievement is the result of a focused message being effectively communicated to the pilot population. For future initiatives such as training for intentional or unintentional flight into icing conditions, the ARC recommends a similar multi-media outreach reinforced by the safety learning objectives established by the FAA.

This type of training initiative is necessary for flight into icing conditions for several reasons. First, the majority of the icing accidents occurred in aircraft that are not certified for flight into known ice. These aircraft are not required to contain procedures for inadvertent flight into icing conditions only the simple statement that "flight into known ice is prohibited". Therefore, pilots faced with an inadvertent encounter with ice have no guidance from the manufacturer on exit procedures, approach configuration or speed considerations. Adding to this lack of knowledge is the misconception among pilots that all aircraft are aerodynamically tested to some level of ice regardless of the certification of the aircraft. For aircraft that are certified for flight into known ice, there is great misunderstanding as to how much ice that aircraft is "certified" to carry and when the pilot must begin the exit from icing conditions. It doesn't help matters that the certification standard for flight into known ice has changed dramatically over the years and that there is little operationally significant material offered to pilots. Secondly, there are many, deeply ingrained misconceptions among the pilot population with respect to best procedures and practices to follow in icing conditions. Despite greater scientific understanding of flight characteristics and aircraft performance in icing conditions and with ice adhering to the aircraft, pilots still maintain and perpetuate many false beliefs. The only way to alter these misconceptions is through a targeted training effort.

There are several good examples of icing training available to pilots today, however the training can be improved and the message better focused to encompass all the areas in which the ARC found deficiencies. It would also be most helpful if training topics were developed and final training material promoted by the FAA as in the model of runway safety. This would ensure that a focused message is delivered that encompasses all of the areas of training recommended by the ARC and that the message is delivered to all operators of part 23 aircraft.

In the evaluation of icing accidents, several topics emerged that requires focused training in order to reduce the icing accident rate. Those training topics are listed below. In order to have the greatest impact on learning, all the training should be given in practical terms. For example, give real world, practical guidance for determining if an aircraft is certified for flight into known ice and knowing the limitations of that certification; real world, practical guidance of how a wing stall feels and technique for recovery versus a tail stall feel and recovery.

B) DISCONNECTS BETWEEN THE CERTIFICATION AND OPERATIONS WORLD

As was discovered in the recent Part 23 Certification Process Study undertaken by the FAA, the Part 23 Icing Certification ARC discovered several disconnects between the certification and operations world. Better communication of flight testing parameters would ensure pilots understand the information and limitations of flying their aircraft in icing conditions.

(1) THE DIFFERENCE BETWEEN STALL WARNING AND AERODYNAMIC STALL

Pilots need to be made aware of the fact that the stall warning system (stall warning horn, etc) may not work properly on an iced-up airplane (particularly one certificated before current rules went into effect). The first warning of an impending stall may be an aerodynamic buffet or increasing sloppiness of the flight controls rather that the stall warning horn, light, stick shaker, etc.

(2) THE DIFFERENCE BETWEEN WING STALL AND TAIL STALL

Recent emphasis upon empennage stalls on iced-up airplanes may cause pilots to NOT use normal stall recovery procedures – reduce angle of attack, add power – when a stall is encountered. Pilots should be aware that approach and landing with partial flaps will most likely preclude an ice contaminated tailplane stall (ICTS), and pilots of newer airplanes in which ICTS is tested should follow AFM limitations and procedures. Normal stall recovery procedures should be followed unless specific evidence of a tail stall exists, or normal stall recovery procedures are ineffective.

(3) THE MEANING OF "APPROVED FOR FLIGHT INTO KNOWN ICE"

The ARC recommends that the FAA emphasize the conditions and visual cues that define aircraft certification level and emphasize that operationally, no matter what the certification, no aircraft has the capability for unlimited safe flight in all icing conditions. Training should emphasize a consistent set of icing definitions between the operations, certification and weather forecasting with respect to known icing and potential icing conditions. Those definitions should be the current, FAA approved terms defined in the AIM for "known or observed or detected ice accretion", "forecast icing conditions", "known icing conditions" and "potential icing conditions" as well as information from the FAA legal interpretation dated January 16, 2009. That legal interpretation states: ""Known icing conditions" involve circumstances where a reasonable pilot would expect a substantial likelihood of ice formation on the aircraft based upon all information available to that pilot. Known icing conditions exist when a pilot knows or reasonably should know about weather reports in which icing conditions are reported or forecast." "A pilot must consider the reasonable likelihood of encountering ice when operating an aircraft." "Area forecasts alone are generally too broad to adequately inform a pilot of known icing conditions. Such forecasts may cover a large geographic area or represent too long a span of time to be particularly useful to a pilot." A pilot, and his or her proper analysis of that information in evaluating the risk of encountering known icing conditions during a particular operation. The pilot should consider factors such as the route of flight, flight altitude, and time of flight when making such an evaluation. Pilots should also carefully evaluate all of the available meteorological information relevant to a proposed flight, including applicable surface observations, temperatures aloft, terminal and area forecasts, AIRMETs, SIGMETs, and pilot reports (PIREPs). As new technology becomes available, pilots should incorporate the use of that technology into their decision making process. If the composite information indicates to a reasonable and prudent pilot that he or she will be operating the aircraft under conditions that will cause ice to adhere to the aircraft along the proposed route and altitude of flight, then known icing conditions likely exist.

(4) THE DIFFERENT CATEGORIES OF CERTIFICATION FOR "FLIGHT INTO KNOWN ICE"

Pilot training should include the level of protection the certification of the aircraft provides from a pilot perspective. Since most pilots are not familiar with part 23 certification standards or the changes that have occurred in icing certification over the years, it is important to convey that depending on certification level and when the aircraft certification was obtained there is a wide range of conditions that were tested or not tested as the case may be.

In general, aircraft can be classified into three areas:

1. Airplanes not equipped nor approved for flight in icing conditions. Education and training should emphasize the following:

   a. In-flight icing accidents and incidents involving these airplanes have outnumbered those on icing certificated airplanes in recent years.
   b. No flight testing is conducted to show the airplane can safely exit an inadvertent encounter - pilots of these airplanes should be aware that these airplanes are not tested for “inadvertent” icing encounters.
   c. There are only requirements for engine induction icing, and for IFR approved airplanes, ice protection for the pitot and static sources.
   d. Pilots should not believe the myth that “thicker” general aviation airplane airfoils are more tolerant of ice accretion. FAA research has dispelled that myth, as described in Advisory Circular 20-73A.

2. Airplanes with ice protection but prohibited from flight in known icing. AOPA Safety Advisor No.22 at http://www.aopa.org/asf/publications/sa22.pdf addresses the subject.
   a. “Non-hazard” systems are meant simply to buy time for a pilot to escape from unexpected icing conditions.
   b. Non-hazard systems have no requirement to demonstrate that they can protect your airplane during icing conditions.

3. Airplanes certified for flight in icing conditions. These airplanes can be subdivided further by when they were certified:
   a. The earliest certifications were “approved” for flight in icing conditions if they were properly equipped. There was no real requirement for testing of these systems.
   b. Testing of ice protection systems initially tested for stall buffet only and had no icing climb gradient requirements.
   c. New aircraft certified today must meet climb gradient requirements, have published climb performance in icing conditions, are tested with critical ice shapes, and must meet stall warning requirements with critical ice shapes covering the entire span of the wing.
   d. The FAA is in the process of requiring testing of Super-cooled Large Droplets for part 23 aircraft.

For all aircraft, regardless of the certification level:

- Do not assume that your aircraft was tested for the conditions that you might be facing on any given day.
- Icing conditions can vary greatly from one exposure to another as can it’s affect on aircraft performance.
- No aircraft, regardless of certification level, will be able to indefinitely maintain flight in all icing conditions.

- Ice protection is primarily used to protect aircraft during transient encounters in icing conditions. Always plan to exit icing conditions.

(5) HOW TECHNOLOGY HAS CHANGED THE PERFORMANCE OF DEICE / ANTI-ICE EQUIPMENT

Two areas in which certification information is valuable to pilots are the certification assumptions in how ice protection systems are to be operated, and their actual performance. For example, fluid systems are designed and tested as anti-ice systems. Certification testing assumes there will be no ice on the protected parts of the airplane. If ice is allowed to build before activating the system, it may take several minutes before shedding occurs. Therefore these systems must be activated at the first sign of ice accretion. If ice is observed forming on protected parts, the flow rate must be increased. If maximum flow rate cannot keep ice off the airplane, the airplane is in severe icing and must exit immediately.

For pneumatic deicing boots, pilots should understand that there may be conditions in which ice may not shed completely or at all after a cycle. This is particularly true as airspeed or ambient temperature decreases. Pilots of airplanes with modern boots should not mistake this as the phenomenon known as “ice bridging.” What they are seeing is residual ice which will eventual shed. Most airplanes today have “modern” boots – operating pressure of 15 psig or higher, “inflation tube diameter of one inch or smaller (some designs have 1 .75 inch at the stagnation), and fast inflation and deflation times (typically 6 seconds, but to the eye, tubes will appear fully inflated in less than a second). Much of this information on pneumatic boot performance is in AC 91-74A. Pilots should follow their AFM procedures, and also know that early and often cycling of the boots will not hurt shedding performance. Since most part 23 icing events occur on approach and landing, pilots should cycle boots before configuring for approach. Research has shown that ice adhesion inhibitors, for example the product “ICEX” for Goodrich boots, greatly improve shedding performance (AIAA-2007-1090, “Residual and Intercycle Ice for Lower-Speed Aircraft with Pneumatic Boots”). Products not approved by the boot manufacturer or airplane manufacturer should not be applied to boots.

(6) GROUND DE-ICE PROCEDURES``

Training should focus on the importance of the clean aircraft concept and approved methods for removing snow / ice from the airframe. Special emphasis should be placed on the issues related to using fluids / methods to remove ice or snow and reasons why it’s important to only use methods and fluids approved by the manufacturer (materials compatibility, pooling of fluids in flight control surfaces, etc).

C) FOCUSED ICE TRAINING

Previous attempts to educate the pilot population on the dangers associated with icing conditions went into great detail on areas that were not necessary or simply added to confusion regarding airframe ice. Many training resources for pilots still cover the different types of ice (rime, mixed, clear, etc.) however there is little practical training on how airframe ice affects aircraft control, for example. The training recommendations below should focus on the practical, real world application of the following subjects.

(1) INTERPRETING WEATHER REPORTS IN ORDER TO PREDICT AREAS OF POTENTIAL ICING CONDITIONS

Freezing Rain, Freezing Drizzle, Severe icing, etc and what that means real world - Pilots should be familiar with weather conditions likely to cause in-flight icing: Freezing rain or freezing drizzle at the surface, temperatures aloft less than about +3 degrees Celsius plus high water and content in the air, certain types of frontal and orographic activity. It is important for a pilot to know how to use weather products to identify the presence and location of such conditions. Recently developed NOAA "Java tools" available online can provide forecasts of temperatures aloft, air mass water content, and icing probability in map form, easily adjustable for various MSL altitudes.

(2) IDENTIFY AND ADHERE TO PERSONAL MINIMUMS

FAA and Industry emphasize the use and adherence to personal minimums for any flight. Weather related personal minimums used in FAA-Industry Training Standards (FITS) usually focuses on winds, ceiling and visibility. The ARC recommends FITS increase emphasis on icing related personal minimums which include "find and avoid" as well as exit strategies based on pilot/aircraft capabilities, icing reports and forecasts. This emphasis on icing related personal minimums should be included in FITS or traditional training in the industry.

(3) HOW TO "DETECT" ICE – PREFLIGHT AND AIRBORNE

On newly certificated aircraft, manufacturers may provide specific visual cues to warn pilots of icing conditions that exceed the ice protection systems' capability, or require an immediate exit from the icing region. The rate of ice accretion is an important factor in effectiveness of ice protection systems. The ice-carrying characteristics of individual airplanes may be significantly different.

(4) DEICE STRATEGIES FOR PREFLIGHT

Training should focus on the importance of the clean aircraft concept and approved methods for removing snow / ice from the airframe. Special emphasis should be placed on the issues related to using fluids / methods to remove ice or snow why it's important to only use methods and fluids approved by the manufacturer (materials compatibility, pooling of fluids in flight control surfaces, etc). Training should include weather related factors in maintaining the clean aircraft for takeoff (example: freezing precipitation falling prior to takeoff but not adhering to wing).

(5) DEMONSTRATE HOW EVEN MINUTE ACCRETIONS AFFECT PERFORMANCE

One myth that is prevalent in general aviation is that small amounts of ice result in little aerodynamic penalty. With even a minute amount of ice, there is a resultant loss of lift and large increase in drag. Research flight tests have shown maximum lift losses up to 25% and drag increases of 84% with just the thickness of 40 grit sandpaper on the airfoil leading edges. This corresponds to a stall speed increase on average of 12 knots. It should be pointed out that this roughness level is difficult to remove with pneumatic deicing boots under most conditions.

Another myth floating around is that high speed laminar flow airfoils are more susceptible to ice than “thicker,” conventional airfoils. FAA sponsored research available in AC 20-73A dispels that myth.

The roll of angle of attack must also be pointed out. The lift and drag penalties are not linear with angle of attack. Going back to report DOT/FAA/AR-06/48, one can see that at the angle of attack for normal operational airspeeds (2-6 deg), there is no or very little lift loss. As soon as angle of attack increases above 6 deg, a lift penalty occurs, and the penalty increases with angle of attack. Drag increment due to ice also increases with angle of attack. The result is a rapid loss of lift as airspeed is reduced below a certain threshold. This explains the high number of hard landings in the accident database.

(6) DEMONSTRATE HOW RAPID ACCUMULATION AFFECTS TIME AVAILABLE FOR EXIT / EXIT STRATEGIES

Tests conducted at NASA Glenn Research Center on several modern airfoils demonstrated that in some instances, exposure to clear icing for just two minutes could double the drag, reduce the maximum lift by 25%-30% and reduce the critical angle of attack by 8 degrees (which would correspond to a substantially higher stall speed). Training should emphasize that in icing conditions with rapid accumulation, there is very little time available for exit. Exit strategies should be considered before entering icing conditions and personal minimums set in determining when to exit the conditions.

(7) ATC ASSISTANCE AVAILABLE AND ATC OBLIGATIONS / PIC AUTHORITY

Remove the stigma of requesting immediate assistance from ATC and declaring an emergency and teach pilots that rejecting a controller’s instructions is their right and obligation if those instructions can lead to an unsafe condition. Final authority and responsibility for the safety of a flight rests with the pilot in command. ATC may be able to provide PIREP or other information regarding enroute icing conditions. Do not hesitate to request assistance from ATC. However, as pilot in command, it is important to be firm with ATC when a pilot encounters conditions beyond their airplane's capability that require an altitude or course change. Pilots must have an exit strategy, and communicate needs clearly to ATC. If ATC is not responsive, the pilot must advise ATC that if the course or altitude requested is unavailable, an emergency will be declared and required changes will be made.

(8) LAST RESORT CHOICE

An off airport landing may be embarrassing but is a better option than uncontrolled flight into terrain.

(9) AUTOPILOT USE IN OR AFTER FLIGHT IN ICING CONDITIONS

The autopilot may mask dangerous airspeed losses - monitor airspeed closely when the autopilot is engaged in icing conditions. When ice is accumulating on the airplane the autopilot should be disconnected at least once every five minutes to ensure normal airplane trim and handling qualities are maintained. Unless authorized in the airplane flight manual, the vertical modes of the autopilot that maintain a constant rate of climb, decent, or pitch should not be used. Pilots should be prepared for the possibility of unusual control forces and flight control displacements when disconnecting the autopilot, especially in severe icing conditions.

(10) SINK RATE WITH ACCUMULATION

The role of lift/drag degradation in icing events is poorly understood and has not been part of icing training or in the literature. Although there is almost always some type of lift/drag degradation which precedes a catastrophic event, the most common event in which it manifests itself is hard landing. Out of 137 part 23 airplane icing accidents in the period studied, 37% were hard landings or landing short of the runway. Approximately one third of the part 23 accidents identified as applicable to the SLD rule are hard landings with no fatalities. This is also related to the role of angle of attack as discussed above, since a high angle of attack is achieved in the flare. Training should emphasize a slow reduction in power during the flare, and the fact the higher drag due to ice will require more power to maintain the same sink rate as in non-icing.

(11) CONFIGURATION AND SPEED CONSIDERATIONS AFTER FLIGHT IN KNOWN ICE FOR APPROACH AND LANDING

Approximately 51% of icing encounters result in mishaps during approach and landing, and 73% of accidents attributed to SLD occur in these two flight phases.. Although the landing events were typically non-fatal hard landings and landing short of the runway, two thirds of the events on approach were fatal and were typically a stall. The ARC recommends increased training emphasis on approach and landing strategies after icing encounters. Specifically, train operational tactics with ice adhering to the aircraft such as delayed descent, avoiding prolonged approach vectors, keeping speed up, and delaying/limiting flap configuration changes.

D) Changes to FAA training and testing material

(1) Review training materials

- Update training products on FAAST web site. There are numerous icing training products and where to start is confusing. One product deals entirely with type of ice (rime, mixed, clear).
- Review NASA training products to determine if they need to be revised.
- Update the Aeronautical Information Manual (AIM). In particular, update definition of severe icing, add information on ASOS limitations, add information on snow and warm temperatures.
- Update Advisory Circular 91-74A.
- Update Airplane Flying Handbook icing information (Chapter 12) and add inadvertent icing encounter information to (Chapter 16) Emergency Procedures.

(2) Review knowledge exam material, prepare questions (in order of priority if not all are selected)

- IFR — Non-FIKI or non-equipped airplanes
- Commercial — FIKI
- ATP — FIKI

(3) Develop list of emphasis items for type rated airplanes that are certificated for flight in icing at current amendment and under SLD amendment (add these to ATP PTS). Examples:

- Severe icing recognition- photos
- Minimum airspeed for flaps up operation and approach and landing
- Flap limitations
- Autopilot limitations
- Stall warning and stall recovery procedures that emphasize reduction of angle of attack
- Add simulated decelerations (1 kt/sec) to first indication of stall with autopilot engaged
- Train first indication of stall in icing conditions (stall warning for new airplanes, buffet for certain older airplanes)

11. TASK 9 RECOMENDATIONS

A) BACKGROUND

The following task was added in the third quarter of 2010: “Determine if implementation of NTSB Safety Recommendation A-10-12 is feasible for part 23 airplanes for operations in icing conditions”.

The referenced NTSB safety recommendation states: “*For all airplanes engaged in commercial operations under 14 Code of Federal Regulations Parts 121, 135, and 91K, require the installation of low-airspeed alert systems that provide pilots with redundant aural and visual warnings of an impending hazardous low-speed condition.*” The recommendation applies to non-icing as well as icing flight. The ARC was tasked to address only part 23 airplanes operating in icing conditions, and therefore decided to address part 23 regulations for new type certificates, amended type certificates, and supplemental type certificates.

The ARC reviewed the NTSB safety recommendation letter and noted that the NTSB is recommending a system in addition to the stall warning system and an aural indication to complement existing visual low airspeed awareness cues: “In this accident, the pilots did not likely see the rising low-speed cue on the IAS display, the downward-pointing trend vector, or the airspeed indications change to red. As a result, the NTSB concludes that an aural warning in advance of the stick shaker would have provided a redundant cue of the visual indication of the rising low-speed cue and might have elicited a timely response from the pilots before the onset of the stick shaker.”

The ARC reviewed icing accidents for which there is flight data recorder data. The common scenario is a reduction of airspeed, typically 1 – 2 kt/sec leading to a stall. The autopilot is engaged in altitude hold or vertical speed mode in a climb, and the flightcrew is unaware of the airspeed decay. The flightcrew is aware of the icing conditions and the ice protection systems are operating. The FAA has written SAFO06016 and SAIB CE-11-18 to make pilots aware of these concerns.

B) PROPOSED RULE

The ARC decided that a low airspeed alert system is not needed for icing conditions if the stall warning system is robust. Current part 23 guidance, which the ARC recommends to be promulgated into a rule, requires that the stall warning margin and the means of indications be the same as non-icing flight. The stall warning system on new part 23 airplanes is designed to function with the most critical ice accretion possible in Appendix C conditions. The fact that no airplane certified for icing to latest part 23 icing regulation (Amendment 23-43) has experienced an icing event supports this decision. It is acknowledged that most of these airplanes require a type rating and that icing limitations and procedures are training emphasis items. One single engine, reciprocating engine airplane certified to the latest amendment requires biennial icing training via the AFM limitations section. Many of these airplanes incorporate a glass cockpit in which the low airspeed cues are scheduled for icing. The ARC has recommended regulations to require stall warning in applicable SLD conditions for new airplanes. Therefore, for new airplanes that will require stall warning in Appendix C and applicable SLD conditions, the ARC believes a low airspeed alert system should not be required. The majority of the ARC discussions, which follows, focused on the existing fleet and the feasibility of a rule that would affect amended and supplemental type certificates.

(1) FLIGHT IN ICING VERSUS NON-ICING CONDITIONS

The ARC discussed rule language that would not distinguish icing flight from non-icing flight in consideration of the NTSB recommendation that a low airspeed alert would increase safety in non-icing conditions. The ARC decided to recommend rule language that only applied to flight in icing conditions for the following reasons:

- The ARC was tasked to only determine recommendations for flight in icing conditions
- The ARC did not have a database of event history for non-icing flights and therefore did not have sufficient information to assess the potential benefits of a broad action to address operations in non-icing conditions.
- A system to address non-icing flight may be more complicated and costly than icing flight. For example, an alert may have to be based on angle of attack, rather than airspeed.

An airspeed alert system for flight in icing, due to higher stall and operating speeds, must be active only in icing conditions to avoid nuisance warnings in non-icing flight. Therefore, there will be cost associated with tying the system to a system such as airframe, propeller, or engine ice protections system.

(2) AIRPLANES CERTIFIED FOR FLIGHT IN ICING VERSUS NOT CERTIFIED FOR FLIGHT IN ICING

The ARC also discussed applicability to an airplane not certified for flight in icing. The ARC evaluated part 23 icing accidents in which SLD was not evident. Out of these events, 71% of the airplanes involved were not certified for flight in icing (that means airplanes not certified under CAR 3 or Part 23). This indicates such airplanes inadvertently encountering icing is a larger safety issue than icing certified airplanes. However, the ARC decided to apply the rule only to airplanes certified for flight in icing for the following reasons:

- A system designed for inadvertent encounters must be active in non-icing conditions, and nuisance warnings could be a large issue.
- Envelope protection systems are starting to be certified on part 23 airplanes. These systems activate at a factor of 1.2 of the non-icing

stall speeds, which should provide protection with inadvertent ice accretions.

- Limiting applicability of the rule reduces its cost,
- Older part 23 airplanes not certified for icing typically do not have glass cockpits and therefore applicability of the rule (if 23.1311) would be limited anyway.

(3) AUTOPILOT

The ARC discussed whether a new rule should apply only when the autopilot is engaged. Analysis of events indicated 4 out of 69 in which there is evidence of no autopilot, or no autopilot upon airplane delivery. All four of these airplanes were not certified for flight in icing. Most part 25 icing events with flight recorder data and cockpit voice recorder data indicate airspeed decay with autopilot engaged. However, documented incidents on part 23 airplanes, combined with at least one part 23 event with FDR and CVR data, and the excellent icing service history of certain part 23 airplanes with no autopilot at delivery, point to the conclusion that the autopilot is engaged for most icing events. Also, since the autopilot is disengaged for landing on part 23 airplanes, there should be no nuisance during landing flare, which had been discussed as a potential issue. As a result, the ARC limited the proposed rule to only when the autopilot is engaged. This reduced applicability reduces the cost and targets the specific safety issue. A minority of the ARC believed a low airspeed alert should not be tied to the autopilot and should function even with the autopilot off.

Since the targeted safety issue is airspeed awareness when the autopilot is engaged, the ARC first looked at adding a paragraph to § 23.1329, similar to § 25.1329(h). The ARC subsequently decided that either § 23.1311 or § 23.1419 was more appropriate. There was no consensus reached on which rule would be more appropriate.

C) OPTIONS

(1) OPTION #1 - RECOMMENDED RULE LANGUAGE FOR § 23.1419

(h) If an automatic pilot system is installed:
(1) The automatic pilot system must be capable of operation in part 25, Appendix C icing conditions.

(2) For airplanes where ice accretions are present on protected surfaces during normal airframe ice protection system operation:
(i) When the automatic pilot system is operating, a means must be provided to prevent the aircraft from reaching an unsafe low airspeed when operating in Appendix C icing conditions
(ii) If a cockpit annunciation is the means of compliance, the means must be visual and either aural or tactile.

Proposed paragraph (h)(1) prevents an applicant complying with proposed (h)(2) by a prohibition of autopilot use in icing. NTSB safety recommendations A-06-51, which is closed with unacceptable action, asked the FAA to require all operators of turbopropeller-driven airplanes to instruct pilots, except during intermittent periods of high workload, to disengage the autopilot and fly the airplane manually when operating in icing conditions. The ARC consensus is that the use of an autopilot, even in icing, generally increases safety when operating in IMC conditions and especially in single pilot operations which is common for Part 23 aircraft. Currently, the use of autopilot is allowed in icing but the pilot is advised to periodically disconnect the autopilot to evaluate if any controllability issues are being masked. Prohibiting the use of autopilot in icing altogether as an alternative means of compliance to this proposed new wording would mean pilots would have less use of their autopilots exactly when they are likely to need them the most. This could possibly introduce more safety issues than it remedies by resulting in loss of situational awareness in IMC conditions. The issues raised by the NTSB in their safety recommendation letter are mitigated by a means to indicate an unsafe low airspeed as required by this proposed rule. The evidence of this is the safety record of airplanes certified for icing at Amendment 23-43, in which the stall warning system is designed and tested to provide margin with critical Appendix C ice accretions on protected and unprotected surfaces. Additional evidence is AD 2007-10-15 on the Cessna Caravan which required a Low Airspeed Awareness System. This AD removed an interim prohibition on autopilot use in icing and there have been no in-flight icing related accidents of the model. A similar example is AD 2001-20-17 on the model EMB-120.

Regarding (h)(1), the ARC recommends a similar rule be added to proposed 23.1420: "(xx) If an automatic pilot system is installed:

> (xx) The automatic pilot system must be capable of operation in the Appendix O icing conditions for which the airplane is approved.

In paragraph (h)(2), "For airplanes where ice accretions are present on protected surfaces during normal airframe ice protection system operation" the ARC noted that applicable icing events were only with airplanes in which ice is present on protected surfaces in normal system operation (e.g. intercycle or residual ice on pneumatic boots). The ARC noted that airplanes equipped with fluid freezing point depressant systems and thermal anti-ice systems are not in the accident list. The intent of this language is to exclude these airplanes.

The means required in (h)(2)(i) can be an annunciation or a system that prevents the airplane from reaching an unsafe airspeed. A stall warning system that complies with § 23.207 with critical part 25, Appendix C ice accretions is an acceptable means. Airplanes with a certification basis that includes § 23.1419 at Amendment 23-43 or later will have a stall warning system that is compliant.

An annunciation need only be based on airspeed, as determined by an analysis of icing accidents in which data is available. The annunciation may be based on a certain threshold above icing stall speed, or a certain threshold below icing operating "bug" speed. If the latter, the AFM Supplement must specify an icing operating speed for all phases of flight, and the AFM Supplement must require the "bug" speed to be set in icing for all flight phases.

The ARC recognized that icing stall speed may not be available to modifiers of older airplanes, and the icing operating speeds may not be specified. There would be a large cost to determine critical ice accretions, manufacture simulated ice shapes, and flight test those ice shapes. The ARC analyzed icing stall speed data for several pneumatic boot equipped airplanes and determined that a generic value of icing stall speed may be used, negating the need for ice shape flight testing. The ARC determined a value of a 20% increase in stall speed due to critical Appendix C ice accretions may be used by applicants to schedule a low airspeed annunciation. Another value may be used if substantiated by the applicant. The ARC recognized the 20% value is conservative for most part 23 airplanes, since the average increase of eight airplanes evaluated is closer to 14%. However, outlier data of an airplane with a common wing airfoil section (NACA 23XXX), drives the 20%. The annunciation should be provided at some margin above the icing speed to account for pilot recognition and action initiation. The ARC adopted 3 KCAS from § 25.207(e), although an ARC minority voted for the part 23 margin of 5 KCAS. The ARC recognized that a non-icing operating speed if at 1.3 times non-icing stall speed should not cause a nuisance if the annunciation is airspeed based and not angle of attack based. However, the absence of nuisance warning is expected to be demonstrated, and if a nuisance occurs, the annunciation threshold can be reduced closer to 1.2Vs, but not below 1.2Vs.

Since a non-icing operating speed that is at least 1.3 times non-icing stall speed is not expected to cause nuisance, the ARC expects in many applications an increase in icing operating speed will not be required. Applicants can always propose an increase for icing to be conservative. Increases in landing distance in this case should be published in the AFM Supplement, if required in the certification basis. Increases in landing distance can be determined analytically, in the absence of flight test data.

The ARC members evaluated airplane models for which their company is the TC holder. The ARC concluded that most applications the low airspeed annunciation will require a flap position indication to avoid nuisance indications. The accident record shows a low airspeed annunciation is required for the approach phase of flight. An annunciation would not be required for the landing flare for two reasons – one, the accident history shows landing flare events are typically not fatal, and two, in most designs, it would be difficult to avoid a nuisance warning during flare. The ARC studied accidents to determine if an annunciation could be required for the approach flap setting and not the full (landing), but the result was inconclusive. However, if full flaps were prohibited in icing as a result if ice contaminated tailplane stall susceptibility testing or analyses, then an annunciation would not be required for full flaps.

An envelope protection that prevents the airplane from stalling in icing would be an acceptable means of compliance. The modifier in these projects would not have icing stall speed data. However, using the generic guidance for annunciations, a system that prevents the airplane from slowing below 1.2Vs non-icing would be compliant.

Paragraph (h)(2)(ii) requires a tactile or aural annunciation in addition to a visual annunciation. Study of documented icing events show that the flightcrew are not adequately monitoring the airspeed indicator. The NTSB noted in their safety recommendation letter for A-10-12, that distraction and workload considerations may have made it difficult for the pilots to visually detect features on the airspeed display depicting the development of a low speed condition (including a trend vector and a low-speed cue), so a redundant aural alert might have provided them with an effective warning about the decreasing airspeed.

The means required in (h)(2) does not have to disengage the autopilot. This is consistent with the guidance in AC 25.1329-1B for § 25.1329(h), which the ARC reviewed. It may be preferable on some designs to leave the autopilot engaged and have the pilot make a specific action to take control of the airplane and manually disengage the autopilot. If the autopilot disengages without warning, an upset may be experienced. In either case, the means and AFM procedures should be demonstrated in flight test.

ADVANTAGES OF 23.1419 VERSUS 23.1311:

- If in 1419, it is clear the proposed rule only applies to airplanes certified for flight in icing.
- Moving proposed rule into § 23.1419 and out of § 23.1311 (or § 23.1329) would potentially make this rule applicable to more modification projects. Any project that affects safe flight in icing is an "affected" area" and is considered in the changed product rule analysis (per § 21.101). Alternatively, if the proposed rule stays in § 23.1311, adding an autopilot to a known icing certified airplane may not be considered as the affected area under § 21.101. As a result, the revised § 23.1311 requirements would not be applied.
- A § 23.1311 rule may inhibit the incorporation of new avionics, which may reduce pilot workload and safety. Glass cockpits by themselves may be a safety enhancement and are not a factor in icing accidents..
- A § 23.1311 is targeting new glass cockpits because implementation of a low airspeed alert is much less costly compared to only an autopilot installation, but the safety improvement targets autopilot use in icing and

not the glass cockpit. A § 23.1311 rule targets new glass cockpit modifications because implementation of a low airspeed alert is less costly compared to only an autopilot installation.

(2) OPTION #2 - RECOMMENDED RULE LANGUAGE FOR 23.1311

Add new language to § 23.1311 Electronic Display Instrument Systems:

> (8) If the applicant is seeking certification for flight in icing conditions, incorporate visual cues, and either an aural or tactile warning, to provide awareness to the pilot that the airspeed is below the reference operating speed for the airplane configuration,

This rule already incorporates language regarding visual display of instrument markings in paragraphs (a)(6) and (a)(7).

ADVANTAGES OF § 23.1311 VERSUS § 23.1419:

- Rule Consistency – There is concern about consistency with previous ARC recommendations, which were to specific Subpart B rules and not 23.1419.

- Visibility – STC applicants may not be aware of requirements embedded within § 23.1419

- Scope of § 23.1419 – Section 23.1419 outlines certification requirements for aircraft ice protection systems (IPS). Although § 23.1419 can apply when changes are made to the aircraft that do not directly affect the IPS, these are usually changes to the exterior of the aircraft which can affect how ice accretes. An applicant would typically not have to show compliance to § 23.1419 for changes such as re-wiring the IPS or changing the layout of the control panel for example. Systems that are independent of the IPS, but which may be affected by icing (i.e. windshields, pitots, fuel vents), should be addressed in their own rules.

- Cost/benefit - Linking this change with § 23.1311 would allow an operator to install and/or upgrade autopilots without forcing them to also upgrade avionics. At the same time, new avionics systems would be required to possess improved low airspeed awareness by a low cost means. It was recognized by the ARC that incorporating a low speed alert is much easier accomplished with less cost through avionics upgrades, since most part 23 autopilot systems are not tied to airspeed. However, some ARC members felt avionics should not be forced to upgrade if the avionics are not the source of the low airspeed event.

- Practicality on older models - The practicality of requiring operators to meet a new § 23.1329 or § 23.1419 new rule seems problematic. The operator of an older part 23 airplane with analog gages and either an older autopilot or no autopilot at all could benefit from upgrading to a newly certified autopilot. Autopilots can be used for holding a heading or altitude and for course tracking. Many are capable of making turns, climbs and descents in order to do this. Some are capable of holding a desired vertical speed in a climb or descent, but this simply means they are holding to a desired rate such as 500 ft/min. Even more advanced systems have flight envelope protection capabilities. This means that as the aircraft approaches stall or overspeed, the autopilot gradually reduces maximum bank and vertical speed to keep the wing flying. Unlike an autothrottle system, none of these systems will actually affect engine settings to maintain a desired airspeed. To do anything more than hold a desired rate of climb or descent requires that the autopilot be coupled to a primary flight display, requiring an upgrade to a new "glass" avionics system. Currently this can be a very expensive upgrade for an individual operator and may compel them to keep their existing avionics rather than upgrade to a new more capable (safer) autopilot.

Some members believed aural and tactile warnings are out scope for § 23.1311. However, another member stated as (a)(6) shows precedence for requiring the speed warning device functionality of § 23.1303(e) (specifically aural warnings) if an electronic display is replacing that instrument.

D) APPLICABILITY OF THE PROPOSED RULE

(1) TYPES OF MODIFICATIONS

- First Time an Autopilot is Certified on an Airplane

  The majority of the ARC believed that the proposed rule should be applied to modification projects in which an autopilot is being certified for the first time on that particular icing certified model. One member agreed only if the modification also included a glass cockpit, which would make compliance less costly. One other member disagreed entirely and felt the rule should not be applied to autopilots but to new avionics. The issue was not only cost to comply, particularly for small airplanes, but this member believed if a low airspeed alert was required, it should be required regardless if autopilot is engaged or not. This member added that an autopilot is a safety enhancement by itself.

- Replacement Autopilot with No New Modes, Features or Performance

  If the modification involved replacing an existing autopilot on an icing certified airplane with a new one that incorporated no new modes, features, or change in performance, the new rule should not apply, according to the ARC. There was near consensus. Two members stated that service history should be used to determine applicability of the proposed rule.

- Replacement Autopilot with New Modes, Features or Performance

  If the replacement autopilot incorporated new modes, features, or performance differences, the ARC was almost evenly split as to whether the proposed new rule should apply. Three members stated that service history should be used as criteria. One member believed that if the new autopilot was simple and did not incorporate modes such as altitude hold or vertical speed, no, otherwise yes.

- Glass Cockpit

  If an amendment to 23.1311 is adopted, a glass cockpit upgrade would be applicable. If an amendment to 23.1419 were adopted, a glass cockpit upgrade by itself would not be an affected area under the Changed Product Rule and compliance to the rule would not be required. However, if the glass cockpit tied in to the autopilot, then the modification would require assessment per AC 21.101 to determine applicability of the proposed 23.1419 rule change.

- Gross Weight Increase

  A gross weight increase reduces airplane performance and increases the potential for the airplane to reach the low airspeed regime, and reduces the acceleration during stall recovery. A gross weight increase greater than 5% is deemed significant under the Changed Product Rule and would require assessment per AC 21.101 to determine applicability of the proposed 23.1419 rule change. Consideration should be given to an engine change, resulting in power/thrust increase, in conjunction with the weight increase which may mitigate the above issues.

- Changed Product Rule

  The ARC discussed the changed product rule, § 21.101, and the associated Advisory Circular 21.101-1A, during the applicability discussions. Many in the ARC believed that the AC would have to be revised if the new rule was to apply to any new autopilot on an airplane certified for icing because Appendix 1 of the AC classifies an autopilot installation as a “Not Significant” change. The ARC also discussed the phrase “and of any other regulation the [FAA] finds is directly related” in § 21.101(b) and its guidance in Step 8 in Figure 1 of AC 21.101-1A. This criteria may deem the proposed type certification basis to be inadequate – that is, the change includes characteristics that were not foreseen during the initial (or previously approved) type certification. The ARC believed that this may not be universally interpreted and the AC should be revised.

E) BENEFIT SUMMARY

The ARC reviewed the database described in Section 9 of this report. Accidents included in the SLD applicable list in Table 13 of this report were excluded, as well as part 23 airplanes that were not equipped nor certified for icing. This included three events on airplane models subject to Cessna Service Bulletin MEB97-4. The list was then reduced to events in which there was evidence of a loss of control at low airspeed. Examples include witnesses observing the airplane descending out of clouds in an uncontrolled state, or radar that indicated a loss of airspeed. An example is “"aircraft slowed from 270 to 150 ground speed in 4 minutes, then slowed to 100 knots in the next 12 seconds." An attempt was made to limit the list to airplanes in which an autopilot was installed, in accordance with the proposed rule. However, in most events this data was unavailable and an installed autopilot was assumed. The resulting applicable list is in Table 19.

Table 19 – Events Applicable to Task 9 Proposed Rule

DATE	AC TYPE	LOCATION	FATAL	INJURY	HULL LOSS
1/15/2009	Commander 690C	Wray, CO	2	0	Yes
2/9/2007	BE-H18	Great Bend, KS	1	0	Yes
11/29/2005	CE-425	Belgrade, MT	1	0	Yes
12/6/2004	CE-208B[1]	Bellevue, ID	2	0	Yes
10/29/2003	CE-208B[1]	Cody, WY	1	0	Yes
11/8/2002	CE-208B[1]	Parks, AZ	4	0	Yes
5/5/2001	CE-208B[1]	Steamboat Springs, CO	1	0	Yes
4/4/1999	PA-46-350[2]	Waldron, AR	1	0	Yes
1/31/1996	BE-65-E90	Flagstaff, AZ	3	0	SD
4/12/1995	BE-65-B80	Great Bend, ND	1	0	SD
2/14/1995	PA-46-310P[2]	Chippewa, WI	2	2	SD
2/12/1995	690 (Twin Commander)	Guthrie, OK	2	0	Yes
1/26/1994	CE-421C	McCook, NE	2	3	Yes
11/21/1992	BE-60-A60	Snoqualmie Pass, WA	6	0	Yes
2/14/1990	MU-2B-60[1]	Putnam, TX	5	0	Yes
9/2/1981	MU-2B-25[1]	McLeod, TX	5	0	Yes
12/6/1980	MU-2B-40[1]	Ramsey, MN	5	0	Yes
1/30/1980	690A (Twin Commander)	Newcastle, OK	2	0	Yes
4/7/1979	BE-58TC	St. Anne, IL	6	0	Yes
1/19/1979	PA-60-601P	Grand Rapids, MI	4	2	Yes

SD – substantial damage

Note 1 - Airworthiness Directives required installation of Low Airspeed Alert systems for flight in icing on these airplanes. No icing events since AD.

Note 2 - Airworthiness Directive required modification of stall warning heating circuit. No icing events since AD.

All aircraft were certified to § 23.1419 at Amendment 23-14 or earlier, including Civil Air Regulations (CAR) 3. No aircraft in the events database were certificated under. § 23.1419 Amendment 23-43 (latest amendment for part 23 icing certification).

The ARC noted that all but three of the airplanes in the list had takeoff gross weight above 6,000 lb., and 12 out of the 20 were turboprops. The majority of the ARC believes that restricting the rule to airplanes above 6,000 lb. may be an option to be evaluated during the economic analysis of the rule. One member believed the rule could be targeted to only turboprop equipped airplanes, and one member believed it should be targeted to only turboprop airplanes above 6,000 lb. gross weight. One technical rationale that supports using the powerplant type criteria is that reciprocating powered airplanes have shorter spool up times for airspeed recovery, however one observation was that stall recovery with ice accretion is effected by angle of attack reduction. If either were pursued, the ARC noted that all the part 23 models in part 121 service would potentially be subject to the rule, and 74% of the airplanes in part 135 service are models that would be applicable (80% if all turbine engines were included). Therefore limiting the rule applicability as discussed may potentially reduce the rule cost and burden on small airplane owners while protecting the majority of the flying public. The above analysis was based on SPAS data from May, 2011.

The ARC made an interesting observation on airplane not certified for icing. Before the airplanes not certified for icing were excluded from the applicable Task 9 list, they made up 71% of the events. The ARC believes education and training, and the introduction of envelope protection systems in the fleet will reduce these accidents. (The latter is based on the assumption that envelope protection systems activate at a nominal 1.2 times non-icing stall speed.)

F) COST SUMMARY

(1) DESIGN AND CERTIFICATION

The cost to comply with the proposed rule would be a function as to whether the modification incorporates a glass cockpit. An autopilot on a part 23 airplane would not have airspeed data. The ARC estimates that 86% of autopilot modifications on part 23 airplanes incorporate a glass cockpit. The costs associated with a glass cockpit installation are lower because airspeed information is already available, however the glass cockpit software would have to be developed and tested to display a low airspeed alert. The ARC does not have the expertise to provide this cost data and recommends the FAA obtain this data from avionics manufacturers. These modifications, in addition to software and display modifications, would require a signal to indicate an ice protection system is activated (to indicate the airplane is in icing conditions) and a flap position signal. The average estimate provided by airframe manufacturers on the ARC is 140 man-hours. The required modification would require a flight test to determine proper function and verify absence of nuisance alerts. The average cost provided by airframe,manufacturers is 65 man-hours and $6,000. These estimates assume flight testing will not require ice shapes and the flight test evaluations piggy-back evaluations of the autopilot or glass cockpit.

(2) <u>RECURRING COSTS</u>

The unit cost increase of an autopilot installation should be estimated by the avionics manufacturers. Increase in airplane weight is expected to be negligible, and operations should be small since operating speeds should not be required on most modifications.

G) GUIDANCE

Since there was no consensus on whether a proposed new rule should be in § 23.1311 versus § 23.1419, the ARC did not draft recommended guidance as it did for SLD and ice crystals. The ARC believes the following should be addressed in the guidance:

Acceptable means of compliance (the discussions in section B Proposed Rule) should be included)

Applicability (the discussions in section C Applicability of the Proposed Rule) should be included)

Regardless of which rule is eventually proposed, the ARC recommends edits to AC 23.1311 in Section 17.7 "Low Speed and High Speed Awareness Cues."

- This section should reference the proposed rule and state that for airplanes subject to the Task 9 rule, the low airspeed awareness cue should be based on icing V_{SO} when in icing conditions (the ice protection system may be used to indicate this).
- For airplanes in which the stall warning system is scheduled for icing, the low airspeed awareness cue should be based on the icing stall speed. This reflects industry practice and the revised AC 23.1419-2E can be referenced.
- For other part 23 airplanes certified for icing, it is good practice to schedule the low airspeed awareness cue on icing stall speed when in icing conditions.

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
ARC Charter

Effective Date: 2/19/2010

SUBJ: Part 23 Icing Aviation Rulemaking Committee

1. Purpose of this Charter. This charter creates the Part 23 Icing Certification Aviation Rulemaking Committee (ARC) according to the Administrator's authority under Title 49 of the United States Code (49 U.S.C.) § 106(p)(5). This charter also outlines the committee's organization, responsibilities, and tasks.

2. Audience. We have written this charter for employees within the Office of the Associate Administrator for Aviation Safety. The audience for this charter also includes employees of the Office of the General Counsel and the Office of Aviation Policy and Plans.

3. Background. On October 31, 1994, an accident involving an Aerospatiale Model ATR72 series airplane occurred in which icing conditions, believed to include freezing drizzle drops, were reported in the area. The FAA and others conducted an extensive investigation of this accident. This investigation led to the conclusion that freezing drizzle conditions created a ridge of ice on the wing's upper surface aft of the deicing boots and forward of the ailerons. The NTSB concluded that the ridge of ice resulted in uncommanded roll of the airplane. The atmospheric conditions (freezing drizzle) that may have contributed to the accident are outside the icing envelope specified in Appendix C of part 25 of the Federal Aviation Regulations (14 CFR part 25) for certification of the airplane. Freezing rain is another atmospheric condition that also is outside the icing envelope. These conditions constitute an icing environment known as supercooled large drops (SLD). Appendix C of part 25 is also used for certification of part 23 airplanes for icing. The effects of SLD on part 23 airplanes are more significant than they are on part 25 airplanes. The smaller size of part 23 airplanes results in a larger collection efficiency, aerodynamic penalties are higher due to their smaller scale, they typically have reversible flight controls, and their power thrust margins are smaller. Accident reviews have shown most SLD events belonged to small airplanes (14 CFR part 23).

a. The NTSB issued various safety recommendations to the FAA following the Model ATR72 accident. One of the recommendations, A-96-56, states in part that:

> If the manufacturer cannot demonstrate safe operations in certain icing conditions, operational limitations should be imposed to prohibit flight in such conditions. Flightcrews should also be provided with the means to determine positively when they are in icing conditions that exceed the limits for aircraft certification.

b. Another recommendation, A-96-54, states:

> Revise the icing criteria published in 14 Code of Federal Regulations (CFR), parts 23 and 25, in light of both recent research into aircraft ice accretion under varying conditions of liquid water content, drop size distribution, and temperature, and recent developments in both the design and use of aircraft. Also, expand the appendix C icing certification

Distribution: A-W (VS)-2, A-X (VS)-2 Initiated By: ACE-111 envelope to include freezing drizzle/freezing rain and mixed water/ice crystal conditions, as necessary.

c. In response to these NTSB safety recommendations, the FAA tasked the Aviation Rulemaking Advisory Committee (ARAC) on December 8, 1997 (62 FR 64621). Their task was to define an icing environment that includes supercooled large drops (SLD) and devise requirements to assess the ability of aircraft to safely operate either for the time to exit or to operate without restriction in SLD conditions. The ARAC was asked to consider the need to define a mixed phase icing environment (supercooled liquid and ice crystals). They were also tasked to study the effects icing requirement changes could have on pilot compartment view, airspeed indicating system, static pressure systems, and angle-of-attack systems. The task was revised in June 2000 to address 14 CFR part 25 only.

d. In December 2005, the Aviation Rulemaking Advisory Committee's (ARAC) Ice Protection Harmonization Working Group (HWG) completed their final report on recommended rulemaking and advisory material related to supercooled large drop (SLD) conditions and ice crystal/mixed phase conditions. The committee's work had the support of the Flight Test HWG, the Powerplant Installation HWG, and the Engine HWG. The report included recommendations for a new appendix to 14 CFR part 25, defining an SLD environment, and a new 14 CFR part 33, Appendix D to address ice crystal/mixed phase conditions. Included in the report are recommendations addressing 14 CFR part 25 aircraft performance and handling qualities, engine installation effects, ice protection system requirements, and 14 CFR part 33 engine requirements. ARAC approved the report and sent it to the FAA in March 2006.

4. Organization and Administration of the Part 23 Icing Certification ARC. We will set up a committee of members of the aviation community, including airplane icing specialists representing diverse viewpoints. FAA participation and support will come from all affected lines-of-business. Where necessary, the committee may set up specialized work groups that include at least one committee member and invited subject matter experts from industry and government.

The charter is set up as follows:

a. The committee sponsor is the Manager, Small Airplane Directorate, who:

(1) Appoints members or organizations to the committee, at the manager's sole discretion;

(2) Receives all committee recommendations and reports;

(3) Selects industry and FAA co-chairpersons for the committee; and

(4) Provides administrative support for the committee, through the Aircraft Certification Service.

b. The co-chairpersons will:

(1) Determine (with other committee members) when a meeting is required (a quorum is desirable at committee meetings, but not required);

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(2) Arrange notification to all members of the time and place of each meeting;

(3) Draft an agenda for each meeting and conduct the meeting;

(4) Keep meeting minutes; and

(5) Provide status updates to the Manager, Small Airplane Directorate, at 6 months and 12 months from the effective date of this charter.

5. Committee Membership

a. The committee will consist of members from the Federal Aviation Administration, Small Airplane Directorate and selected Aircraft Certification Offices. It will also consist of about 20 members, representing manufacturers of part 23 airplanes approved for known icing, consultant designated engineering representatives (DERs) who have certified part 23 airplanes for icing, operators of part 23 airplanes approved for icing, pilot unions, and aviation associations.

b. Each member or participant on the committee should represent an identified part of the aviation community and have the authority to speak for that community. Membership on the committee will be limited to promote discussions. Active participation and commitment by members will be essential for achieving the committee objectives and for continued membership on the committee. The committee may invite additional participants as subject matter experts to support specialized work groups.

6. Public Participation. Persons or organizations outside the committee who wish to attend a meeting must get approval in advance of the meeting from a committee co-chairperson or designated federal representative.

7. Committee Procedures and Tasks.

a. The committee advises and provides written recommendations to the Manager, Small Airplane Directorate, ACE-100.

b. Committee tasks include, but are not limited to, the following:

(1) Review the ARAC recommendations related to the proposed part 25 regulations and guidance for SLD, mixed phase, and ice crystals, and recommend how they need to be modified for part 23.

(2) Recommend part 23 regulations that will codify the guidance in Advisory Circular 23.1419-2D on activation and operation of ice protection systems, stall warning in icing conditions, and ice contaminated tailplane stall (ICTS).

(3) Recommend revisions to current § 23.1419 on airplane performance requirements in icing that require an exemption to the 61 knot stall speed requirement in icing.

(4) Determine applicable accidents and incidents that can be used for benefits in the economic analysis.

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11. Distribution. This charter is distributed to director-level management in the Office of the Associate Administrator for Aviation Safety; the Office of the Chief Counsel, the Office of Aviation Policy and Plans, and the Office of Rulemaking.

Administrator

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APPENDIX B – PART 23 ICING ARC MEMBERS

Point of Contact	Company	Phone
Karl Berg	Honda Aircraft	336-662-0246 x1022
Tom Bond	FAA Icing Chief Scientist & Technical Advisor	216-433-3900
Greg Bowles	GAMA	202-393-1500
Pedro Fernando Almeida Di Donato*	ANAC	55-12-37972614
Marcelo Leao Domingos	Embraer	55-12-3927-6610
Jim Duncan	Piper Aircraft	772-299-2684
Chuck Enders	FAA Flight Standards, Air Transportation	202-493-1422
John Fisher	FAA Engine & Propeller Directorate	781-238-7149
Michael H Grossmann	NATA	330-498-9333
Kristine Hartzell	AOPA	301-695-2086
John Hazlet	RACCA	818 847 0000 x300
Garrett Homan	Cirrus Design	218-788-3490
Jim Hoppins	Cessna Aircraft	316-517-8926
David Johns*	Transport Canada	613-941-8384
Jerry Jordan	CAV Aerospace	913-706-6460
Kurt Laurie	Cessna Aircraft	316-517-1984
Mário Celso dos Anjos Oliveira Leite	ANAC	55-12-37972434
Jim Martin*	Transport Canada	613-952-4311
Jason Nickel	Hawker Beech	316-676-0297
Jerry Ostronic	FAA Flight Standards, Air Transportation	412-886-2580 x332
David Parkins	Designated Engineering Representative	607-269-0702 x223
Paul Pellicano	FAA Small Airplane Directorate	404-474-5558
Andy Pierce	FAA Flight Standards, Air Transportation (Part 135)	202-267-8238
Everett Rochon	FAA Flight Standards, General Aviation & Commercial	202-267-7413
David Schwartz	Piper Aircraft	772-299-2682
Dennis van de Laar	National Air Transportation Association	703-575-2041
Gary Welsh	Hawker Beech	316-676-6923

* Non voting - foreign airworthiness authority

APPENDIX C – PART 23 AIRPLANE SEVERE ICING AIRWORTHINESS DIRECTIVES

Airplane Model	Docket	Final Rule
Aerostar Aircraft Corporation Models PA-60-600, PA-60-601, PA-60-601P, PA-60-602P, and PA-60-700P Airplanes	97-CE-56-AD	98-04-23
Pilatus Britten-Norman Ltd., Models BN-2A, BN-2B, and BN-2T Airplanes	97-CE-54-AD	98-04-21
Pilatus Aircraft Ltd., Models PC-12 and PC-12/45 Airplanes	97-CE-53-AD	98-20-28
Partenavia Costruzioni Aeronauticas, S.p.A. Model P68, AP68TP 300, AP68TP 600 Airplanes	97-CE-51-AD	98-04-20
Mitsubishi Heavy Industries, Ltd., MU-2B Series Airplanes	96-CE-61-AD	96-25-02
Harbin Aircraft Manufacturing Corp., Model Y12 IV Airplanes	97-CE-50-AD	98-04-19
Empresa Brasileira de Aeronautica S.A. Airplanes. (Embraer) Models EMB-110P1 and EMB-110P2 Airplanes	96-CE-02-AD	96-09-12
Dornier Luftfahrt GmbH, 228 Series Airplanes	96-CE-04-AD	96-09-14
De Havilland, Inc., DHC-6 Series Airplanes	96-CE-01-AD	96-09-11
The Cessna Aircraft Company, 208 Series	96-CE-05-AD	96-09-15
The Cessna Aircraft Company, Model T210R Airplane	98-CE-19-AD	98-20-33
The Cessna Aircraft Company, Models T210, P210, P210R Airplanes	97-CE-62-AD	98-05-14 R1
The Cessna Aircraft Company Models T303, 310R, T310R, 335, 340A, 402B, 402C, 404, F406, 414, 414A, 421B, 421C, 425, and 441 Airplanes	97-CE-63-AD	98-04-28
Jetstream Aircraft Limited Models 3101 and 3201 Airplanes	96-CE-07-AD	96-09-17
The New Piper Aircraft PA-23, PA-30, PA-31, PA-34, PA-39, PA-40, and PA-42 Series Airplanes	98-CE-77-AD	99-14-01
The New Piper Aircraft Corporation Models PA-46-310P and PA-46-350P Airplanes	97-CE-60-AD	98-04-26
Beech Aircraft Corporation Models 99, 99A, A99A, B99, C99, B200, B200C, 1900, 1900C, and 1900D Airplanes	96-CE-03-AD	96-09-13
Raytheon Aircraft Company 200 Series Airplanes	98-CE-17-AD	98-20-38
Raytheon Aircraft Company Models E55, E55A, 58, 58A, 58P, 58PA, 58TC, 58TCA Airplanes, and 60, 65-B80, 65-B90, 90, F90, 100, 300, and B300 Series Airplanes	97-CE-58-AD	98-04-24
Raytheon Aircraft Company Model 2000 Airplanes	97-CE-59-AD	98-04-25
AeroSpace Technologies Of Australia Pty Ltd., Models N22B and N24A.	97-CE-49-AD	98-04-18
SIAI Marchetti, S.r.1 Models SF600 and SF600A Airplanes	97-CE-64-AD	98-05-15
SOCATA--Groupe AEROSPATIALE, Model TBM 700 Airplanes.	97-CE-55-AD	98-04-22
Twin Commander Aircraft Corporation Models 500, 500-A, 500-B, 500-S, 500-U, 520, 560, 560-A, 560-E, 560-F, 680, 680-E, 680FL(P), 680T, 680V, 680W, 681, 685, 690, 690A, 690B, 690C, 690D, 695, 695A, 695B, and 720 Airplanes	97-CE-57-AD	98-20-34
Fairchild Aircraft Corporation, SA226 and SA227 Series Airplanes	96-CE-06-AD	96-09-16

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

Advisory Circular

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

Date:
Initiated by: ACE-100

AC No: 23.1419-2E

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, and part 25, Appendix O.

Earl Lawrence
Manager, Small Airplane Directorate
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 Advisory Circular (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 23.1419-2D, Certification of Part 23 Airplanes for Flight in Icing Conditions, dated April 19, 2007, is 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 and Appendix O. 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 and § 23.1420 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 must 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.

(4) Amendment 23-XX added a requirement to comply with § 23.1420 for airplanes seeking certification for flight in icing, which adds requirements for flight in supercooled large drop (SLD) conditions. Amendment 23-XX also:

(a) Added SLD requirements for propellers in § 23.929, windshields in § 23.775, and static ports in § 23.1325.

(b) Added SLD and ice crystal requirements for engines in § 23.1093(b)

(c) Added SLD and ice crystal requirements for pitot probe in § 23.1323, and added § 23.1324 for angle of attack/stall warning sensor instruments,

(d) Revised the Subpart B requirements in § 23.1419

(e) Codified ice protection system activation and operation guidance in § 23.1419

(f) Deleted § 23.1416 because the requirements are addressed in §§ 23.1309 and 23.1322.

(g) Replaced the requirement for illumination of ice accumulations provided by §23.1419(d) with a new §23.1403.

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 21-16F	"RTCA Document DO-160 versions D, E, and F, "Environmental Conditions and Test Procedures for Airborne Equipment," November 19, 2009.
AC 21-40A	"Guide for Obtaining a Supplemental Type Certification," September 27, 2007.
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," April 12, 2005.
AC 23.629-1B	"Means of Compliance with Title 14 CFR, Part 23, § 23.629, Flutter," September 28, 2004.
AC 23.1309-1D	"System Safety Analysis and Assessment for Part 23 Airplanes," January 16 2009.
AC 91-74A	"Pilot Guide Flight in Icing Conditions," December 31 2007.
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.

(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.

(7) FAA Technical Report DOT/FAA/06-60, "Propeller Icing Tunnel Tests on a Full-Scale Turboprop Engine," March 2010

(8) FAA Technical Report DOT/FAA/AR-09/10, “Data and Analysis for the Development of an Engineering Standard for Supercooled Large Drop Conditions,” March 2009

(9) FAA Technical Report DOT/FAA/AR-09/13, "Technical Compendium From Meetings of the Engine Harmonization Working Group", April 2009.

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, “Revision A, July 2007.
ARP5624	“Aircraft Inflight Icing Terminology,” March 3, 2008.
AIR1168/4	“Ice, Rain, Fog, and Frost Protection,” July 1990. .
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.
AS5498	"Minimum Operational Specification for Inflight Icing Detection Systems," October 2001.

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. Airplanes must also be able to safely operate in or exit the icing conditions defined by part 25 Appendix O.

The applicant, however, has several certification options available for Appendix O icing conditions. The airplane can be certified for—

- The ability to detect Appendix O conditions and safely exit all icing conditions,

- The ability to operate safely throughout a portion of Appendix O icing conditions and safely exit all icing conditions when that portion of Appendix O is exceeded, or

- The ability to operate safely throughout all the Appendix O icing conditions.

Sections 23.1419 and 23.1420 provide specific airframe requirements for certification for flight in the icing conditions defined in Appendices C and O.

The "approved portions" of 14 CFR Part 25, Appendix O as used in the proposed regulations and guidance material are intended to refer to aircraft that are certified against 23.1420(a)(2) or (a)(3). For aircraft certified against 23.1420(a)(1) the exposures in Appendix O are not approved and require exiting all icing conditions. The phrase "with exposures in accordance with 23.1420(a)(1), (a)(2) or (a)(3)" is intended to require consideration of the environmental conditions within the Appendix O environment, as well as the exposure durations as defined in 23.1420 and 14 CFR 23 Appendix TBD which contains ice shape definitions for exposure to 14 CFR 25, Appendix C and Appendix O for part 23 aircraft.

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. Aeroelastic stability analyses should use the mass distributions derived from ice accumulation up to and including those that can accrete in the applicable icing conditions in part 25, Appendices C and approved portions of Appendix O. This includes any accretions that could develop on control surfaces. The analyses need not consider the aerodynamic effects of ice shapes.

(3) Means for Inspecting upper Wing Surface in Ground Icing Conditions. On some high wing airplanes, the wing upper surface cannot be reached for a tactile inspection, or visually observed from the ground. Part 23 airplanes may operate into airports without any ground equipment. For these airplanes, the design should incorporate provisions to allow the flightcrew close access to the wing upper surface to facilitate a pre-takeoff contamination inspection. Recessed steps and handles in the fuselage, in proximity to the wing leading edge, would be one example.

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 23.1309-1D 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 part 25, Appendix C 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 when the ice protection system is not 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.

1. Pneumatic deicing 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. . For detect and exit aircraft, failures of the windshield system need not be considered in combination with Appendix O exposures due to the low probability of occurrence. 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.

(7) Appendix O Icing Conditions.

(a) Airplanes Certificated to Operate in Appendix O or a Portion of Appendix O Conditions (§ 23.1420 (a)(2) and § 23.1420(a)(3)).

1. The system safety analyses accomplished for flight in part 25, Appendix C icing conditions should be accomplished for flight in the part 25, Appendix O icing conditions for which the airplane is certified to operate.

2. The applicant may assume that the average probability for encountering Appendix O icing conditions is 1×10^{-2} per flight hour. This probability should not be reduced based on phase of flight.

3. Flight testing of failure ice shapes should be accomplished to validate hazard classifications and AFM exit procedures.

(b) Airplanes Certificated to Detect and Exit Appendix O Icing Conditions (§ 23.1420(a)(1) and § 23.1420(a)(2)).

1. It is not necessary to conduct system safety assessments for flight in the icing conditions defined in appendix O of part 25 of this chapter for which the airplane is certified to safely exit following the condition's detection.

2. A system safety assessment is required for any system utilized to detect icing conditions for which the airplane is not certified.

(c) Detection of Appendix O Conditions for which the Airplane is not Certified

1. An applicant may assume that the hazard classification for an unannunciated encounter with Appendix O conditions while the ice protection system is activated is <u>hazardous</u>, in accordance with AC 23.1309-1D, provided that the following are true.

(aa) The airplane is similar to previous designs with respect to Appendix O icing effects, and

(bb) The applicant can show that the icing event history of all conventionally designed airplanes is relevant to the airplane being considered for certification.

2. If an aircraft is not similar to a previous design, an assessment of the hazard classification may require more analysis or testing. One method of hazard assessment would be to consider effects of ice accumulations similar to those expected for aircraft being certified under § 23.1420. Such ice shapes may be defined from a combination of analysis and icing tanker or icing wind tunnel testing. Aerodynamic effects of such shapes could be evaluated with wind tunnel testing or, potentially, computational fluid dynamics. Hazard classification typically takes place early in a certification program. Therefore, a conservative assessment may be required until sufficient supporting data is available to reduce the hazard classification.

3. Visual Cues. Typical system safety analyses do not address the probability of crew actions, such as observing a visual cue before performing a specified action. As advised in AC 23.1309-1D, quantitative assessments of crew errors are not considered feasible. When visual cues are to be the method for detecting Appendix O conditions and determining when to exit them, the applicant should assess the appropriateness and reasonableness of the specific cues (see section 15 of this AC for additional guidance).

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. See AC 23-16C for more information.

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. Section 23.1323(d)(1) requires the airspeed indicating system on aircraft certificated for flight in icing conditions to be designed to protect against SLD icing conditions. At a minimum, the pitot probe ice protection must be capable of handling the portion of the SLD environment the aircraft is certificated to operate in per section 23.1420(a) – detect and exit SLD, partial SLD operations, or unlimited SLD operations. The compliance should include any effects of ice accretions upstream of the probes that may disrupt the airflow.

(1) Applicable Icing Conditions. For aircraft approved for flight into icing, the pitot probe ice protection must be designed to 14 CFR 25 Appendix C and Appendix O icing conditions with exposures in accordance with 23.1420(a)(1), (a)(2) or (a)(3).

(2) TSO Authorizations. Compliance with the technical standard order (TSO) qualification standard for electrically heated pitot probes (TSO-C16a) is not sufficient by itself to demonstrate compliance with § 23.1323(d)(1). TSO C16a, "Electrically heated pitot and pitot-static tubes," references Society of Automotive Engineers (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." However it does not contain tests for Appendix O icing conditions. The applicant is responsible for showing that the pitot heat is adequate for the applicable Part 25 Appendices C and O icing conditions, and Part 33 Appendix D mixed phase and ice crystal conditions. If this proof of compliance is not obtained in flight tests, analysis and/or icing tunnel test data should be submitted. Compliance to the probe water catch aspects of Appendix O may be found by similarity to the Appendix C environment due to the reduced water contents.

(3) Mixed Phase Icing and Ice Crystals. Section 23.1323(d)(2) specifies mixed phase and ice crystal conditions that are required for certain aircraft. Recent cloud characterization research has indicated that approximately 40 percent of icing condition events consist of liquid water drops and ice crystals (mixed phase icing conditions). Also, glaciated atmospheric conditions, which consist solely of ice crystals, are encountered during aircraft operations. The operating rules do not prohibit operations in mixed phase and ice crystal icing conditions. Recent incident history indicates that flightcrews have experienced temporary loss of or misleading airspeed indications that can be attributed to mixed phase icing or ice crystal conditions. The vast majority of incidents for which there is data have occurred during operation at high altitude and high airspeed. 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 and O design requirements. Therefore, aircraft certificated for operation at altitudes higher than 29,000 feet MSL and speeds above Mach .75 have the additional requirement of protecting against mixed phase icing and glaciated ice crystals. These requirements also apply to lesser-performing aircraft where loss of or misleading airspeed information causes substantial risk for the flight. The terminology used in section 23.1323(d)(2) of "critical function" is defined in AC23.1309-1D as "a function whose loss would prevent the continued safe flight and landing of the airplane." Potential examples of this include fly-by-wire aircraft or aircraft with airspeed-dependant control schedules. It is the responsibility of the applicant to determine whether the hazard is critical by using the appropriate system safety analyses.

(a) Applicable Icing Conditions. For aircraft that meet the performance or system criticality criteria described in 23.1323(d)(2), the pitot probe ice protection should be designed to meet the mixed phase and ice crystal conditions defined by Part 33, Appendix D.

(b) British Specification 2G.135, "Specification for Electrically-Heated Pitot and Pitot-Static Pressure Heads." Some pitot tube manufacturers now elect to 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 conditions to test probe performance in mixed-phase and ice crystal conditions. Icing tunnel testing such as this, with simulated mixed-phase and glaciated icing, is an acceptable way to demonstrate compliance with § 23.1323(d)(2) when combined with analysis to reach the extents of the Part 33, Appendix D environment.

(c) Probability of Mixed Phase or Ice Crystal Conditions. As noted above, recent cloud characterization data indicates a high probability of occurrence for mixed phase icing conditions. There are no accepted standard data for the probability of mixed phase icing conditions, or for the probability of total water content levels within such conditions. However, the total water content of such conditions is a distributed probability similar to Appendix C. The most probable mixed phase icing conditions are at relatively low total water contents, with the highest total water contents being least probable. In addition, the critical high water content ice crystal conditions typically are associated with high altitude cumulus activity, which has limited standard extents within part 33, Appendix D. For aircraft that rely on batteries for emergency power supplies on pitot heater systems, compliance with Appendix C icing conditions should be shown over the duration of the emergency. For systems that comply with the Appendix C conditions under these conditions, the probability of critical mixed phase and ice crystal icing conditions may be considered as remote.

(d) Water Contamination. Evaluation of proper drainage should be evaluated as installed on the aircraft. Meteorological conditions that may need to be considered include flight through drizzle or rain prior to cold soaking the aircraft. Pitot, AOA and stall warning systems should operate after such an encounter.

(4) Pitot Heat Indication Systems. A system for indicating to the pilot and flight crew when the pitot heat is off or not working is required by Section 23.1326. The indication must be presented to the flight crew if the pitot heat system is commanded ON and any heating element is not operating. Also, the indication is required if pitot heat is switched OFF during takeoff or in flight if the potential for icing conditions exist. The indication may be presented using the electronic flight instrument system, crew alerting system, or a system with similar functionality if the airplane is equipped with such a system.

(a) Ground Operation. Some pitot probe heating systems may generate heat levels high enough to require additional system logic or procedures to minimize or turn off the pitot heat while on the ground (with little or no airflow) in order to protect equipment or structure from thermal damage. Since accurate airspeed information is only required for safe flight, there is no safety benefit to indicating the pitot heat system is OFF for ground operations.

(b) Dark Cockpit Concept. Applicants may employ the "dark cockpit" philosophy when displaying system status and indications to the flight crew. When the pitot heat system is commanded to the OFF state by the flight crew and the potential for icing conditions does not exist, it is not required to indicate that the pitot heat is OFF. Icing conditions cannot exist when OAT is above freezing. A +5°C threshold has been accepted to provide a safe margin in case a sudden drop in temperature is encountered when flying in IMC.

j.Angle of Attack and Stall Warning Sensor Protection. Similar to the airspeed indicating system, Section 23.1324 requires that each sensor installed for the angle of attack system must have a means to prevent malfunction from icing conditions. This includes any sensor (such as lift detector or lift transducer) that is used in the stall warning systems. Section 23.1324 requires a heated angle-of-attack system sensor or equivalent means to prevent malfunction due to icing conditions.

(1) Icing Approval. For aircraft approved for flight into icing, the angle of attack and stall warning ice protection must be designed to 14 CFR 25 Appendix C and Appendix O icing conditions with exposures in accordance with 23.1420(a)(1), (a)(2) or (a)(3) and ice crystals per 14 CFR 33, Appendix D.

(2) Types of Systems.

(a) Vane. Conventional, vane-style angle of attack sensors are not likely to be susceptible to ice crystals. A qualitative analysis based on the service history on vane angle-of-attack sensors is an acceptable means of compliance.

(b) Multi-purpose probes. Some angle of attack probes sense dynamic pressure differentials (similar to pitot probes) to calculate angle of attack. This type of probe can be a high efficiency collector of ice crystals in the same manner as pitot probes. For such probes, applicants should address the ice accretion characteristics for ice crystals and protection against mixed phase and ice crystal conditions.

(3) Position Error. 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.

(4) TSO Authorizations. 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 § 23.1324. 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. 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 applicant is responsible for showing that stall warning heat is adequate throughout the appropriate icing conditions. If this proof of compliance is not obtained in flight tests, analysis and/or icing tunnel test data should be submitted.

(5) Water Contamination. Consideration should be given for the impingement or runback of water that may freeze within sensing devices that require the free movement of components as part of their sensing functionality. Meteorological conditions that may need to be considered include. flight through rain prior to cold soaking the aircraft. Pitot, AOA and stall warning systems should operate after such an encounter.

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. For aircraft certified for flight into known icing, the applicable icing conditions are defined by Part 25, Appendix C and the applicable portions of Part 25, Appendix O (in accordance with 23.1420(a)). Mixed phase icing and ice crystals have not been shown to cause issues with static pressure systems and therefore do not need to be addressed. Means of showing compliance include anti-icing devices, alternate source for static pressure, or demonstration by test that the static port does not accrete ice under any condition. When the port is heated, a thermal evaluation should be conducted to demonstrate that the ice protection is adequate. Consideration should be given to ice formations on the airframe in the vicinity of the port mounting location that may affect the static pressure measurement..

l. 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

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

(3) Fluid Quantity.

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

(b) If it is desired that the airplane be dispatched with less than full fluid in the reservoir, the AFM should contain a chart or table to allow the crew to determine the minimum fluid level. The AFM limitations should state a minimum dispatch fluid level that is the higher of the following two values:

1. 90 minutes based on the flow rate required in critical continuous maximum icing conditions, correcting for cloud horizontal content.

2. 45 minutes based on the flow rate required in critical continuous maximum icing conditions, with no correction for cloud horizontal extent.

(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.

m. Cockpit Displays

(1) **Stall Warning Schedule.** Indication should be provided to the pilot that the icing stall warning schedule is active if AFM limitations or procedures (e.g. higher approach airspeed) are changed from non-icing.

(2) Low Airspeed Awareness. If a low airspeed cue is provided, it should be based on icing stall speed when the stall warning is on the icing schedule.

n. Windshield Heat Systems
For certification in the icing conditions specified in Appendix O, the time increment for the windshield should be consistent with the approved portions per 23.1420(a)(2) or (a)(3). Acceptable methods of compliance include analysis validated by natural icing, tanker or dry air testing

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. 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 also used to verify proper ice protection system operation, collect protected surface temperature data to validate thermal analysis, and 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.

(3) Flight Tests in Icing Conditions. Flight tests in icing conditions, which may include 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 and Appendix O as recommended in paragraph 14(f) of this AC to verify the airplane's ability to safely operate throughout that icing envelope.

b. 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.

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) Air Data. See paragraph 10.i., 10.j.and 10.k of this AC.

(5) 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.

(5) Ice Inspection Light(s). The installation should be evaluated for both in and out of clouds during night flights to determine that adequate illumination exists in the required areas (activation of ice protection systems and/or identification of severe icing cues), and that excessive glare, reflections or other distractions to the flight crew do not exist. The evaluation should consider flight both in and out of cloud, but may be accomplished without flight into actual icing conditions. The Airplane Flight Manual or other approved manual material must describe the means and location for determining ice formations.

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 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: pre-activation ice, 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. An applicant should provide a temperature versus response time plot for their installed ice detector and show that, at temperatures for which runback ice occurs on critical surfaces that either the response time is less than 60 seconds or runback ice has not yet formed during the response time. Runback ice should be evaluated empirically and should be evaluated using the same means of compliance as the detector response time data. An applicant may then take credit for an advisory ice detection system and use a shorter time to determine pre-activation ice.

(c) Engine and Cooling Inlets. See AC 23-16B.

(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 at amendment 23-XX and higher, the subpart B requirements defined in § 23.21(c)(1) 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. Analysis should be accomplished to show that the location of the instrumentation will allow measurement of freestream conditions (or appropriate correction factors). See AC 20-73A for guidance on measuring the icing conditions. 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.

(2) Documentation of Ice Accretion. 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.

(3) Is Instrumentation Always Needed? The need for icing instrumentation on specific tests may be considered with respect to the type of testing and similarity to prior measured natural icing exposures. In some cases, external icing instrumentation packages may have an effect on the aircraft handling characteristics, or the ice thickness maybe the significant variable. Comparison of ice thickness and general correlations to prior measured icing conditions may be sufficient for some types of testing.

(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. Part 25, Appendix O Icing Conditions – See paragraph 14.f. of this AC regarding the necessity to flight test in Appendix O conditions.

4. 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 which may occur on one or multiple flights.

(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. Handling qualities and performance should be subjectively reviewed and determined to be in general correlation with those found in dry air testing. Refer to Table 3. for performance, stability, control and maneuverability requirements.

(aa) Holding. A target accretion thickness equivalent to the 45-minute duration encounter in Appendix C Continuous Maximum on an unprotected part of the wing.

(bb) Landing. A target accretion thickness equivalent to a 5-minute duration encounter in Appendix C Continuous Maximum on an unprotected part of the wing.

2. Pre-activation Ice. Dependent on activation of ice protection as defined in Table 2.

3. Two Minute Delayed Ice Protection System Activation. For engine ice protection systems, which for aft fuselage mounted engines can include the inboard wing ice protection system, a delay of two minutes in the continuous maximum icing conditions of appendix C to part 25 is utilized to validate the ice shedding analyses and § 33.77 ice slab test results. To minimize flight testing, an applicant has the option of conducting this evaluation after the tests in Table 3 are conducted, provided the tested ice accretion is conservative for both tests.

(c) 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. AC 20-73A, Appendix P provides a checklist that may be used in drafting a natural icing test plan. Some additional considerations are:

1. Engine operation and equipment operation 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. Fuel system venting should not be affected by ice accumulation.

3. Ice shedding. See paragraph 16 of this AC.

4. Stall Warning and Maneuver Margin. The stall warning margin should be evaluated with various ice accretions as summarized in Table 3. See paragraph 13.c. of this AC and the guidance for § 23.207 in Appendix 6.

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

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

6. Ice detection cues or ice detection system operation. See paragraph 15 of this AC.

7. **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.

8. **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.

9. **Autopilot.** See paragraph 17 of this AC.

10. **Vibration and Buffet.** Should be evaluated, including propeller vibration.

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

12. AFM. AFM limitations and procedures should be evaluated.

13. Performance and Handling Qualities in Appendix C Icing Conditions. Airplane performance and handling qualities are degraded by ice accumulations in various ways depending upon type, shape, size, and location of these accumulations.

a. Flight Tests

(1) Section 23.1419 at Amendment 23-XX or Later. Airplane performance, controllability, maneuverability, and stability may be degraded from the non-iced airplane but must not be less than certain requirements in part 23, subpart B, as defined in § 23.21(c)(1). Guidance for each applicable 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). However, as a minimum, stability and controllability should be evaluated at minimum holding speed in holding configuration and V_{REF} in all approved approach and landing configurations. It is not required to test at high airspeeds. Instead, the maximum airspeed defined in the guidance for 23.251 may be used. It is not required to test flight conditions at altitudes above the part 25, Appendix C icing envelopes.

(2) Section 23.1419 prior to Amendment 23-XX. See prior revisions of AC 23.1419-2E.

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 summarize the ice accretions defined in part 23, Appendix TBD, part I. .

TABLE 2. ICE ACCRETION DEFINITIONS, part I of APPENDIX TBD OF PART 23

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
Takeoff	Not required.	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.

TABLE 2. ICE ACCRETION DEFINITIONS, part I of APPENDIX TBD OF PART 23

<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>Final Takeoff</td><td>Not applicable.</td><td>Same as “takeoff” ice except ice accretion occurs between liftoff and 1,500 feet above the takeoff surface.</td></tr>
<tr><td>Enroute</td><td colspan="2">Ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, during the en route phase, in part 25, Appendix C, continuous or intermittent maximum icing conditions.</td></tr>
<tr><td>Holding</td><td colspan="2">Ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, during a 45-minute hold in part 25, Appendix C, continuous maximum icing conditions.</td></tr>
<tr><td>Approach And Landing</td><td colspan="2">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 and landing phase is 5 minutes at the critical Appendix C Continuous Maximum Icing Conditions.</td></tr>
<tr><td>Pre-Activation</td><td colspan="2">The ice accretion prior to normal system operation is the ice accretion formed on the unprotected and normally protected surfaces prior to activation and effective operation of any ice protection system in continuous maximum atmospheric icing conditions. Pre-activation ice is a function of ice detection procedures, ice detector system design and performance, and operating procedures, as shown in below:
<table>
<tr><th>IPS Activation</th><th colspan="2">Part 23 Pre-activation Ice Accretion
(The left and right columns provide two approaches that may be used. The right column provides typical values that may be used in lieu of system specific data)</th></tr>
<tr><td>Visual of First Indication of Accretion on Reference Surface</td><td>Time to detect (1)
+30 seconds (2)
+IPS response time</td><td>2 minutes (2)</td></tr>
<tr><td>Potential Icing Conditions
(OAT and Visible Moisture)</td><td>+30 seconds (2)
+IPS response time</td><td>30 seconds (5)</td></tr>
</table></td></tr>
</table>

TABLE 2. ICE ACCRETION DEFINITIONS, part I of APPENDIX TBD OF PART 23

	Primary IDS and Manual IPS Activation	IDS response time(3) +10 seconds +IPS response time	30 seconds (3)(5)
	Primary IDS and Automatic IPS Activation	IDS response time(3) +IPS response time	20 seconds (3)(5)
	Advisory IDS(3)	IDS response time (4) +10 seconds (2) +IPS response time	60 seconds (4)(5)

Notes:
(1) Total time not to exceed 2 minutes
(2) Easily recognizable by the flight crew in all foreseeable conditions (e.g., at night in clouds)
(3) Applicant should show that the response time of the ice detector at freezing fractions of one is less than stated time.
(4) In low freezing fractions conditions, applicant should show that detector will annunciate prior to ice accretion on critical surfaces. This may be accomplished by comparing icing tunnel tests to response times provided by the detector manufacturer.
(5) Add delay time due to any IPS activation logic

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 mechanical ice protection systems at a small temperature band near freezing. Empirical data should be obtained on thermal systems due to current lack of capability of analysis codes to calculate shape and location of runback ice. Empirical data should be obtained on mechanical IPS airfoils at the following conditions, as a minimum, at the LWC values within part 25, Appendix C:

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.)	a. total air temperatures of 24 degrees to 35.5 degrees F; b. time required to transit a continuous maximum cloud of up to 55 nm, correcting liquid water content for horizontal extent.	
Thin, rough	A thin layer of ice that may occur on or aft of protected surfaces of operating mechanical deicing systems, such as pneumatic deicing boots. Should be simulated with 16-20 grit sandpaper and chordwise extent should consider any impingement aft of protected areas with substantiated roughness. The extents should consider the largest MVDs and drop distributions effects.	

TABLE 2. ICE ACCRETION DEFINITIONS, part I of APPENDIX TBD OF PART 23

Critical	The ice accretion, applicable to the phase of flight that has the most adverse effect on performance and flying qualities. For protected surfaces, pre-activation and normal IPS operation (intercycle ice, residual ice, thin, rough ice, and runback ice, if applicable), should be accounted for. In order to reduce the number of ice accretions to be considered when demonstrating compliance: (1) The more critical of takeoff ice and final takeoff ice may be used throughout the takeoff phase. (2) Holding ice may be used for the en route, holding, approach, landing, and go-around flight phases 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 validated 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. 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 pre-activation and normal IPS ice accretions 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. 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. Deicing boot manufacturer's analyses show that intercycle ice does exist with propeller deicing systems and their analyses do not account for ice runback. Propeller icing research (Paragraph 6.b., Reference 7) shows that propeller icing efficiency in icing conditions varies greatly with icing conditions and deicing system design. The research results support the assumption of a nominal thrust penalty shown in Figure 1.

(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 the value in Figure 1 to account for propeller runback ice and intercycle ice, unless data substantiates another amount. The applicant can assume there is zero efficiency loss at an airplane total temperature of 0 °C, and interpolate between this temperature and the -5°C static temperatures in Figure 1.

(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.

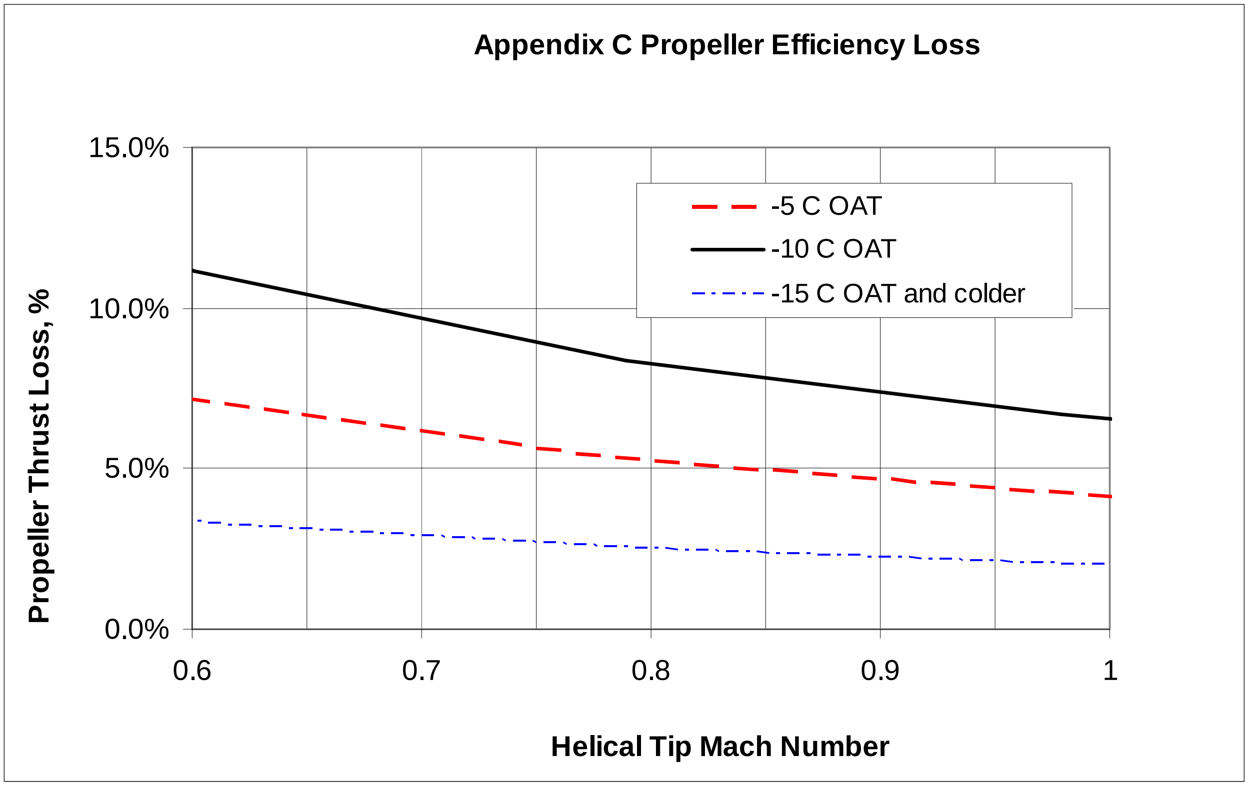

Figure 1 – Appendix C Propeller Thrust Loss

(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, normal IPS operation.	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	Equivalent to a 5-minute approach at critical conditions, normal IPS operation	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, IPS off Note: Optional. In lieu of natural ice accretion condition testing may be accomplished with simulated ice shapes	Optional	• Bank-to-bank rapid rolls, 30 degrees – 30 degrees at 1.2 V_{S1}; • Pull-up to 1.5g / pushover to 0.5g • Decelerate to stall warning plus one second (1 knot/sec. deceleration rate, wings level, power off) Recover using the AFM recommended stall recovery technique.
The following test only applies to airplanes in which IPS activation is based on visual cues and which pre-activation ice (and subsequent stall warning bias) is considered the critical ice accretion for normal IPS system operation, as defined in Table 2.			
Flaps up, gear up	Defined pre-activation ice, normal IPS operation	Optional	• Bank-to-bank rapid rolls, 30 degrees – 30 degrees at 1.2 V_{S1}; • 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 AC 20-73A and prior revisions of AC 23.1419-2E.

(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.

2. **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.

3. **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, the pushover maneuver can be accomplished to 0.5g rather than 0g, preceded with a pull-up to 1.5g. The criteria below in (ee) through (gg) apply to the pushover, and for the pull-up, the airplane must demonstrate suitable controllability and maneuverability throughout the maneuver, including recovery, with no tendency to diverge in pitch or other indications of a stalled tailplane.

(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 must 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 must demonstrate suitable controllability and maneuverability throughout the maneuver, including recovery, with no tendency to diverge in pitch or other indications of a stalled tailplane. It must be possible to recover from the pushover without exceeding a 50 lb. pull force.

(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.

(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. Section 23.1419(d) contains requirements for boot activation. See paragraph 15 of this AC for guidance. Deicing systems must have a mode that will automatically cycle the system, or alert the pilot to cycle the system, after activation, in accordance with § 23.1419(f).

g. Emergency and Abnormal Operating Conditions. Flight investigations should be conducted to verify that, after pilot recognition of emergency and abnormal operating conditions, the AFM procedures are effective, 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° – 30°; • 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° – 30°; • 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

If the autopilot is intended to be used with the ice shape configurations defined in table 5, the manufacturer should also show the airplane can be safely flown and landed with AFM procedures.

14. Super Cooled Large Drop (SLD) Conditions. Section 23.1420 requires that the airplane operate safely in the supercooled large droplet (SLD) icing conditions defined in part 25, Appendix O of this chapter.

a. Icing Envelopes. The conditions included in the part 25 Appendix C icing envelopes are unchanged by the addition of Appendix O. See AC20-73A and DOT/FAA/CT-88/8-1 "Aircraft Icing Handbook" for details on the Appendix C icing envelopes. Appendix O was developed to provide a representative icing environment for supercooled large drops (SLD), which are not included in Appendix C and which include freezing drizzle and freezing rain conditions. An FAA detailed report on the development of Appendix O is available from the FAA Technical Center (reference report DOT/FAA/AR-09/10, dated March 2009)

(1) Appendix O defines freezing drizzle and freezing rain environments by using four spectra of drop sizes with associated liquid water content (LWC) limits. Following are the four drop size spectra.

(a) Freezing drizzle with a median volume diameter (MVD) less than 40 microns. In addition to drizzle drops, which are defined as measuring 100 µm to 500 µm in diameter, this environment also contains smaller drops with diameters less than 100 µm.

(b) Freezing drizzle with a MVD greater than 40 microns. In addition to freezing drizzle drops, this environment also contains smaller drops, with diameters less than 100 µm.

(c) Freezing rain with a MVD less than 40 microns. In addition to freezing rain drops, which are defined as measuring more than 500 µm in diameter, this environment also contains smaller drops with diameters of less than 100 µm.

(d) Freezing rain with MVD greater than 40 microns. In addition to freezing rain drops, this environment also contains smaller drops with diameters of less than 100 µm.

(2) Use of Appendix C is not changed by the addition of Appendix O. Appendix O is designed to be similar to Appendix C and to be used in much the same manner. The principal differences between using Appendix O and using Appendix C are that for Appendix O, the applicant must now——

(a) Consider four icing conditions rather than two when determining critical icing conditions, and

(b) Address drop size distributions.

b. Section 23.1420 requires compliance with § 23.1420(a)(1), (a)(2), or (a)(3).

(1) § 23.1420(a)(1). When complying with § 23.1420(a)(1), the applicant must provide a method for detecting that the airplane is operating in Appendix O icing conditions. Following detection, the airplane must be capable of operating safely while exiting all icing conditions.

Certification for 23.1420(a)(1)) requires a means of alerting flightcrews when Appendix O conditions are encountered (§ 23.1420(a)(1)).

(2) § 23.1420(a)(2). If the applicant seeks certification for safe operation in portions of Appendix O conditions, such as freezing drizzle only, or during specific phases of flight, § 23.1420(a)(2) applies. If this option is chosen, following detection of conditions that exceed the selected portion of Appendix O, the airplane must be capable of operating safely while exiting all icing conditions. Certification for a portion of Appendix O (§ 23.1420(a)(2)) requires a means of alerting flightcrews when those portions of Appendix O are exceeded (§ 23.1420(a)(2)).

(a) Initial certification for flight in a portion of Appendix O conditions will likely include all of freezing drizzle or all of freezing rain. Certification for flight in a portion of Appendix O conditions depends upon the applicant substantiating an acceptable way for the flightcrew to distinguish the portion of Appendix O conditions for which the airplane is certified from the portion of Appendix O conditions for which the aircraft is not approved. A 2009 review of engineering tool capabilities found that current technology does not support distinguishing between freezing drizzle and freezing rain in flight. Therefore certification for a portion of Appendix O will be challenging and will require close coordination with certifying authorities. Certification for a portion of Appendix O allows latitude for certification with a range of techniques and technology that may be available in the future.

(b) However, initial certifications could be restricted to operation in Appendix O conditions by phase of flight. However, if certification is sought for takeoff/landing in freezing drizzle based solely on weather reporting provided by the airport, certification must also be done for freezing rain due to inaccuracies in current weather reports.

(3) § 23.1420(a)(3). Section 23.1420(a)(3) applies when the applicant seeks certification for all of the icing conditions described in Appendix O. An airplane certified to § 23.1420(a)(3) must be capable of safely operating throughout the conditions described in Appendix O and does not need a means to detect Appendix O conditions. In effect, when § 23.1420(a)(3) is chosen, the airplane is certificated for flight in icing without any specific airplane flight manual procedures or limitations to exit icing conditions.

c. Ice Accretions.

(1) Some Areas of interest for Appendix O. The following are some areas of interest specific to supercooled large droplet conditions:

(a) Ice shapes aft of protected areas of lifting surfaces. Appendix O icing conditions may result in a ridge of ice or ice roughness aft of the protected areas. On aircraft with reversible flight controls, a ridge of ice may cause uncommanded deflections of the control surfaces, which may result in an aircraft upset. Aircraft may also incur reduced maximum lift and stall at lower angles of attack, independent of the flight control system. Appendix O ice buildups can result in increases in stall speeds and potentially alter stall characteristics.

(b) Ice shapes on unprotected areas of lifting surfaces. Ice shapes resulting from Appendix O icing conditions can extend further aft on the airfoil than those from Appendix C icing conditions. When portions of the airfoil leading edge are unprotected, performance and handling qualities can potentially be affected.

(c) Ice shapes on unprotected airframe regions. Areas of the airframe which do not accrete ice under Appendix C conditions should be examined for impingement and accretion in Appendix O conditions. The applicant should evaluate such issues as visibility through the windshield, ice accretion on fuel vents, locations of air data sensors, and potential airflow disturbance (for example on the airplane nose) from Appendix O accretions that could influence performance of the air data sensors.

(d) Drag and power effects. Aircraft may exhibit reduced performance in Appendix C conditions because ice accretions cause increased drag and reduced lift. Such impacts can be increased in Appendix O conditions, since the accretions may extend further aft on protected areas, extend beyond protected areas, or occur in areas not typically protected (extended accretions on the fuselage and the lower wing surface, for example). Ice accretions may be rough and cause large local drag increases.

(e) Engine considerations. Ice accumulation on the airframe and on air induction system components resulting from Appendix O icing conditions should be analyzed for potential ingestion of ice by the engine (relative to requirements of § 23.1093) and potential blockage effects. See AC 23-16B.

(2) Airframe Ice Accretions.

(a) Pre-Detection Ice Accretion. This ice accretion, defined as pre-detection ice in 14 CFR 23, Appendix TBD, part II(b)(3), refers to the ice accretion existing at the time the flightcrew becomes aware that they are in Appendix O icing conditions and have taken action to begin exiting from all icing conditions. The time that the applicant should assume it will take to detect Appendix O icing conditions exceeding those for which the airplane is certified should be based on the means of detection. In general, we expect that the time to detect exceedance icing conditions may be significantly longer for a detection means relying on the flightcrew seeing and recognizing a visual icing cue than it is for an ice detection system that provides an attention-getting alert to the flightcrew.

1. Visual Cues. See paragraph 15.e.(3) of this AC for time to detect Appendix O conditions

2. System. For Appendix O ice detection systems and Aerodynamic Performance Monitors that comply with the reliability requirements of § 23.1309, pre-detection ice is the maximum time the system was demonstrated to detect Appendix O conditions. If only freezing drizzle conditions are demonstrated by test, the applicant would need to show by analysis and design that the detection time for freezing rain would be equal or smaller.,

(b) Aircraft Certified to Detect and Exit Appendix O Conditions (§ 23.1420(a)(1) or § 23.1420(a)(2). Use the ice accretions in Table 6, below, to evaluate compliance with the applicable subpart B requirements for operating safely after encountering Appendix O atmospheric icing conditions for which the airplane is not approved, and then safely exiting all icing conditions.

Table 6 Appendix O Detect and Exit Ice Accretion

Flight Phase/Condition -	**Appendix O Detect-and-Exit Ice Accretion** Part II , Paragraph (b) of Appendix TBD OF PART 23
Ground Roll	No accretion
Takeoff	No accretion[1]
Final Takeoff	No accretion[1]
En Route	No accretion
Holding	Exposure sequence: (1) Either Appendix C holding ice or Appendix O holding ice for which the airplane is approved, whichever is applicable, (2) Pre-detection ice, (3) Accretion from one standard cloud horizontal extent (17.4 nautical miles) in Appendix O conditions for which the airplane is not approved, followed by (4) Accretion from one standard cloud horizontal extent (17.4 nautical miles) in Appendix C continuous maximum icing conditions. The total time in icing conditions need not exceed 45 minutes. Appendix O conditions colder than -13°C are not required to be analyzed.

[1] Takeoff is not permitted when Appendix O conditions beyond those in which the airplane is certified to operate exist in the vicinity of the departure airport.

Flight Phase/Condition -	**Appendix O Detect-and-Exit Ice Accretion** Part II , Paragraph (b) of Appendix TBD OF PART 23
Approach	The more critical of holding detect-and-exit ice and the combination of: (1) Ice accreted during a descent in the cruise configuration from the maximum vertical extent of the Appendix C maximum continuous icing conditions or the Appendix O icing environment for which the airplane is approved, whichever is applicable, to 2,000 feet above the landing surface, where transition to the approach configuration is made, (2) Pre-detection ice, and (3) Ice accreted at 2,000 feet above the landing surface while transiting one standard cloud horizontal extent (17.4 nautical miles) in Appendix O conditions for which the airplane is not approved and one standard cloud horizontal extent (17.4 nautical miles) in Appendix C continuous maximum icing conditions. Appendix O conditions colder than -13°C are not required to be analyzed.
Landing	No accretion
Pre-activation Ice Accretion	No accretion[1]
Pre-detection Ice Accretion	Ice accreted on protected and unprotected surfaces during: • The time it takes to detect and identify Appendix O conditions (based on the method of detection) beyond those in which the airplane is certified to operate, and • The time it takes the flight crew to refer to and act on procedures, including coordinating with Air Traffic Control, to exit the icing conditions beyond those in which the airplane is certified to operate (minimum of two minutes).
Failures of the Ice Protection System	No accretion

(c) Aircraft Certified to a Portion or all of Appendix O Conditions (§ 23.1420(a)(2) or § 23.1420(a)(3) Use the ice accretions in Table 7, below, to evaluate compliance with the applicable subpart B requirements for operating safely in Appendix O atmospheric icing conditions for which the airplane is approved.

Table 7 - Appendix O Ice Accretion

Flight Phase/Condition -	**Appendix O Ice Accretion** Part II , Paragraph (c) of Appendix TBD OF PART 23
Ground Roll	No accretion if Type II, III or Type IV fluids are approved for the airplane.
Takeoff	Ice accretion occurring between lift-off and 400 feet above the takeoff surface assuming ice accretion starts at lift-off. No ice accretion prior to lift-off if Type II, III or Type IV fluids are approved for the airplane.
Final Takeoff	Ice accretion occurring between 400 ft and the height at which the transition to the en-route configuration and speed is completed, or 1500 ft above the take-off surface, whichever is higher, plus “Takeoff” ice accretion. No ice accretion prior to lift-off if Type II, III or Type IV fluids are approved for the airplane.
Climb	Ice accretion during the climb after takeoff. Ice accretion includes ice accreted during takeoff phase plus the most critical of climb through 6,000 feet in freezing drizzle, or climb through 3,500 feet in freezing rain.
En Route	Ice accreted during the en-route phase of flight.
Holding	Ice accreted during a hold with no reduction for horizontal cloud extent (i.e., the hold is conducted entirely within the 17.4 nautical mile standard cloud extent). A hold of 45 minutes should be considered for OAT at and above -13°C, and the time required to transit 17.4 nm should be considered below -13°C.
Approach	Most critical ice accretion of: (1) Ice accreted during a descent in the cruise configuration from the maximum vertical extent of the Appendix O icing environment to 2,000 feet above the landing surface, followed by transition to the approach configuration and maneuvering for 15 minutes at 2,000 feet above the landing surface; and (2) Holding ice (if the airplane is certified for holding in Appendix O conditions).

Flight Phase/Condition -	**Appendix O Ice Accretion** Part II , Paragraph (c) of Appendix TBD OF PART 23
Landing	Most critical ice accretion of: (1) Approach ice plus descent from 2,000 feet above the landing surface to 200 feet above the landing surface with a transition to the landing configuration, followed by a go-around maneuver in accordance with Airplane Flight manual procedures from 200 feet to 2,000 feet above the landing surface, holding for 15 minutes at 2,000 feet above the landing surface in the approved maximum flap holding configuration, and a descent to the landing surface in the landing configuration; and (2) Holding ice (if the airplane is certified for holding in Appendix O conditions).
Pre-activation Ice Accretion	Ice accreted during the time for the flightcrew to recognize icing conditions and activate the ice protection system, plus the time for the ice protection system to perform its intended function.
Pre-detection Ice Accretion	Ice accreted during the time for the flightcrew to detect Appendix O conditions, refer to and initiate procedures, and any time for systems to perform their intended functions (if applicable). Pre-detection ice need not be considered if there are no specific crew actions or systems changes associated with flight in Appendix O conditions.
Failures of the Ice Protection System	Same criteria as for Appendix C, but in Appendix O conditions.

(d) Shape and Texture of Simulated Ice. Ice shapes for Subpart B of part 25 testing are typically based upon icing tunnel tests or CFD computations or both. Current CFD programs do not provide roughness information. Roughness levels and aft extent of roughness for Appendix O ice shapes should be determined from icing tunnels or tanker testing, if the capabilities exist. Characteristics of roughness, such as particle density and height of roughness elements, may be critical and should be simulated on the flight test airplane. However, when the empirical capabilities do not exist, the roughness levels (or equivalents) as defined in **Table 8**, below, may be used for Appendix O ice accretions.

Table 8 Appendix O Ice Accretion Roughness

<table>
<tr><th>Ice Type</th><th>Roughness Height (mm)</th><th>Percent of Surface Covered</th><th>Notes</th></tr>
<tr><td>FZRA or FZDZ, thin accretions; thickness < 3mm (0.12 inch)</td><td>1.5 to 2 mm (0.06 to 0.08 inch)
or
16 to 20 grit sandpaper</td><td rowspan="4">Particle density to cover 50% to 70% of total area</td><td>Use to simulate pre-detection, initial accretions, or roughness on computed ice shapes</td></tr>
<tr><td>FZDZ thickness > 3 mm (0.12 inch)</td><td rowspan="2">3 to 6 mm (0.12 to 0.24 inch) Mean particle size ~4.5mm</td><td rowspan="3">Intercycle, residual, unprotected surfaces</td></tr>
<tr><td>FZRA thickness ≥ 3 mm (0.12 inch) and ≤ 6 mm (0.24 inch)</td></tr>
<tr><td>FZRA thickness > 6 mm (0.24 inch)</td><td>6 to 8 mm (0.24 to 0.31 inch)
Mean particle size ~7 mm</td></tr>
<tr><td colspan="4">Notes:
1. The simulated roughness elements should approximate roughness elements observed in icing tunnels or natural icing. Smooth and spherical elements should not be used because they may result in non-conservative aerodynamic results.
2. For computed ice shapes, the roughness simulation should be extended aft to the limits of predicted accretion (where the ice accretion thickness is calculated as 0.015").</td></tr>
</table>

(d) **Ice Adhesion Inhibitors.** The guidance for part 25, Appendix C icing conditions apply to part 25, Appendix O icing conditions.

(e) **Number of ice shapes for dry air flight testing**.

1. The ice accretion(s) used to show compliance should consider the speeds, configurations (including configuration changes), angles of attack, power or thrust settings, etc. for the flight phases and icing conditions that they are intended to cover.

2. The ice accretion(s) used to show compliance should consider the entire Appendix O envelopes, including temperatures near freezing where runback may accrete behind mechanical ice protection systems.

3. In determination of critical ice shapes for flight testing of Appendix O ice shapes, the following should be considered:

- The critical freezing drizzle ice shape

- The critical freezing rain ice shape.

4. Any of the applicable ice accretions (or a composite accretion representing a combination of accretions) may be used to show compliance with a particular Subpart B requirement if that accretion is either the ice accretion identified in the requirement or is shown to be more conservative than the ice accretion identified in the requirement.

5. The ice accretion that has the most adverse effect on stall angle of attack and handling characteristics may be used for compliance with the airplane performance requirements if any difference in performance is conservatively taken into account.

6. An Appendix O ice shape may be used in lieu of Appendix C ice shape to show compliance if it can be shown to be more critical.

7. The number of shapes may be reduced based on similarity to an airplane in which flight test data shows the critical ice shape configuration(s).

(3) Propeller Icing. 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. Propeller icing research (Paragraph 6.b., Reference 7) was able to duplicate this ice accretion and supports the propeller efficiency losses in Figure 2 in part 25, Appendix O icing conditions.

(a) Propeller efficiency loss should be the value in Figure 2 to account for propeller runback ice and intercycle ice, unless data substantiates another amount. The applicant can assume there is zero efficiency loss at an airplane total temperature of 0 °C, and interpolate between this temperature and the static temperatures in Figure 2.

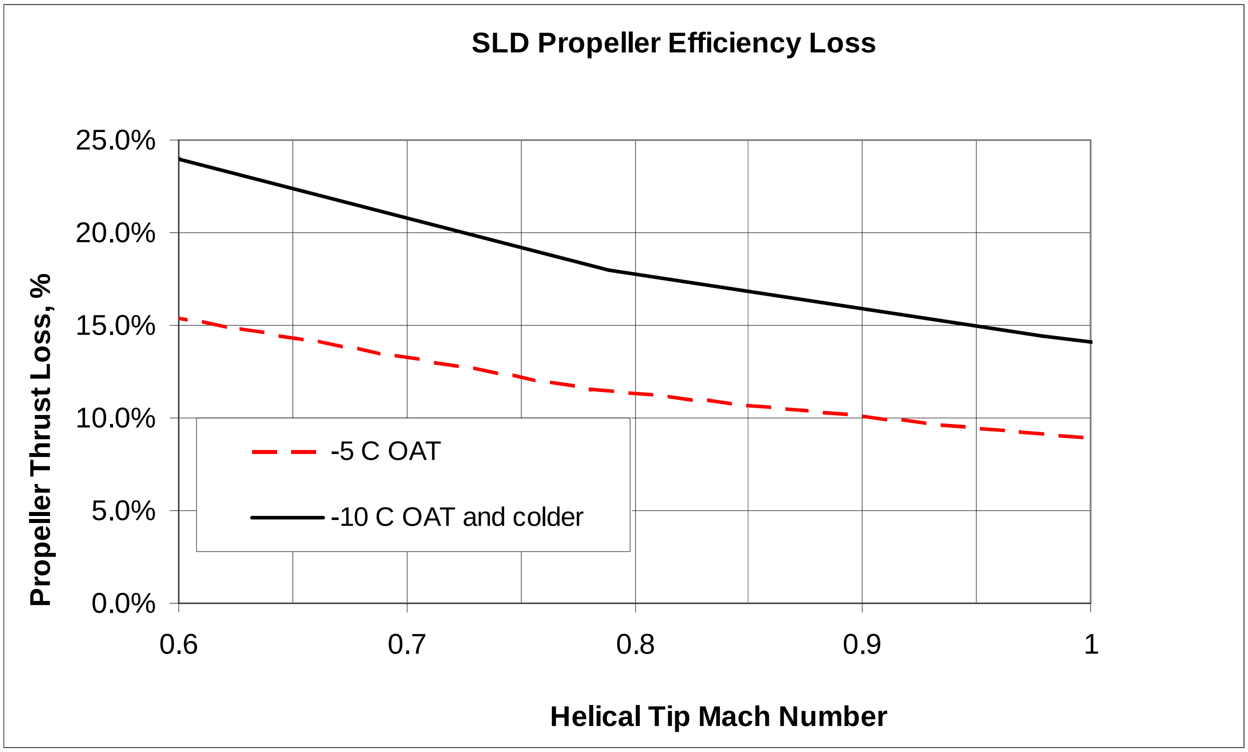

Figure 2 - SLD Propeller Thurst Loss

(b) Testing, analyses or similarity should be conducted to verify the deice system minimizes intercycle and runback-ice accretions.

d. Engineering Tools. Appendix 7 of this AC provides guidance on the use of tools based on their state of development in 2009.

e. Subpart B Requirements. Section 23.21 (c) defines the Subpart B regulations that the airplane must be shown to be compliant with critical SLD ice shapes.

(1) Detect and Exit SLD Conditions. Appendix 8 contains an example flight test program to show compliance to 23.21(c)(2).

(2) Certification to all of Appendix O. The same regulations required for Appendix C ice accretion, with the addition of § 23.67(c)(1), are required for critical SLD conditions for which the airplane is to be certified. The guidance in Appendix 6 is applicable with the critical ice accretions in Appendix O for which the airplane is certified.

(3) Certification to a portion of Appendix O. The following provides guidance to an applicant who chooses to approve their airplane for two specific phases of flight, takeoff and landing.

(a) Takeoff. Appendix 9 contains an example flight test program for an applicant who chooses to approve their airplane for operation in Appendix O for takeoff.

(b) Landing. The critical ice accretions for showing compliance with applicable Subpart B regulations should consider the approach and landing phases.

f. Natural Icing Flight Tests. Section 25.1420(a) requires that the airplane operate safely in the SLD icing conditions defined in Part 25, Appendix O.

(1) Flight testing in measured, natural Appendix O icing conditions should be accomplished for:

(a) Airplanes certified for unrestricted flight in Appendix O or a portion of Appendix O conditions should be flight tested in natural Appendix O icing conditions for each phase of flight for which approval is sought (i.e., compliance with § 23.1420(a)(3) or § 23.1420(a)(2), or

(b) Airplane derivatives whose ancestor airplanes have a service record that includes a pattern of accidents or incidents due to inflight encounters with Appendix O conditions.

(c) For certification to 23.1420(a)(3), flight test encounters should include at least one freezing drizzle and one freezing rain encounter.

(2) For airplanes certificated to detect Appendix O icing conditions and safely exit all icing conditions, flight testing in measured, natural Appendix O conditions should not be required to show compliance to § 23.1420(a)(1) if:

(a) Design analyses show that the critical ice protection design points (i.e., heat loads) are adequate under the conditions of Appendix O and various airplane operational configurations;

1. Certain angle of attack/stall warning sensors, such as wing mounted vane type, are empirically tested

(b) For the Appendix O distributions where the capability exists, icing tunnel tests or icing tanker tests, and analytical codes are used to determine critical ice shapes on lifting surfaces.

1. The simulated, critical ice shapes are flight tested to show compliance with applicable Subpart B regulations.

(c) Appendix O detection method(s) are certified as described in section 15 of this advisory circular.

(d) Subsequent designs may be able to use similarity to past certifications.

15. Ice and Exceedance Icing Conditions Detection. Sections 23.1419(e) specifies requirements regarding activation of the IPS. These requirements are only applicable to Appendix C icing conditions. Section 23.1420(c) requires compliance with § 23.1419(e),(f) and (g) for the selected portion or all of Appendix O as applicable. Sections 23.1420 (a)(1) and (a)(2), respectively, require a means to alert the flightcrew that they are in Appendix O icing conditions or have reached Appendix O icing conditions from which they must exit.

a. **Compliance with § 23.1419(d).** This section of the rule requires either a primary ice detection system, substantiated visual cues and an advisory ice detection system, or AFM procedures to activate the IPS based on visible moisture and temperature. A fourth option of AFM procedures based on visual cues is available for airplanes in the normal, acrobatic and utility category,

(1) Primary ice detection system. A primary ice detector must either alert the flightcrew to operate the IPS using AFM procedures or automatically activate the IPS before an unsafe accumulation of ice on the airframe, engine components, or engine air inlets occurs. The primary ice detection system must perform its intended function for the airplane configurations, phases of flight, and within icing envelopes of Appendix C and Appendix O. Laboratory tests should demonstrate the ice detector's ability to function properly within all of the required icing conditions and airplane operating envelope. If the ice detector cannot detect ice at low freezing fractions and ice accretes on the airplane in such icing conditions, the applicant should show that the airplane can be operated safely with the ice accretions. If safe operation cannot be substantiated, installation of an icing conditions detector may be required. Approval of the primary ice detector should include flight tests in measured natural icing conditions to verify analyses and laboratory test results, as well as to verify that the ice detector system performs its intended function. The primary automatic ice detection system should be designed to prevent continuous cycling of engine thrust in intermittent icing conditions.

(2) Advisory ice detection system. The advisory ice detector, in conjunction with a primary cue, such as visible ice accretion on referenced or monitored surfaces, should advise the flightcrew to initiate operation of the IPS using AFM procedures. An advisory system is not the prime means used to determine if the IPS should be activated. The AFM must state the flight crew has primary responsibility for detecting icing conditions or ice accretions. Analyses and tests similar to those performed for a primary ice detector should be performed for an advisory ice detector to understand its characteristics, limitations, and installation.

(3) Certification of an ice detection system

(a) Certification plan. The applicant should present an icing certification plan to the cognizant aircraft certification office. This plan should include the method selected for demonstrating the ice detector system's compliance with §§ 23.1301, 23.1309, 23.1419, 23.1420, and all other applicable sections. Advisory Circular 20-73 A, Appendix K, provides guidance on certification of ice detector systems. That appendix provides guidance regarding ice detection response times as the freezing fraction drops below 1. That guidance is equally applicable to advisory and primary ice detection systems.

(b) Performance of the ice detector system when installed. In addition to the guidance in Advisory Circular 20-73 A, Appendix K, the following guidance applies.

1. The applicant should conduct flow field and boundary-layer analyses of candidate installation positions to ensure that the ice detector sensor is not shielded from impinging Appendix C and Appendix O water drops.

2. The ice detection system should be shown to operate in the range of conditions defined by Appendix C and the applicable portion of Appendix O. Sections 23.1419 and 23.1420 also require a combination of tests and analysis to demonstrate performance of the ice detector and the system as installed on the airplane. This could include icing tunnel and icing tanker tests to evaluate ice detector performance. The applicant may use droplet impingement analysis to determine that the ice detector functions properly over the droplet range of Appendix C and the applicable portions of Appendix O when validated through natural or artificial icing tests (e.g. tanker, icing tunnel).

3. The applicant should demonstrate that the airplane can be safely operated with the ice accretions formed at the time the ice protection system becomes effective, following activation by the ice detector. This includes low freezing fraction conditions. If an applicant provides a temperature vs. response time plot for an ice detector and demonstrates that no ice accretes on flight surfaces at temperatures where the response time is greater than 60 seconds then a 60 second pre-activation ice encounter may be used in developing the pre-activation ice shape.

4. 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 ice detection system to detect these conditions.

5. The detector and its installation should minimize nuisance warnings.

6. SAE AS5498 "Minimum Operational Performance Specification for Inflight Icing Detection Systems" provides a standard and qualification considerations for inflight ice detection systems.

(c) Ice detector system safety considerations. The unannunciated failure of a primary ice detection system is assumed to be a catastrophic failure condition, unless characteristics of the airplane in icing conditions without activation of the airframe ice protection system(s) are demonstrated to result in a less severe hazard category. Ice detector reliability, hardware and software criticality requirements, for both primary and advisory systems, shall be consistent with the hazard classification for ice detectors resulting from a 1309 hazard analysis. If visual cues are the primary means of ice detection, the pilots retain responsibility to monitor and detect ice accretions when an advisory ice detection system is installed. However, the natural tendency of flightcrews to become accustomed to using the advisory ice detection system elevates the importance of the detector and increases the need to make flightcrews aware of an advisory ice detection system failure. Therefore, an undetected failure of the advisory ice detector should be considered a major hazard.

(4) **Visual cues.** Visual cues can either be direct observation of ice accretions on the airplane's protected surfaces or observation of ice accretions on reference surfaces.

(a) The first indications of any of the following are examples of what could be used as visual cues.

1. Accretions forming on the windshield wiper posts (bolt or blade).

2. Accretions forming on propeller spinners.

3. Accretions forming on an ice evidence probe.

4. Accretions on the protected surfaces.

(b) If accretions on protected surfaces cannot be observed, a reference system would be necessary if compliance with § 23.1419(d)(2) or (d)(4) is desired. The applicant should consider providing a reference surface that can be periodically de-iced to allow the flightcrew to determine if the airframe is continuing to accumulate ice. Without a means to deice the reference surface, compliance with § 23.1419(d)(2) or (d)(4) would require operation of the IPS as long are there is ice on the reference surface, even when additional ice is not accumulating.

(c) Field of view. Visual cues should be developed with the following considerations.

1. Visual cues should be within the flightcrew's vision scan area while seated and performing their normal duties at various airplane attitudes.

2. Visual cues should be visible during all modes of operation (day, night, and in cloud).

(d) Verification. During the certification process, the applicant should verify the ability of the crew to observe visual cues or reference surfaces. The visual cues should be evaluated from the most adverse flightcrew seat locations in combination with the range of flightcrew heights, if available. For a single pilot airplane, the visual cue must be visible from the pilot seat. For airplanes certified with two flightcrew, a visual cue should be provided for both the left and right seats. Consideration should be given to the difficulty of observing clear ice, or accretions on painted surfaces, or the differentiating between characteristics and size of ice that should not require special knowledge or skills. The adequacy of the detection method should be evaluated in all expected flight conditions. The applicant can carry out night evaluations with simulated accretions to assess visibility in and out of cloud. Methods used to substantiate visual cues should be agreed to with appropriate certification authorities..

(e) Airplane Flight Manual (AFM). The limitations section of the AFM must specify that the IPS must be operated when ice accretion is detected anywhere on the airplane and also must describe the visual cues verified in certification.

(5) Temperature cue. The temperature cue used in combination with visible moisture should consider static temperature variations due to local pressure variations on the airframe. If the engine and airframe IPS are both activated based on visible moisture and temperature, a common conservative temperature for operation of both systems should be used. For example, if the engine IPS is activated at +5ºC static air temperature or less, the airframe IPS should be activated at the same temperature, even if it is substantiated that the airframe will not accrete ice above +2ºC static air temperature. This would ease the flightcrew workload and increase the probability of procedural compliance.

(a) If this provision is used, the flightcrew should be able to easily determine the static air temperature. A display of static air temperature or a placard can be provided showing corrections for temperature vs. air speed to the nearest degree Centigrade in the region of interest (that is, around 0ºC).

(b) Airplane Flight Manual (AFM). The limitations section of the AFM should identify the specific static or total air temperature and visible moisture conditions that must be considered conditions conducive to airframe icing and should specify that the IPS must be operated when these conditions are encountered.

b. Compliance With § 23.1419(e). This paragraph of § 23.1419 states that requirements of §§ 23.1419(d) are applicable to all phases of flight unless it can be shown that the IPS need not be operated. To substantiate that the IPS need not be operated during certain phases of flight, the applicant should consider ice accretions that form during these phases and establish that the airplane is able to safely operate in the continuous maximum and intermittent maximum icing conditions of Appendix C and the applicable portions of Appendix O.

c. Compliance With § 23.1419(f).

(1) This paragraph of § 23.1419 requires that after the initial activation of the IPS—

(a) The IPS must operate continuously, or

(b) The airplane must be equipped with a system that automatically cycles the IPS, or

(c) An ice detection system must be provided to alert the flightcrew each time the IPS must be cycled.

(2) Some examples of systems that automatically cycle the IPS are—

(a) A system that senses ice accretion on a detector and correlates it to ice accretion on a protected surface. This system then cycles the IPS at a predetermined condition.

(b) A system that cycles the IPS based on the use of a timer. It should be substantiated that the airplane can safely operate with ice accretions that form between the time one deicing cycle is completed and the next cycle is initiated. If more than one cycling time (a choice of 1- or 3-minute intervals for example) is provided, it should be substantiated that the flightcrew is able to determine which cycle time is appropriate.

(c) A system that directly senses the ice thickness on a protected surface and cycles the IPS.

(d) A common attribute of the above systems is that the pilot is not required to manually cycle the IPS after initial activation.

(3) Some types of ice detection systems that alert the flightcrew each time the IPS must be cycled could be the same as the automatic systems discussed above, except that the system alerts the crew each time the IPS must be manually cycled. Flightcrew workload associated with such a system should be evaluated. Because of flightcrew workload and human factors considerations, a timed system without an ice sensing capability should not be used to meet this requirement. The ice shedding effectiveness of the selected means for cycling the ice protection system should be evaluated during testing in natural icing conditions.

d. Compliance With § 23.1403. Compliance with §23.1403 applies to aircraft certified for flight into icing conditions. The requirement is intended to address any visual ice accumulation requirements such as activating ice protection systems (§23.1419) or determining whether an exit from severe icing conditions (§23.1420(a)(1) or (a)(2)) is required. If the aircraft operating procedures do not depend on crew observation of ice accretions, an icing inspection light may not be required. An example of this would be installation of a primary ice detection system for activating ice protection system, rather than visual observation of icing. When considering whether visual cues are necessary, both AFM normal and abnormal procedures should be considered. Handheld flashlights are not an acceptable means of compliance.

e. Compliance with § 23.1420(a)(1) or (a)(2). These paragraphs of § 23.1420 require that a means be provided to allow the flightcrew to detect when Appendix O conditions are encountered or when the selected portion of Appendix O conditions is exceeded. Means for determining when the selected portion of Appendix O icing conditions is exceeded may include visual means, ice detectors, or an airplane performance monitor.

(1) Ice detectors. An ice detector system installed for compliance with § 23.1420(a)(1) or (a)(2) is meant to determine when conditions have reached the boundary of the Appendix O icing conditions in which the airplane has been demonstrated to operate safely. The applicant should accomplish a droplet impingement analysis and/or tests to ensure that the ice detector is properly located to function during the aircraft operational conditions and in Appendix O icing conditions. The applicant may use analysis to determine that the ice detector is located properly for functioning throughout the droplet range of Appendix O conditions when validated with methods described in SAE ARP 5903. The applicant should ensure that the system minimizes nuisance warnings when operating in icing conditions.

(a) The low probability of finding conditions conducive to Appendix O ice accumulation may make natural icing flight tests a difficult means of demonstrating that the system functions in conditions exceeding Appendix C. The applicant may use flight tests of the airplane under simulated icing conditions (icing tanker). The applicant may also use icing wind tunnel tests of a representative airfoil section and ice detector to demonstrate proper functioning of the system and to correlate signals provided by the detectors with the actual ice accretion on the surface.

(2) Aerodynamic performance monitor (APM). A crew alerting system using pressure probes and signal processors could be developed for quantifying pressure fluctuations in the flow field from contamination over the wing surface. This technology does exist, but full development is necessary before incorporating it into the crew warning system.

(3) Visual Cues. Visual cues can range from direct observation of ice accretions aft of the airplane's protected surfaces to observation of ice accretions on reference surfaces. Responding to a cue should not require the flightcrew to judge the ice to be a specific thickness or size. Examples of visual cues are—

- Accretions forming on side windshields,
- Accretions forming on sides of nacelles,
- Accretions forming on propeller spinners aft of a reference point,
- Accretions forming on radomes aft of a reference point, and/or
- Accretions forming aft of protected surfaces.

(a) Verification. See guidance for Appendix C conditions in paragraph 15.a.(4).

(b) Time to detect conditions outside Appendix C. The amount of ice needed for reliable identification is a function of the distinguishing characteristics of the ice (for example, size, shape, contrast compared to the surface feature that it is adhered to), the distance from the pilots (for example, windshield vs. engine vs. wingtip), and the relative viewing angle (location with respect to the pilots' primary fields of view). In the absence of specific studies or tests validating visual detection times, the following times should be used for visual detection of exceedance icing conditions following accumulation of enough ice to be reliably identified by either pilot in all atmospheric and lighting conditions:

1. For a visual reference located on or immediately outside a cockpit window (for example, ice accretions on side windows, windshield wipers, or icing probe near the windows) – 3 minutes.

2. For a visual reference located on a wing, wing mounted engine, or wing tip – 5 minutes.

(c) Validation. Visual cues should be validated by two of the following methods, analysis, icing wind tunnel tests, measured natural icing tests, or icing tanker ~~t~~ tests. In the unique case of using two methods to validate visual cues on the windows of the cockpit, a combination of appendix C natural icing encounters validating 3D ice accretion or impingement analysis will satisfy the two method approach described above. The cues should consider the drop distributions of Appendix O, to establish that these cues would be appropriate in the restricted Appendix O icing conditions. If a reference surface is used, the applicant should validate that it correlates with ice accumulation on the critical surfaces.

1. Icing Tunnel Tests. Icing tunnel tests should be used for surfaces that are practical to test, such as aft of protected area of wing leading edge.

2. Hybrid airfoil models are often used in icing wind tunnels to match the flow and impingement characteristics of the leading edge of the airfoil. Models designed for testing over a wide range of AOAs may have limited fidelity in aft impingement regions of the airfoil (10% or 20% x/c). As such, models designed for a specific operating conditions may be used to confirm the CFD predictions of drop impingement for visual cues, and the CFD codes can then be used to further validate over a wider range of operating conditions

3. Surfaces that are impractical to test in an icing tunnel. Except for validation of visually-based detect and exit cues of 14 CRF Part 25 Appendix O conditions, an acceptable method would be to compare the analytical results of impingement calculations (CFD) against observed impingement limits in Appendix C conditions. If the comparison provides sufficient correlation, it may be acceptable to use the CFD code to extend the results to predict the observation of larger drops required to detect and exit the Appendix O conditions for geometries where icing tunnel testing would be impractical, such as side windows. This would provide the comparison of two methods as discussed above.

4. Natural Appendix O Flight Test. If a manufacture is using natural icing as a method of validating cues, the instrumentation should be appropriate for the conditions (e.g. if validating for large drops, the instrumentation should be capable of measuring large drops).

16. Ice Shedding. Ice shed from forward airplane structure and components 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.

Current 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, dedicated flight tests points should be conducted to evaluate ice shedding trajectories and damage to the airplane. 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, and then flown into warmer temperatures to facilitate shedding. Flight test evaluation should also account for the critical, predicted trajectories in terms of normal operational angle of attack and sideslip. Trajectory and impingement analysis may be used to predict the critical trajectories and minimize the total number of test points required. One test point for each critical trajectory should be sufficient if the original ice accretion, shed trajectory, and any resultant damage is adequately documented. 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.

If flight tests are not conducted, an impact damage analysis should consider the worst-case ice shed event. The impact damage analysis may take conservative credit for the ice breaking up or shedding in pieces during the shedding event. Ice slabs consistent with those defined in AC20-147A (draft) have been found to typically break up during engine ingestion events, and therefore the applicant's analysis can assume slab-shaped ice sheds to break up to ½ of the original slab length. Ice that is not slab-shaped (e.g. double-horn shapes or radome "caps") should not be assumed to break up during the shed event, however credit may be taken for smaller, thinner pieces (e.g. rivulets, nodules, feathers, small horns, etc.) shedding off the core ice shape prior to the shed event. The applicant may use different break up criteria if it can be substantiated with test data.

17. Autopilot. The accumulation of ice on the airplane wings and airframe can have an effect on airplane characteristics and autopilot performance. Autopilot operations may mask the onset of an icing condition/configuration that would present the pilot with handling difficulties when resuming manual aircraft control, particularly following any automatic disengagement of the autopilot.

In general, it is not necessary to conduct an autopilot evaluation that encompasses all weights, center of gravity positions (including lateral asymmetry), altitudes, and deceleration device configurations. However, if the autopilot performance with ice accretion shows a significant difference from the non–contaminated airplane or testing indicates marginal performance, additional tests may be necessary.

The proposed tests herein will approve autopilot operation in the icing conditions. A test program should assess the potential vulnerability on autopilot to icing conditions by evaluating autopilot performance during artificial ice shape tests and during natural icing tests. These tests will evaluate autopilot performance, autopilot low speed characteristics, and adequacy of autopilot alerts to warn the pilot of degrading aircraft handling qualities. Critical ice shapes must be chosen with the particular test purpose in mind. Tests might have to be performed with multiple configurations of ice shapes which address possible handling qualities/performance and/or control surface hinge moment issues. The applicant will need to discuss this topic with the administrator prior to final approval. If necessary, appropriate limitations and procedures should be established and presented in the AFM.

a. Natural Icing Conditions Tests:

(1) All autopilot modes should be evaluated in Appendix C 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.

(2) In case flight in any portion of Appendix O will be approved with autopilot engaged, flight test evaluations of autopilot modes as for appendix C should be conducted. For SLD detect and exit approval, only artificial ice shapes tests should be accomplished.

(3) De-icing. If the airplane is configured with a de-icing system, the autopilot should demonstrate satisfactory performance during the shedding of ice from the airplane. This can be demonstrated during autopilot evaluations in natural Appendix C icing conditions.

b. Ice Shapes Tests. The following represents an acceptable test program for qualification of the autopilot in Appendix C and applicable Appendix O in addition to the tests in natural icing conditions:

Note: The autopilot should be evaluated during the course of the certification program with ice shapes. Appendix O ice shapes may degrade the performance of the flight guidance system, but should be safe for operation**.**

Table 9 Autopilot Test Conditions

Configuration	*Speed*
High lift devices retracted/gear up configuration:	• Min speed in icing. • VMO/VNE or 250 KIAS, whichever is less or a speed at which it is demonstrated that the airframe will be free of ice accretion
All approved approach configurations	• VREF speed in icing

(1) Autopilot Turns - In the configurations and speeds listed in Table 9, with critical ice shapes from appendix C and applicable appendix O (detect and exit and approved portions), conduct the following maneuver: autopilot maximum angle of bank turn in one direction and

then rapid reversal of angle of bank in the other direction. Autopilot should smoothly roll into and out of turns without large overshoots in bank angle or during roll out on headings.

(2) Approach - If the autopilot has the ability to fly a coupled instrument approach and/or go-around, conduct the following maneuvers per AFM procedures with the airplane configured as in item (1) above and:

1. Coupled approach using all normal flap selections.
2. Go-around using all normal flap selections.
3. Glideslope capture from above the glidepath, if applicable.

(3) Low Speed Characteristics. Low speed 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.

(a) Critical ice shapes from appendix C and applicable appendix O (detect and exit and approved portions).
(b) Most adverse weight and center of gravity position, symmetric fuel loading.
(c) Autopilot servos set to minimum torque/authority.
(d) In the configurations listed in Table 10, trim at the specified speeds and conduct the following maneuvers:

1. Set the autopilot in altitude hold, reduce power/thrust to establish a 1 to 2 kt/sec deceleration rate, until stall warning;
2. Pilot recovery should be initiated 1 second after stall warning.
3. For aircraft that have autopilots that do not have the capability to disconnect at stall warning, or autopilots with low airspeed protection, AFM procedures for autopilot should be followed (e.g., manual disconnect at stall warning).
4. Recovery should be evaluated by applying manufacturers recommended procedures.
5. Evaluate the aircraft response, need for directional/lateral control, airspeed increase, and altitude loss (assuming autopilot will disconnect as designed at stall warning). During the recovery, verify that no hazardous flight conditions develop.

Table 10 Autopilot Low Airspeed Tests

Aircraft Configuration	*Initial Test Speed*	*Maneuver*
High lift devices retracted/gear up configuration:	• Min holding speed in icing	• Straight • Turning (maximum autopilot bank turns.)
Highest lift landing configuration approved in icing conditions/gear down:	• VREF speed in icing	• Straight • Turning (maximum autopilot bank turns.)

(4) Autopilot Indications. If the autopilot is holding a sustained lateral control command, it could be indicative of an unusual operating condition for which the autopilot is compensating. Examples of such unusual operating conditions are asymmetric lift and/or drag due to asymmetric icing, fuel imbalance, or asymmetric thrust. In the worst case, the autopilot may be operating at or near its full authority in one direction. If the autopilot were to disengage while holding this lateral trim, the result would be that the airplane could undergo a rolling moment that could possibly take the pilot by surprise. Therefore, an indication will be required to permit the crew to manually disengage the autopilot and take control prior to any automatic autopilot disengagement. Unusual control position or bank angle may be shown to be an acceptable indication.

18. 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. Section 23.1581 states that an airplane flight manual (AFM) must be furnished with each airplane and must contain information necessary for safe operation because of design, operating, or handling characteristics.

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 not approved

(a) If compliance to § 23.1419 not shown, "Flight Into Known Icing Conditions is Prohibited."

(b) If compliance to § 23.1420(a)(2) or (a)(3) not shown, "Flight in Freezing Drizzle, Freezing Rain, or Severe Icing Conditions Prohibited. "

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

b. AFM Limitations Section. Section 23.1583 states the AFM must contain operating limitations determined under part 23. The AFM should provide the pilot with the information needed to operate the ice protection system while in icing conditions or prior to encountering icing conditions. 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." Information should also include:

(1) Icing Conditions. For airplanes with a certification basis that includes § 23.1419 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." Any airplane manufactured after 1973 that does not have § 23.1419 amendment 23-14 or higher in the certification basis must have a statement "This airplane is prohibited from flight into known icing conditions."

(2) Airspeed

(a) Minimum airspeed limitations for each configuration approved for icing conditions.
(b) Maximum airspeed limitation (if any)

(2) Flap. 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). These limitations should reflect the configurations used to determine critical ice accretions for certification.

(3) Autopilot. If an autopilot is installed and approved for flight in non-icing conditions, or required in non-icing flight for compliance to § 23.1523, it will be required for flight in icing conditions based on operational requirements. Similarly, if an autopilot equipped airplane is approved for any portion or phase of flight in Appendix O conditions, the autopilot will be required to operate in those Appendix O conditions.

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

1. Mistrim indication or autopilot alert prior to disconnect
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.

(b) If an autopilot was not shown to operate safely in Appendix O conditions in accordance with Section 17 of this AC or an applicant chooses to prohibit autopilot use in Appendix O conditions, autopilot operation should be prohibited if any of the following conditions in icing flight are experienced:

1. Severe icing;
2. Freezing drizzle or freezing rain

(4) Performance. 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.

(5) Takeoff.

(a) Clean Wing Concept. 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." Add any additional surfaces deemed critical.

(b) Pre-Takeoff Contamination Check for Turbojet Powered Airplanes

1. Turbojet airplanes without wing leading edge high lift devices. The AFM Limitations section should also require a pre-takeoff visual and tactile inspection of the wing leading edge and upper surface in ground icing conditions. 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), and one of the following conditions:

(aa) 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 with engines mounted behind wing. The manufacturer should either show one of the three:

(aa) Show that undetected ice accumulation does not occur on the wing upper surface due to cold soaked fuel (which may be accomplished by analysis of fuel system geometry); 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 and 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.

(6) Appendix O Conditions.

(a) If compliance is based on §§ 23.1420(a)(1) or 23.1420(a)(2), the Limitations section must include a requirement that the flightcrew exit all (Appendix O and C) icing conditions immediately upon recognition that the Appendix O icing conditions exceed the certification boundary. Example language is provided below:

"Severe icing may result from environmental conditions outside of those for which the airplane is certified. Intentional flight into severe icing conditions may result in 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 when using the ice protection systems, and may seriously degrade the performance and controllability of the airplane.

Operations in icing conditions were evaluated as part of the certification process for this airplane. Freezing drizzle and freezing rain conditions were not evaluated and are considered severe icing conditions for this airplane.

Intentional flight, including takeoff and landing, into freezing drizzle, freezing rain or other severe icing conditions is prohibited. A flight delay or diversion to an alternate airport is required if these conditions exist at the departure or destination airports. {Applicant should insert visual cue description here} is an indication of severe icing conditions that exceed those for which the airplane is certified. If severe icing, freezing drizzle, or freezing rain is encountered, immediately request priority handling or declare an emergency from air traffic control to facilitate a route, altitude change, diversion or immediate approach and landing as required to exit all icing conditions. Stay clear of all icing conditions for the remainder of the flight, including landing, unless it can be determined that ice accretions no longer remain on the airframe."

(b) For certification of detection and exit of Appendix O in accordance with § 23.1420(a)(1) and §23.1420(a)(2) the Limitations section should contain appropriate limits that consider the certification assumptions with respect to portion (phase of flight, freezing drizzle, freezing rain, etc.) Example language for an airplane approved to takeoff and land in Appendix O is below:

""Severe icing may result from environmental conditions outside of those for which the airplane is certified. Intentional flight into severe icing conditions may result in 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 when using the ice protection systems, and may seriously degrade the performance and controllability of the airplane.

Operations in icing conditions were evaluated as part of the certification process for this airplane. Freezing drizzle and freezing rain conditions were not evaluated in any phase of flight except takeoff and landing.

Except for takeoff and landing, intentional flight into freezing drizzle or freezing rain conditions is prohibited. If freezing drizzle or freezing rain conditions are encountered during a hold (in any airplane configuration) or in the en route phase of flight (climb, cruise, or descent with high lift devices and gear retracted), or if {Applicant should insert cue description here}, immediately request priority handling or declare an emergency from air traffic control to facilitate a route or altitude change to exit all icing conditions. Stay clear of all icing conditions for the remainder of the flight, including landing, unless it can be determined that ice accretions no longer remain on the airframe."

(c) The Limitations section must contain specific detection criteria – visual cues, specific to the aircraft that indicate flight is in appendix O icing conditions for which it is not approved.

(7) Equipment Limitations.

(a) The Limitations section must contain the conditions for which all ice protection equipment must be activated.

1. Section 23.1419 (e) requires one of three options. If compliance to 23.1419(e)(2) is elected, the AFM should state that the IPS be activated at the first sign of ice accretion anywhere on the airplane. The procedures section can direct the pilot to look at specific location on the airplane.

2. If an Advisory Ice Detection system is installed, the AFM must state that the pilot is responsible for detection of ice accretion, however AFM may state that ice protection must be activated "at first sign of ice accretion or ice detection annunciation, whichever occurs first."

(b) 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).

(c) All icing inspection lights must be operative before flight into known or forecast icing conditions at night. The Master Minimum Equipment List (MMEL) must include functional icing inspection lights.

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

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

(8) Placard. The AFM should contain a list of required placards.

c. AFM Normal Procedures Section. Section 23.1585(a) requires the pilot be provided with the necessary normal 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 use of the system(s) in a safe manner.

(1) Preflight. 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.

(a) 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.

(b) 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.

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

(2) In-flight. 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.

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

(b) Procedures for operation of the ice protection system, including activation and deactivation, must be established and documented in the Airplane Flight Manual, in accordance with § 23.1419(h). Information should be provided to indicate that a de-icing system should not be de-activated until the completion of an entire deicing cycle after leaving icing conditions. An anti-icing system should not be de-activated before leaving icing conditions.

(c) The following statement should be included, including those airplanes approved for Appendix O conditions: "Convective clouds, above the freezing altitude, that are vigorously growing should be avoided since they may contain icing conditions exceeding those for which the aircraft has been certified."

(d) The recommended procedure for the various flight phases in icing conditions should be considered (e.g., whether flaps or landing gear extended, airspeed). AFM recommended procedures would include this operating information. These procedures should reflect the certification assumptions in critical ice shape determination.

1. Holding
2. Approach
3. Landing
4. Missed approach

(e) Procedures for re-setting the stall warning system to the non-icing schedule if the design permits, after leaving icing conditions should be specified. Procedures should include pilot verification that airplane is free of ice accretion.

d. AFM Abnormal or Emergency Procedures Section. . Section 23.1585(a) requires the pilot be provided with the necessary abnormal and emergency procedures for safe operation. The system components should be described with sufficient clarity and depth that the pilot can understand their function. These procedures should include proper pilot response to cockpit warnings and a means to diagnose system failures

(1) Procedures to be followed when ice protection systems fail and/or warning or monitor alerts occur, or suspected unannunciated failures occur, should be provided. Examples include minimum airspeeds to preclude wing stall and reduced flap deflection to preclude ice contaminated tailplane stall (ICTS).

(2) Include any changes to other AFM abnormal or emergency procedures resulting from flight in icing conditions.

(a) For compliance with §§ 25.1420(a)(1) or 25.1420(a)(2):

1. The method used to determine when icing conditions must be exited, must be provided in the AFM abnormal/emergency procedures section, as well as appropriate failure indications and crew procedures. An example for a visual cue on the aircraft is:

The following shall be used to identify freezing rain/freezing drizzle icing conditions and severe icing:

"Accumulation of any ice on the wing aft of the protected area."

2. In addition to method certified by the applicant to exit icing conditions, the following should also be provided:

"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) It is possible to experience severe ice accretions not visible to the flight crew, such as lower wing surface accretion on a low wing airplane or propeller blade accretion. Performance losses greater than the performance section of the AFM may be an indication of severe icing conditions."

Manufacturers may consider adding additional performance cues (e.g. XX knots speed loss, torque required) as indicators of severe icing.

3. The abnormal/emergency procedures section should contain guidance relative to exiting the icing environment. 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. Flaps may be retracted following detection of Appendix O if applicant demonstrates retraction can be safely accomplished, critical ice shape determination accounted for ice accretion with flaps extended, testing to Subpart B used the appropriate flap, and applicant shows by analysis there will not be mechanical interference with leading edge flap ice accretion.

(b) For certification of certain phases of flight to Appendix O, information defining these restricted phases should be provided. This information should include any aircraft configurations associated with the restricted phases of flight such as flap position, gear extension, or airspeed.

(3) Stall warning and stall recovery procedure. Applicants should evaluate their recommended stall recovery procedures to assess its suitability in icing conditions and include in AFM. The procedure should consider basic airmanship techniques which establish the re-attachment of the boundary layer (flow) of air over the aircraft's wing surfaces. Such techniques should include a *definite lowering or pushing forward of the aircraft's nose/reduction of the wing's angle of attack* to ensure that the wing is again producing lift, with loss of altitude no more than necessary to achieve that objective. Procedures may include target pitch attitudes to achieve the reduction of angle of attack.

(4) Ice Contaminated Tailplane Stall Recovery Procedure. Limitations and procedures for maximum flap deflection in icing conditions are sufficient to address ICTS for new airplanes. Training should emphasize flap limitations and not an ICTS recovery procedure.

e. AFM Performance Section. Performance information, derived in accordance with subpart B of part 23, should be provided in the AFM for all relevant phases of flight in accordance with § 23.1587. Data are not required at outside air temperatures warmer than +5°C.

(1) Stall speeds. Effect of critical ice accretions on stall speeds for all icing approved configurations should be provided.

(2) Takeoff performance.

(a) Effects of ice protection system operation and/or ice accretions, if applicable, on takeoff distance and takeoff path, if applicable, should be presented in the same format as the basic non-icing data.

(b) If airplane is approved for takeoff in Appendix O, separate data may be provided for “Freezing Drizzle and Freezing Rain” and “Icing Conditions Other Than Freezing Drizzle and Freezing Rain.”

(3) Enroute climb performance. Enroute climb performance with critical ice accretions should be presented in the AFM in the same format as the basic non-icing data, if required by § 23.69. The critical ice accretion should be based on part 25, Appendix C for airplanes which are not approved for flight in Appendix O in the enroute or holding phase.

(4) Cruise Performance. Not required for certification. The applicant may want to consider providing data based on critical, part 25 Appendix C icing conditions as an additional cue that the airplane is approaching the limits of certification. Examples may be airspeed at maximum power/thrust as a function of weight/altitude/temperature.

(5) Landing Performance

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

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

(c) Landing distance, if required to be determined, should be presented in the AFM in the same format as the basic non-icing data.

(d) The VREF in icing conditions, if different than non-icing, should be clear on the data charts.

(e) If airplane is approved for landing in Appendix O, separate data may be provided for “Freezing Drizzle and Freezing Rain” and “Icing Conditions Other Than Freezing Drizzle and Freezing Rain.”

(7) Appendix O Conditions for Which the Airplane is not Approved. A brief statement that freezing rain and freezing drizzle 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.

(8) Maintenance Manual. The AFM should reference the maintenance manual for ice protection surface cleaning procedures, or application of ice adhesion inhibitors, if the flight crew can be expected to perform this function. The AFM should recommend application of ice adhesion inhibitors in accordance with the manufacturers instructions.

19. 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 (data may be provided by the deicer manufacturer's to address the concerns by similarity to prior installations or testing):

(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?

20. 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 maximum 5.24% difference in stall lift coefficient between the clean airplane and airplane with 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, and maximum takeoff gross weight for airplanes with reversible longitudinal control, 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. Controllability during takeoff with 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. Exceedance Icing Conditions. Icing conditions for which the airplane is not approved.

g. 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.

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

i. 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

Appendix 1

temperatures less than zero degrees C (supercooled), remains in liquid form, and freezes upon contact with objects on the surface or airborne.

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

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

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

m. 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).

n. 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.

o. 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.

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

q. 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.

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

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

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

u. 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.

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

w. 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.

x. 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.

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

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

aa. 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

Appendix 1

2. DEFINITION OF ACRONYMS.

Acronym	Definition
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

Acronym	**Definition**
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_{S1}	Stall speed in a specific configuration
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		23.1547	
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) § 23.1419

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.

Appendix 3

(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.

(g) The service history of the airplane should be reviewed to determine if stall warning and low airspeed awareness should be addressed.

(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) Replacement of Autopilot

Guidance in this AC, paragraphs 17 for autopilots should be consulted. Similarity to the previously approved autopilot through analysis or testing may be acceptable. 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.

(15) Erosion Strips for Deicing Boots

The guidance in Appendix 5 for replacement deicing boots is applicable.

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

1. 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 23.1309-1D 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 § 23.1419 or § 23.1420 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 contain a WARNING that stall warning in icing conditions may 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.

Appendix 5

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.

3. 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-XX

1. In accordance with § 23.1419, Amendment 23-XX, "capable of operating safely" in icing conditions means that the airplane must comply with § 23.21(c)(1) with critical Appendix C ice accretions. Section 23.21(c)(1) defines all of Subpart B but lists the exceptions. Guidance for each subpart B regulation, as related to icing, is in the following Table 6-1.

2. In accordance with § 23.1420, Amendment 23-XX, "capable of operating safely" in icing conditions means that the airplane must comply with § 23.21(c)(3) with critical ice accretions in the portions of Appendix O for which the airplane is certified. Section 23.21(c)(3) defines all of Subpart B but lists the exceptions. Table 6-1 can also be used for compliance guidance, with the exception of takeoff. For takeoff guidance in Appendix O, see Appendix 9.

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

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

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TABLE 6-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-XX		
Regulation	14 CFR Section	Guidance
Takeoff speeds	23.51	Takeoff speeds must be based on stall speed with Appendix C takeoff ice accretions for normal, utility, and acrobatic category turbojet powered airplanes without a wing leading edge high lift device and commuter category airplanes, if the applicant seeks certification for flight in icing conditions, if the stall speed with takeoff ice accretion exceed the threshold defined in § 23.51(d). If applicable, 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.
Takeoff performance	23.53	The effect of operating ice protection systems on engine performance must be accounted for. Must be based on takeoff icing speeds if different than non-icing in accordance with § 23.51(d). It can be assumed there is no ice accretion prior to lift-off for those airplanes in which takeoff ice accretion must be considered.
Accelerate-stop distance	23.55	The effect of any increase due to takeoff in icing conditions may be determined by analysis.
Takeoff path	23.57	
Takeoff distance and takeoff run	23.59	May be calculated by a suitable analysis.
Takeoff flight path	23.61	
Climb: general	23.63	For the regulations defined in § 23.21(c)(1), must be compliant with critical Appendix C ice accretions, except ambient temperatures above 41-degrees F do not need to be addressed.

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

Regulation	14 CFR Section	Guidance
Climb: all engine operating	23.65	Must be shown to be compliant with engine power losses associated with operating ice protection equipment that are not prohibited for takeoff. The effect of ice accretion on climb performance (lift, drag and climb speed) must be accounted for if not excepted per § 23.65(c). For example, accounting for takeoff ice accretion in Appendix C conditions is not required for normal category reciprocating or turboprop powered airplanes. The effect of Appendix C takeoff ice accretion must be accounted for on normal category turbojets if the stall speed increase or climb performance degradation are above the thresholds defined in § 23.65(c). Flight testing of the takeoff ice accretion should be accomplished to evaluate stall speed and climb performance.
*Takeoff climb: one engine inoperative	23.66	Applicable for multiengine airplanes if compliance to § 23.65(c) is required.
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 not excepted per § 23.67(e). For example, accounting for takeoff ice accretion in Appendix C conditions is not required for normal category reciprocating or turboprop powered airplanes. The effect of Appendix C takeoff ice accretion must be accounted for (except for § 23.67(c)(1) on commuter category airplanes and turbojets without a wing leading edge high lift device, such as slats, if the stall speed increase or climb performance degradation are above the thresholds defined in § 23.67(e). Flight testing of the takeoff ice accretion should be accomplished to evaluate stall speed and climb performance.
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.

Appendix 6

TABLE 6-1. PART 23 SUBPART B TESTS FOR SECTION 23.1419 AT AMENDMENT 23-XX		
Regulation	14 CFR Section	Guidance
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 Appendix C ice accretion if the stall speed with critical ice at maximum landing weight with landing flaps, gear down exceeds that in non-icing conditions by more than the greater of three (3) knots CAS or three (3) percent V_{S0}. 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 must still comply with the stall warning and maneuver margin requirements of § 23.207.
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. The effect of landing speed increase on the landing distance may be determined by analysis.
Balked landing	23.77 (a)(b)(c)	Must be compliant with critical ice accretions, all ice protection systems operational, all landing flap settings, at an ambient temperature of 41 degrees F.
General (control)	23.141	Must be shown to be compliant with the regulations defined in § 23.21(c)(1) with critical ice accretions.
Controllability and maneuverabilit y (General)	23.143 (a)(b)	Controllability is evaluated concurrently with other tests, and during the flight, when conducting ice shape and natural Appendix C flight testing. In lieu of the evaluation of sudden engine failures for multi-engine airplanes, the following is accomplished: 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.
	23.143 (c)	Maximum control forces are applicable.

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

Regulation	14 CFR Section	Guidance
`	23.143 (d)(1)	Controllability is evaluated concurrently with other tests, and during the flight, when conducting ice shape and natural Appendix C flight testing.
	23.143 (d)(2)& (d)(3)	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.
	23.143 (d)(4)	Aileron hinge moment reversal and other lateral control anomalies have been identified as causal factors in icing accidents and incidents. The following maneuver, along with the evaluation of lateral controllability during a deceleration to the stall warning speed during the tests to show compliance to §§ 23.201 and 23.203, and the evaluation of static lateral-directional stability for compliance to § 23.177, is intended to determine the susceptibility of the airplanes to aileron hinge moment reversals or other adverse effects on lateral control characteristics due to ice accretion. (a) Holding configuration, holding ice accretion, maximum landing weight, forward center-of-gravity position, minimum holding speed (highest expected holding angle-of-attack); and (b) Landing configuration, holding ice accretion, medium to light weight, forward center-of-gravity position, V_{REF} (highest expected landing approach angle-of-attack). 1. Establish a 30-degree banked level turn in one direction. 2. Using a step input of approximately 1/3 full lateral control deflection, roll the airplane in the other direction. 3. Maintain the control input as the airplane passes through a wings level attitude. 4. At approximately 20 degrees of bank in the other direction, apply a step input in the opposite direction to approximately 1/3 full lateral control deflection. 5. Release the control input as the airplane passes through a wings level attitude. 6. Repeat this test procedure with 2/3 and up to full lateral control deflection unless the roll rate or structural loading is judged excessive. It should be possible to readily arrest and reverse the roll rate using only lateral control input, and the lateral control force must not reverse with increasing control deflection.
	23.143 (e)	Susceptibility to ICTS must be evaluated with pre-activation ice accretions as defined in Table 2. A 0.5g pushover and 1.5g pull-up are required for pre-activation ice in lieu of the 0g pushover.

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

Regulation	14 CFR Section	Guidance
Longitudinal control	23.145 (a)(b)	Must be shown to be compliant with critical ice accretions. Susceptibility to ICTS should be evaluated during flap extension tests.
	23.145 (c)	Not required. Flight tests above V_{MO}/M_{MO} are not conducted for icing certification.
	23.145 (d)	Not required.
	23.145 (e)	Evaluation of failure of primary longitudinal flight control system not required for icing certification.
Directional and lateral control	23.147 (a)(b)	Critical configuration(s) determined from the non-contaminated airplane tests must be evaluated.
	23.147 (c)	Evaluation of failure of primary lateral flight control system not required for icing certification.
Minimum control speed	23.149 (a)	Definition of V_{MC}, applicable to landing phase in icing conditions.
	23.149 (b)	Not required for takeoff phase in Appendix C icing conditions.
	23.149 (c)	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.
	23.149 (d)	Not required.
	23.149 (e)	Applicable to landing phase in icing conditions.
	23.149 (f)	Not required in Appendix C icing conditions.
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.

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

Regulation	14 CFR Section	Guidance
Trim	23.161	The results from the non-contaminated airplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, or if qualitative evaluations with ice accretions show any control anomalies, these cases should be repeated with ice. Otherwise, no dedicated tests with ice accretions required, qualitative evaluations can be accomplished concurrently with other tests.
General (stability)	23.171	Must be shown to be compliant with critical ice accretions.
Static longitudinal stability	23.173	Stability may be degraded from the non-iced airplane but must still be compliant.
Demonstration of static longitudinal stability	23.175	Critical configuration(s) determined from the non-contaminated airplane tests must be evaluated.
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.

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

Regulation	14 CFR Section	Guidance
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 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). If a stick pusher system with anticipation logic installed, deceleration rates slower than 1 kt/sec may need to be conducted to evaluate the highest angle of attack activation of the stick pusher.
Turning flight stalls	23.203	Turning stalls should be evaluated with critical ice accretions similarly to wings level stalls. 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.
Accelerated turning stalls	23.203 (a)(2)	Accelerated turning stalls not required unless tests with no ice show marginal compliance`````

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

Regulation	14 CFR Section	Guidance
Stall warning	23.207 (a)-(c)	Should be evaluated concurrently with stall speed and stall characteristics tests. The stall warning margin with critical ice accretions must be compliant. If the stall warning system incorporates anticipation, deceleration rates slower than 1 kt/sec may need to be conducted to evaluate the highest angle of attack activation of the stall warning system. In addition to the standard stall tests conducted in natural icing and with artificial ice shapes required to show compliance to § 23.1419(b), recovery at stall warning should also be evaluated by applying the manufacturer recommended stall recovery procedures. The following three aircraft configurations should be performed: 1. Flaps up, gear up (wings level) 2. Approach configuration (turn using bank angle of 15 to 30º) 3. Landing configuration approved for icing (wings level) Evaluations should be accomplished as follows: 1. Trim at minimum AFM or V_{REF} icing airspeed 2. Set power/thrust to establish a reasonable deceleration rate that will allow the pilot to reach stall warning while maintaining constant altitude. Note: Vary stall entry rate as required to hold constant altitude during stall entry.

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

Regulation	14 CFR Section	Guidance
Stall warning (continued)	23.207 (a-c)	3. Recover at onset of stall warning + 1 second using appropriate aircraft procedures. Note: Evaluate the aircraft response, need for directional/lateral control, airspeed increase, and altitude loss during recovery maneuver. The aircraft shall exhibit positive control and demonstrate that a pilot of average skill can execute the procedure as defined. 4. The same conditions should be evaluated with the autopilot engaged in altitude hold mode. **Note:** If autopilot design is such that it does not automatically disconnect at stall warning, then per the requirements of AC23.1419-2C evaluations should be conducted with autopilot engaged until aircraft begins to lose altitude. At which point disengage autopilot and initiate stall recovery by utilizing appropriate aircraft procedures.
Maneuver margin	23.207 (d)	40-degree bank level altitude turns and 30 degree/30 degrees bank-to-bank rolls at the flight conditions specified in the regulation should be accomplished to demonstrate the airplane is free of buffet and stall warning with critical ice accretions. All takeoff and approach flap settings should be evaluated. For one-engine inoperative evaluations, only a 30-degree turn is necessary, and the appropriate thrust may be simulated with all engines operating at a reduced power/thrust.
Accelerated stall warning margin	23.207 (e)	Not required.
Acrobatic airplane stall warning	23.207(f)	Applicable for acrobatic airplanes.

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

Regulation	14 CFR Section	Guidance
Stall warning with pre-activation ice	23.207(g)	Must be shown with pre-activation ice that a stall and adverse flight characteristics, such as a large or abrupt roll or yaw excursion, can be prevented in a one knot/sec deceleration after waiting at least one second after stall warning. The pre-activation ice is defined in Table 2 of this Advisory Circular. Recovery at stall warning should also be evaluated by applying the manufacturer recommended stall recovery procedures. The following three aircraft configurations should be performed: 1. Clean (wings level) 2. Approach (turn using bank angle of 15 to 30º) 3. Landing (wings level) Evaluations should be accomplished as follows: 1. Trim at minimum AFM or V_{REF} icing airspeed 2. Set power/thrust to establish a reasonable deceleration rate that will allow the pilot to reach stall warning while maintaining constant altitude. Note: Vary stall entry rate as required to hold constant altitude during stall entry.
Means of stall warning in icing conditions	23.207(i)	The type of stall warning with critical ice accretions representing normal operation of the IPS and pre-activation must be the same as with the non-contaminated airplane. Biasing of the stall warning (resetting schedule 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. It is acceptable to return to the non-icing schedule when the critical wing surfaces are free of ice accretions. The applicant should validate that the means used to determine when the critical wing surfaces are free of ice accretions is reliable under all expected operating conditions.
Spinning	23.221	Not required.
Longitudinal stability and control	23.231	Must be shown to be compliant.

Appendix 6

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

Regulation	14 CFR Section	Guidance
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: $\mathbf{V_{CW} = V_{REF} * \sin(\text{sideslip angle}) / 1.5}$ where: $\mathbf{V_{CW}}$ is the crosswind component, $\mathbf{V_{REF}}$ is the landing reference speed appropriate to a minimum landing weight, and **sideslip angle** is that demonstrated at V_{REF}
Operation on unpaved surfaces	23.235	Not required.
Operation on water	23.237	Required only for seaplanes and amphibians certified for flight in icing conditions..
Spray characteristics	23.239	Not required.
Vibration and buffet	23.251	The non-icing tests should be accomplished with the ice protection systems installed. Should be qualitatively evaluated in conjunction with other dry air ice shape flight tests up to the lower of: 250 KCAS $V_{MO}/M_{MO}/V_{NE}$ A speed at which it is demonstrated that the airframe will be free of ice accretion. Vibration due to propeller icing/de-icing should be evaluated during the natural icing testing.
High speed characteristics	23.253	If applicable, compliance should be shown with airframe ice protection systems installed. Not required with ice accretions.

APPENDIX 7. CAPABILITY OF ENGINEERING TOOLS FOR COMPLIANCE TO § 23.1420

Table 7-1 graphically illustrates results of a 2009 assessment of the capabilities of engineering icing tools. This assessment is described in detail in AC 25-XX. As described in the legend to that table, the capability of each tool for the various applications is classified as green, yellow, or orange, Reliance upon available simulation methods combined with engineering judgment will be required for finding compliance with § 23.1420. Even though a simulation tool type may be classified as green, an applicant must ensure that the specific tool is appropriate for its application and is used in a conservative manner, including consideration of critical-case icing conditions. General and specific concerns that should be considered are discussed in this section of the AC. While **Table 7-1** illustrates the current state of simulation capabilities, we expect that capabilities will improve in the future. We encourage applicants and research agencies to develop and validate the engineering tools currently classified in **Table 7-1** as yellow and orange.

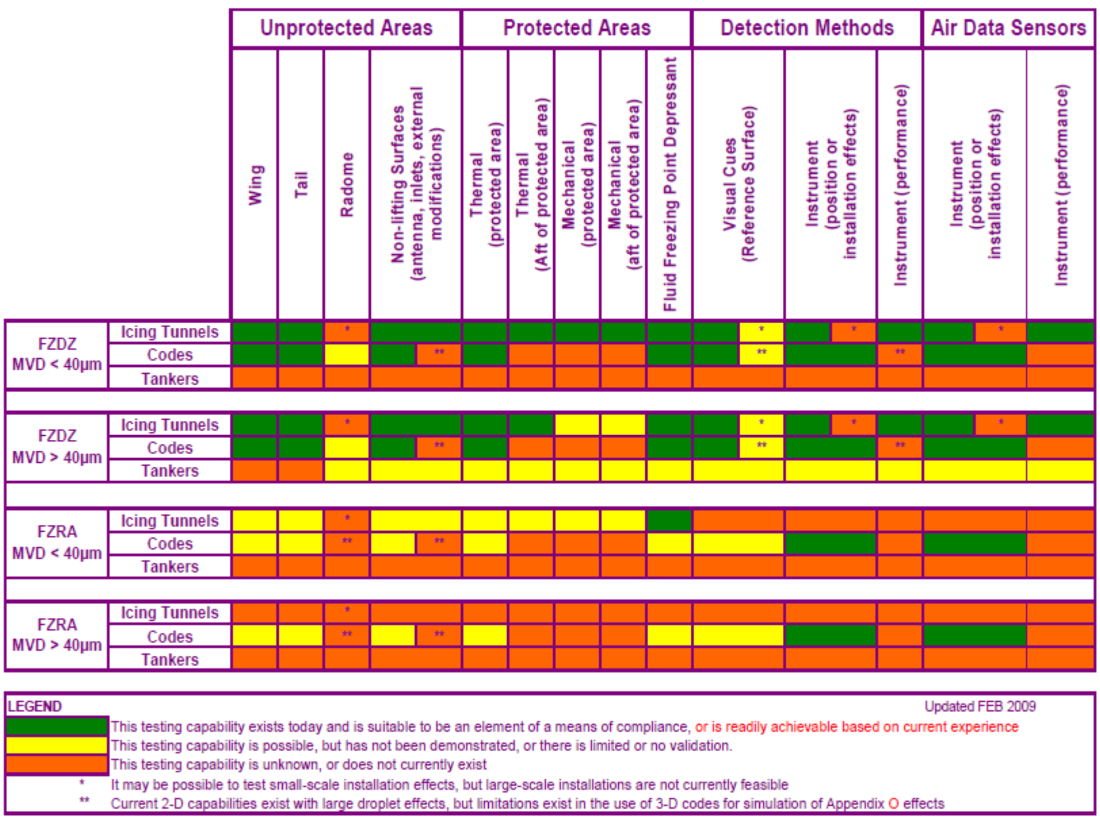

Table 7-1 illustrates that, for some Appendix O conditions, few of the engineering tools are classified as green or yellow for use as a means of compliance. Radomes, for example, have no engineering tools classified as green. In other cases, such as areas aft of protected areas, there is only one simulation tool that is classified as green.

Appendix 7

(1) Capabilities & Limitations of Engineering Tools and Measurement Instrumentation for Appendix O Icing Conditions

(a) _Icing Tunnel. A tunnel that uses a single pressure source for spray bars cannot simultaneously produce the large and small drop distributions (bi-model distributions) defined in Appendix O. However, NASA has developed a technique called "sequencing" that alternates large and small drop sprays to simulate Appendix O conditions. When icing tunnels are used as an element of the means of compliance:

1. Scale effects must be considered for tunnel blockage effects.

2. For FZDZ with a median-volume diameter (MVD)<40µm, the cloud drop distributions in the IRT are similar to existing Appendix C calibrations.

3. A simulation of freezing drizzle may be acceptable without an exact simulation of the drop size distributions defined in part 25, Appendix O. Standard icing tunnel drop distributions may be acceptable to use in lieu of the Appendix O distributions if the water content at the higher drop sizes are conservative. Superposition of the effects on the stagnation region versus any effects aft of the protected areas may be required to represent the local water catch in these locations.

4. If there are concerns about the bi-modal distribution affecting performance of ice protection systems, sequencing should be considered. Sequencing[2] of freezing drizzle conditions has been demonstrated in the IRT for unprotected surfaces. The sequencing technique approximates drop distributions found in natural conditions, however, it results in rougher textures than Appendix C ice shapes.

5. Ice shapes in unprotected areas are generally considered critical from the perspective of producing the largest disruption to the airflow. With a large ice shape, details on the impingement limit characteristics, which may have a less critical effect, may not be essential. However, sequencing between large and small drop conditions may be necessary if standard sprays do not produce the drop distribution appropriate for simulation of the conditions desired. (The phrase "standard spray" method refers to using the IRT nozzles in off-design conditions to generate larger drops for SLD conditions.) In cases where the impingement limit characteristics are important, sequencing may be necessary.

6. In general, sequencing produces rougher textures than a standard spray.

[2] Simulation of a Bi-modal Large Droplet Icing Cloud in the NASA Icing Research Tunnel, M. Potapczuk and D. Miller, R. Ide, and J. Oldenburg, 43rd AIAA ASM, Reno, NV, Jan. 2005

7. Sequencing may not be an appropriate way to test thermal systems because the rate of mass flow per unit area (i.e. mass flux) of the incoming water is not the same for the small and large drop sprays.

8. If sequencing is used to test deicing systems, the ratio of sequencing time to shed cycles should be evaluated to ensure that sequencing does not inappropriately affect the ice shape.

9. The tunnel model should be a full scale model if the tunnel test objective is the definition of ice accretion. A hybrid model may be used provided the more aft impingement of the SLD, compared to Appendix C drops, is accounted for. Experimental tests of methods for designing subscale hybrid airfoils with full-scale leading edges to determine leading edge ice shapes for large-chord airfoil sections has been accomplished in icing wind tunnels (References TBD). These techniques have been used successfully for Appendix C icing conditions. Adapting them to icing tests for SLD conditions requires an evaluation of the areas of interest for impingement analysis and analysis of the flow-field to determine if scale conditions aft of the leading edge can be met considering the compromises necessary in design variables on circulation, velocity distribution and impingement characteristics. Although we anticipate that the hybrid airfoil design technique would be applicable for SLD conditions, such use has not been tested and validated to date.

10. Scale models may be used, with appropriate scaling corrections, to examine impingement limits relative to fuselages or windscreens with scale models. While scaling icing shapes and roughness is still an emerging area of technology, scaling of droplet inertia effects and impingement limits are in a more mature state. This technique may be used to examine visual icing cues, validate location of detection devices, and determine total accretion areas that could be used in drag estimates (if required).

11. The tunnel model should incorporate geometry features such as spanwise gaps or steps.

(b) Computational Fluid Dynamic Tools. Computational fluid dynamic (CFD) tools—the “codes” referred to in the table—are used extensively in certification for Appendix C conditions. CFD tools can provide valuable information on impingement limits, icing limits, ice size, ice shape, and ice thickness for Appendix O conditions. Some validation of collection efficiency and ice shapes has been accomplished for FZDZ; there have been no validation exercises for FZRA. CFD tools have been devised to predict, using mathematical calculation, ice accretion on an airplane in SLD conditions and the behavior of various types of ice protection systems as a result of those accretions. Besides being useful for assessing effects on protected surfaces, these tools can also account for the possibility of SLD ice impingement beyond the ice protection system limits, as well as for possible water runback. No current CFD method, however, can identify the breakup of water into rivulets, roughness formation, ice sliding that may occur under these circumstances, the shape or location of runback ice, or any effect of spanwise features such as steps and gaps.. Thus analysis of the regions behind those that are protected by ice protection systems requires some combination of CFD results, empirical data and test results (if available), and engineering judgment. This usually consists of determining the extent of possible ice formation using some criteria from the computational analysis, such as ice extent, impingement limits, or some minimum ice thickness level. The resulting ice shape would include intercycle or residual ice on the protected region and ice formed aft of the protected region. This result is then combined with guidance on ice roughness levels, such as described elsewhere in this document, to produce a rough ice region that can be evaluated in wind tunnel testing or flight tests.

1. Information can be calculated for drop trajectories for evaluating sensor locations and potential visual cues.

2. Many non-lifting surfaces require testing with 3-D computer codes. At the current time, many 3-D codes do not have large drop effects (such as splashing and break-up). Even without large drop effects, however, 3-D codes can offer information on impingement limits. Although 3-D codes may generate physical models and correlations that can support analysis of large drop icing, the capabilities of performing analyses with 3-D SLD CFD tools have not yet been evaluated. There are codes that may have this potential, but no guidance can be offered at this time for their use.

3. Some codes have limited capabilities with short-chord geometries (e.g., antennas or struts) for Appendix C icing conditions. These limitations are expected to be similar for large drop icing and are typically addressed with empirical methods or icing tunnels. However, for non-lifting surfaces, conservative assessments may be acceptable, such as assuming drop impingement on the full frontal area, assuming the collection efficiency is one, and approximating the shapes appropriate for the temperature (glaze, rime, etc.).

(c) Icing Tankers

1. Icing tankers have been used extensively by some manufacturers for Appendix C icing certifications. Icing tankers typically have a limited plume size and have been used primarily for localized icing effects, such as ice shedding, and for assessing the thermal performance of anti-ice systems.

2. Current tankers do have some limited capabilities to produce freezing-drizzle-sized drops, but they cannot produce the distribution effects. Current tankers do not produce freezing rain distributions either, and the feasibility of producing such conditions is likely limited by drop break-up (due to deceleration effects) and the ability to sub-cool the large drops within a workable flight envelope. Additionally, drop sorting effects are likely, because of higher fall rates of large drops within an Appendix O distribution.

(d) Instrumentation. When making in-situ measurements of Appendix O conditions, it is important to note that technology to make such measurements is rapidly changing. It is essential to consult experts in all phases of the measurement program, including those aware of the latest problems and strengths of each probe. You should use instrumentation suited to the task.

1. Instrumentation must be mounted in appropriate locations on the aircraft, where the measurements are not affected by the airflow.

2. For certification purposes, the instrumentation must be calibrated. An often-overlooked aspect of a measurement program is the need to calibrate the instruments.

3. Appropriate software and analysis techniques are also essential, because complicated algorithms are often needed in the analysis.

4. Instruments are required to measure particle concentrations as a function of size over the complete size range—2 µm to at least 1,500 µm—including cloud drops and precipitation drops. This may require more than one probe.

5. Liquid water content and ice water content (IWC) measurements obtained by integrating 2-D images from spectral measurements generally have larger errors than those obtained from probes specifically designed to make such measurements. Consequently, it is recommended that probes designed to measure LWC and, if necessary, IWC, directly be used, recognizing that some hot-wire devices detect larger drops (>50µm) with reduced efficiency. Mixed-phase clouds can occur frequently, so it is necessary to be able to discriminate between ice and liquid particles, especially for sizes larger than 50µm, so that ice particles are not incorrectly identified as SLDs.

6. For detect-and-exit airplanes (those certifying to §23.1420(a)(1)), it may not be necessary to measure IWC; but for airplanes using natural icing SLD flight tests to certify for a portion of Appendix O (§23.1420(a)(2)) or for unrestricted operations (§23.1420(a)(3)), IWC must be determined in order to assess the SLD conditions.

(1) Component Evaluations

(a) Lifting surfaces. This paragraph is applicable to anti-icing systems aft of protected areas and to deicing systems both on and aft of protected areas.

For detect-and-exit airplanes (§ 23.1420(a)(1)) in freezing drizzle conditions, icing tunnels alone may be used to develop ice shapes, provided that the model appropriately represents the airfoil beyond the FZDZ icing limit. Roughness may be evaluated in icing tunnel testing and replicated on the ice shapes for flight testing. The standard spray[2] method should be used for anti-icing systems because of the varying mass flux of incoming water associated with sequencing. For deicing systems, it is acceptable to use either the standard spray or the sequencing technique.

(b) **Radomes .**

Most radomes are too large to fit into existing icing wind tunnels. Additionally, computational analysis of radomes typically would require 3-D codes. Many 3-D codes do not have large drop effects and if they do not, freezing drizzle ice shapes cannot be simulated. (All 3-D codes have capabilities for testing impingement limits, however.) Radome ice shapes have been developed in the past for Appendix C icing conditions using analysis and observed ice shapes from Appendix C flight tests (typically holding ice shapes).

For detect-and-exit airplanes (§ 23.1420(a)(1)) in freezing drizzle conditions, one method of compliance would be to modify Appendix C ice shapes to account for the larger impingement regions produced in FZDZ as predicted by the 3-D codes. You may use CFD codes to predict ice thickness. Ice roughness should be in accordance with the section headed **Standard Roughness Levels for Appendix O Ice Shapes** later in this appendix. The radome ice tested should reflect the total mass associated with the icing exposures for § 23.1420(a)(1) airplanes, which are defined in 14 CFR 23, Appendix TBD, part II.

(c) Non-Lifting Surfaces (Antennas, Enhanced Vision Cameras, Struts, Auxiliary Inlets)

For non-lifting surfaces that do not require use of 3-D codes, 2-D codes in combination with icing tunnels are available as a means of compliance. However, many non-lifting surfaces require the use of 3-D codes. At the current time, many 3-D codes do not have large drop effects, although some codes may have this potential.

For detect-and-exit airplanes (§ 23.1420(a)(1)), if the non-lifting surface is not critical from an engine ingestion or airframe damage perspective, 3-D codes may provide sufficient information for compliance. However, for more critical surfaces, until large drop effects in 3-D codes are validated, icing tunnels alone may be used to develop ice shapes.

(d) Ice Detection Methods

Different types of ice detection require assessment of their capabilities in large drop conditions, based upon their sensing technology. Vibrating probe type ice detectors which detect ice accretion on a probe through a decrease in the probe's vibration frequency, may experience increased response time in large drop exposures because splashing and aerodynamic forces, particularly in near freezing temperatures, can cause water to shed from sensing surfaces. This physical behavior may also occur with other types of probes.

While CFD can determine whether the large drops impact the ice detection surface, available CFD codes cannot accurately predict aerodynamic forces that cause drop shedding, or freezing fraction effects which may delay freezing. Therefore, use of CFD alone is not acceptable for showing that ice detectors function in large drop conditions. When possible, effects of installation position should be evaluated with a combination of codes and icing tunnels. Devices mounted on smaller surfaces could be assessed in an icing tunnel. However, if the device is mounted on the fuselage, and tunnel blockage effects would preclude a meaningful icing tunnel test, then CFD codes that adequately predict the shadowing and concentration effects may be used to verify that the equipment is properly located.

Because of the lack of engineering tools for FZRA, primary and advisory ice detectors used for compliance with § 23.1420(c) will require validation in natural large drop conditions to substantiate that the detectors function in all Appendix O conditions, unless ground testing with both FZDZ and FZRA drops representative of Appendix O distributions and temperatures can be substantiated. However, if visual cues are certificated as the primary means of compliance with § 23.1420(a)(1)(i) and the airplane is equipped with an ice detector system that is not required for compliance with § 23.1420(a)(1)(i) or § 23.1420(c), then the ice detector need not be tested in natural Appendix O conditions. Certification of visual cues for detect-and-exit airplanes is discussed later in this appendix under the heading Certification for Detect and Exit - § 23.1420(a)(1).

(e) Air Data Sensors

1. Air Data Sensor Position Installation Effects. When possible, you should evaluate the effects of installation position with a combination of CFD codes and icing tunnels. Devices mounted on smaller surfaces could be assessed in an icing tunnel. However, if the device is mounted on the fuselage and tunnel blockage effects would preclude a meaningful icing tunnel test, then codes that adequately predict the shadowing and concentration effects are acceptable as the only method for compliance with installation location requirements.

2. Air Data Sensor Performance Effects. Icing tunnels alone may be used to determine the performance of air-data sensors in Appendix O icing conditions in compliance with §§ 23.1323, 23.1324, and 23.1325. For sensors with collection efficiencies approaching "1," if performance has been shown in FZDZ conditions, then a qualitative analysis based upon water-catch ratios may be used for extrapolation to FZRA conditions. If the Appendix C or mixed-phase or ice crystal conditions are shown to be more critical for air-data sensors than the SLD environment, the number of tests may be reduced. However, the test methods should be validated until confidence is provided. In some cases, such as that of wing leading-edge-mounted lift transducers, icing tunnel tests may still be necessary.

(2) Means of compliance to § 23.1420

(a) Certification for Detect and Exit - § 23.1420(a)(1)

1. Freezing Drizzle (FZDZ)<40µm. FZDZ conditions with an MVD less than 40µm are similar to existing Appendix C distributions with the exception of a small percentage of the mass in drops larger than typical Appendix C conditions. As a result, many of the current Appendix C simulation methods can support compliance. The small percentage of large drops in this distribution can affect the impingement limits and increase the water catch. If visual cues are used for compliance with § 23.1420(a)(1)(i), it may be possible to use codes in combination with icing tunnels to verify the visual cues. Visual cues should not be based on only one engineering method; a second, correlating method should be used.

2. Freezing Drizzle FZDZ>40µm. Where the capabilities of the tools available for FZDZ>40µm are the same as for FZDZ<40µm, the applicant may use similar means of compliance that are adjusted for the FZDZ>40µm icing conditions. The tool capabilities are different for mechanical deicing system protected areas and areas aft of the protected areas.

Note: Icing tunnels are classified as yellow when used for testing for FZDZ >40µm because use of the tunnels appears feasible but has not been demonstrated. Icing tunnel tests alone are acceptable for the development of ice shapes for deicing system protected areas and areas aft of the mechanically protected areas. Sequencing or standard distributions are acceptable, but the ratio of sequencing time to shed cycles should be examined.

3. Freezing Rain (FZRA) (MVD<40µm & MVD>40µm). The capabilities of the tools for FZRA are limited. To simulate accretions on unprotected surfaces and aft of protected areas, CFD codes may be used to determine the difference in impingement region between FZRA and FZDZ. The increase in impingement area can then be simulated using a standard roughness in that region. For areas where a ridge of ice may form, a simulated ridge may be developed using a height developed analytically based upon local water catch. Ridge location could be developed from FZDZ tunnel tests, and the height would be modified based upon the ratio of local water catch (determined with CFD) between FZDZ and FZRA. Other concerns:

Thermal Ice Protection Systems—Analyses to assess water catch and melting/evaporation rates are acceptable for determining the capabilities of thermal systems in FZRA, provided that the analyses are based upon the validated results of the system capabilities performed for Appendix C and FZDZ. Any additional ice that may form on runback ice shapes in freezing rain should be accounted for by analysis of the runback volume. Potential roughness effects ahead of the runback should be addressed.

Mechanical Ice Protection Systems — For assessing mechanical ice protection system performance in FZRA, it is acceptable to use the same pre-activation and intercycle and residual ice shapes as for FZDZ. The limits of accretion should be determined using CFD tools.

Validation of Visual Cues — Use of qualitative analysis is acceptable for assessing whether visual cues used for FZDZ will function in FZRA conditions.

(b) Certification for a Portion of Appendix O - § 23.1420(a)(2)

Current technology does not support distinguishing between FZDZ and FZRA in flight. Because of this, airplanes should not be certificated for compliance with § 23.1420(a)(2) based upon the boundaries between FZDZ and FZRA. Certification to § 23.1420(a)(2) is discussed in the main body of this AC; however, there are concerns about the ability of applicants to define ice shapes which distinguish between the approved portions and the unapproved portions of Appendix O with the current simulation tools. As a result, certification for a portion of Appendix O will be challenging and will require close coordination with certifying authorities.

Certification for a portion of Appendix O that considers phase of flight (e.g., takeoff, holding), as discussed in the body of this AC in paragraph 8(b), may be feasible. Any method of certification for a portion of Appendix O should be included as part of the certification planning and will require approval from the cognizant certifying authority.

(c) Certification for Unrestricted Operations - § 23.1420(a)(3)

The use of simulation tools as described for detect-and-exit airplanes is also acceptable for showing compliance for airplanes certificated in accordance with § 23.1420(a)(3). However, the means of compliance should include flight tests in measured Appendix O icing conditions.

APPENDIX 8. EXAMPLE FLIGHT TEST PROGRAM FOR COMPLIANCE TO § 23.21(C)(2) "SLD DETECT AND EXIT"

1. Stall Speed (§ 23.49).

Stall speeds must be defined with all flap positions approved for flight in icing. There is no requirement to show compliance with the maximum stall speed requirements of § 23.49 (c). The ice shapes to be flown are those determined to be critical "detect and exit" shapes. .

2. Reference landing approach speed (§ 23.73).

There is no requirement for the approach speed to be 1.3 times the stall speed determined with detect and exit ice shapes. The approach speed determined for Appendix C ice accretions may be used, but compliance with these shapes must be shown to the maneuver margin requirements of § 23.207(d). The approach speed with detect and exit shapes must be increased if required for compliance to the maneuver margin requirements.

3. Landing distance (§ 23.75). The landing distances determined for Appendix C operations may be used if the Appendix C approach speed is used following detect and exit of Appendix O icing conditions. If the approach speed must be increased for detect and exit, the increase in landing distance may be determined by analysis.

4. Landing Climb: All-engines-operating (§ 23.77).

When showing compliance with 23.1420(a)(1), in lieu of a specific climb gradient requirement for each aircraft category, the gradient of climb at the landing field pressure altitude must be measurably positive for all aircraft following an SLD icing encounter. For normal category, meeting the positive gradient is required at all field elevations and weights. Guidance shall be included in the AFM that, in the case of an SLD icing encounter, provides the appropriate actions and limitations of the aircraft following the encounter.

Acceptable Test Program. The following represents an acceptable test program:
a. Critical detect and exit ice shape
b. Forward centre of gravity position appropriate to the configuration.
c. Highest lift landing configuration, landing climb speed no greater than VREF.
d. Stabilize at the specified speed and conduct 2 climbs or drag polar checks
as agreed with the Authority. For propeller airplanes, the torque or power should be reduced to simulate the applicable propeller efficiency loss in Figure TBD.

5. Controllability and Maneuverability - General ((§ 23.143).
A qualitative and quantitative evaluation is usually necessary to evaluate the airplane's controllability and maneuverability. In the case of marginal compliance, or the force limits of*§ 23.143(c)* being approached, additional substantiation may be necessary to establish compliance.

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Acceptable Test Program. The following represents an acceptable test program for general controllability and maneuverability, subject to the provisions outlined above:
a. Critical detect and exit ice shape
b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.
c. For all flight phases except takeoff, evaluate controllability (no dedicated test points required, accomplished concurrently during other tests).
d. Deploy and retract deceleration devices at the following conditions:

Configuration	*Trim Speed*
High lift devices retracted configuration:	Minimum Holding Speed • VMO or 250 KIAS, whichever is less
Highest lift landing configuration:	VREF, and • VFE or 250 KIAS, whichever is less

e. Conduct an approach and go-around with all engines operating using the recommended procedure.
f. Conduct an approach and landing using the recommended procedure. These tests should be done at heavy weight and forward centre of gravity.

a. Controllability for Appendix O "Detect and Exit" icing conditions (§ 23.143(f))

Use the critical detect and exit ice shape. For airplanes with unpowered elevators, these tests should also be performed with roughness due to SLD impingement at locations where ice may accrete in normal IPS operation.

b. Pushovers/Pull-ups and Sideslips (§ 23.143(f)(1)(2)(3)(4))
Conduct a pull up to 1.5g and a pushover to 0.5g without longitudinal control force reversal.

Changes in longitudinal control force to maintain speed with increasing sideslip should be progressive, with no reversals or unacceptable discontinuities. Additionally, lateral control movements and forces must not reverse and there should be no lateral control snatching (i.e. sudden, sharp oscillations or reversals in control force) with increasing angle of sideslip .

Acceptable Test Program.

a. The most critical weight, the most critical of aft or forward center of gravity position, symmetric fuel loading.
b. In the configurations listed below, trim the airplane at the specified speed. Conduct pull up to 1.5g and pushover to 0.5g without longitudinal control force reversal.

Configuration	*Trim Speed*
High lift devices retracted, power or thrust for level flight	Minimum Holding Speed
Highest lift landing configuration, idle and go-around power or thrust	VREF-5 and VFE-minimum margin required to avoid exceeding VFE during maneuver

c. Conduct steady heading sideslips to the sideslip appropriate for crosswind approach and landing with thrust or power for approach at VREF.

c. Lateral control evaluation (§ 23.143(f)(5))

Aileron hinge moment reversal and other lateral anomalies have been identified as a causal factor in icing accidents and incidents. The lateral control evaluation is applicable to airplanes equipped with spoilers as well as ailerons. It is applicable to reversible and irreversible lateral control configurations since the effects of the following are being evaluated:
Hinge moment reversal and other lateral anomalies
Stall or partially stall of the outer wing

It should be possible to readily arrest and reverse the roll rate using only lateral control input and the lateral control force should not reverse with increasing control deflection. There is no quantitative requirement for roll rate but roll rate capability should be qualitatively evaluated and shown to be adequate.

Acceptable Test Program. The following represents an acceptable test program for general controllability and maneuverability, subject to the provisions outlined above:
a. Maximum landing weight, forward center of gravity position, symmetric fuel loading.
b. In the configurations listed in the table below, trim at the specified speeds in level flight and conduct the following maneuvers:
i. establish a 30° bank level turn;
ii. Using a step input of approximately 1/3 full lateral control deflection, roll the airplane in the other direction;
iii. When the airplane reaches approximately 20° bank in the opposite direction, apply the same lateral control input in the opposite direction.
iv. Release input and recover as the airplane passes a wings level attitude.
v. Repeat the test procedure with 2/3 and then full lateral control deflection unless the roll rate is judged to be excessive.

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Configuration	*Trim Speed*
Holding configuration:	minimum holding speed (highest expected holding angle-of-attack)
Approach configuration	VREF
Highest lift landing configuration:	VREF

6. Stall Demonstration (§§ 23.201 and 23.203).
Sufficient stall testing should be conducted to demonstrate that the stall characteristics comply with the requirements. In general, it is not necessary to conduct a stall program which encompasses all weights, centre of gravity positions (including lateral asymmetry), altitudes, deceleration device configurations. Compliance to the quantitative roll excursion requirements of § 23.201(d) and 23.203(b)(4) is not required. Roll excursions should not exceed the values in § 23.201(d) and 23.203(b)(4) by a large amount, and roll characteristics should be qualitatively determined to be safe.
Based on a review of the stall characteristics of the non-contaminated airplane, a reduced test matrix can be established. However, additional testing may be necessary if:
• the stall characteristics with ice accretion show a significant difference from the non-contaminated airplane,
• testing indicates marginal compliance, or
• a stall identification system (e.g. stick pusher) is required to be reset for icing conditions.
Acceptable Test Program. The following represents an acceptable test program subject to the provisions outlined above. Turning flight stalls at decelerations greater than 1 knot/sec are not required.
a. Critical detect and exit ice shapes. Unless the applicant can substantiate one ice shape is critical for stall speed and angle of attack, the critical freezing drizzle ice shape, a freezing drizzle ice accretion of short duration that only results in roughness, and the critical freezing rain ice shape should be flight tested. The number of these shapes can be reduced if similarity can be shown to an airplane in which flight test data is available.
b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.
c. Normal stall test altitude.
d. In the configurations listed below, trim the airplane at the same initial stall speed factor used for stall speed determination. For power-on stalls, use the power setting as defined in § 23.201(e)(4) but with ice accretions on the airplane.
Decrease speed at up to 1 knot/sec to stall identification and recover using the same test technique as for the non-contaminated airplane.
i. High lift devices retracted configuration: Straight/Power Off, Straight/Power On, Turning/Power Off, Turning/Power On.
ii. Approach configuration: Straight/Power Off, Straight/Power On, Turning/Power Off, Turning/Power On..
iii. Highest lift landing configuration approved for icing: Straight/Power Off, Straight/Power On, Turning/Power Off, Turning/Power On.

e. For at least one straight/power off stall in each configuration, during the deceleration and at speeds down to stall warning, roll aircraft left and right up to 10 degrees bank using lateral control. It must be possible to produce and correct roll by unreversed use of lateral control. There should be no snatching (i.e. sudden, sharp oscillations or reversals in control force) of the pilot's lateral control.

7. Stall Warning (§ 23.207). As stated in paragraph (i) of the rule, the means for stall warning with Appendix C ice accretion, Appendix O detect and exit and pre-detection, must be the same as in non-icing.

a. Normal Ice Protection System Operation (§ 23.207(h)). The detect and exit ice shape represents ice accretion after the pilot has detected Appendix O conditions and has exited icing conditions. The stall warning margin with detect and exit ice shapes is reduced from Appendix C with the intent that the stall warning schedule designed for Appendix C ice accretions can comply with § 23.207(j). The intent is to avoid designs that require pilot action to implement an Appendix O stall warning schedule. It is assumed that Appendix C stall warning schedules are implemented automatically following activation of the engine or airframe ice protection system.

Acceptable Test Program. The following represents an acceptable test program:

a. In the configurations listed below, trim the airplane at 1.5 VS1.
i. High lift devices retracted configuration: Straight/Power Off, Straight/Power On, Turning/Power Off, Turning/Power On
ii. Approach configuration: Straight/Power Off, Straight/Power On, Turning/Power Off, Turning/Power On
iii. Landing configuration: Straight/Power Off
b. At decelerations of up to 1 knot per second, reduce the speed to stall warning plus 3 seconds, and demonstrate that stalling can be prevented using the same test technique as for the non-contaminated airplane, without encountering any adverse characteristics (e.g., a rapid roll-off). Recovery at stall warning should also be evaluated by applying the manufacturer's procedures.

b. Ice Accretion Prior to Detection of Appendix O icing conditions (for airplanes not certified for flight throughout the icing conditions of Appendix O) (§ 23.207(h)). For assessing compliance with the ice accretion prior to detection of Appendix O icing conditions, it is assumed that the airplane has been in icing conditions long enough for the ice protection system to have been activated. Therefore, any changes to stall warning or stall identification system settings resulting from activation of the ice protection system are assumed to have taken place. The stall warning requirements for pre-detection Appendix O (visual cues) are the same as detect and exit. Therefore if one stall warning schedule is utilized for icing (Appendix C and detect and exit), in most applications the stall warning tests with detect and exit (§ 23.207(j)) can be used to show compliance with (§ 23.207(i).

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If the AFM will prohibit autopilot use following detection of Appendix O conditions, safe operation with autopilot engaged should be shown prior to detection of Appendix O conditions. Approaches to stall warning with pre-detection ice should be accomplished to evaluate airplane response and verify acceptable stall warning margin .

8. Maneuver Margin (§ 23.207(d)). The airplane should be shown to be free of buffet and stall warning in 40° bank turns at approach speed in all approach flap configurations. Tests should be conducted with thrust/power for a 3° glide slope, and with thrust/power to maintain altitude.

9. Wind Velocities (§ 23.233).
Crosswind landings with detect and exit ice should be evaluated on an opportunity basis.
The results of the steady heading sideslip tests with detect and exit 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 noncontaminated airplane, and the flight characteristics (e.g. control forces and deflections) are similar, then the non-contaminated airplane crosswind component is considered valid.
If the results of the comparison discussed in paragraph TBD, 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, similar to the method for Appendix C.

10. Ground and Water Handling Characteristics – Longitudinal stability and control (§ 23.231). No dedicated tests required, can be evaluated during landings.

11. Ground and Water Handling Characteristics – Directional stability and control (§ 23.233). No dedicated tests required, can be evaluated during landings.

12. Operation on water (**§ 23.237).** Applicable for amphibians and seaplanes approved for flight in icing conditions.

13. Vibration and Buffeting (§ 23.251).
Qualitative evaluations should be combined with the other testing. Evaluation can be limited to 250 KCAS, Vne, an airspeed shown to have no ice accretion, or a reduced speed limit published in the AFM for SLD exit procedures.

14. Definition of Sideslip Angle Appropriate to the Type of the Airplane.

For the purpose of showing compliance the requirements presented in this guidance material, the sideslip angle appropriate to the type of the airplane may be defined considering one of the options below:

- The sideslip angle that cover conservatively crosswind operation, engine failure scenarios, and other conditions where sideslip may be experienced within the approved normal flight envelope.

- In the absence of appropriate data, a conservative approach is the adoption of:

  - A value of 15 deg as a conservative approach provided that this value can be considered appropriate for the type of aircraft based on the review of sideslip angle obtained during the demonstration of lateral and directional static stability with landing configuration at Vref.

  - A value based in the following equation based on the theoretical sideslip value for a 30 knots crosswind derived for transport category airplanes. This equation has been shown to conservatively represent (i.e., exceed) the sideslip angles achieved in maximum crosswind takeoffs and landings and minimum static and dynamic control speed testing for a variety of transport category airplanes.

$$\beta = \arcsin\left(\frac{30}{V}\right)$$

$$\textit{Where}: \beta = \textit{sideslip angle}$$

$$V = \textit{Airspeed}\,(\textit{kcas})$$

The results obtained from the use of this equation should be compared with the range of sideslip angles obtained during the steady heading sideslip maneuvers to avoid the adoption of a value greater than the airplane capacity to generate sideslip at operational speeds representative of takeoff and landing.
Note: The equation above maybe modified based on the experience of applicant by changing the constant value by the demonstrated crosswind component obtained during the no-icing tests.

- Any other value agreed with the certification authority.

APPENDIX 9. EXAMPLE FLIGHT TEST PROGRAM FOR COMPLIANCE TO § 23.21(C)(3) FOR APPROVAL TO TAKEOFF IN FREEZING DRIZZLE AND LIGHT FREEZING RAIN

1. General. Approval for takeoff in freezing drizzle and light freezing rain can be accomplished in three phases:

a. Dry air flight tests with ice shapes simulating accretion in the takeoff and initial climb out of freezing drizzle and freezing rain

b. Dry air flight tests with ice shapes simulating residual takeoff and climb ice accretion

c. Takeoff demonstrations in natural Appendix O conditions

2. Takeoff and climb in Appendix O conditions.

a. Ice shape definitions. The ice shapes flown are defined as follows:

1. Takeoff: As defined in table XXX.
2. Final Takeoff: As defined in table XXX.
3. Climb: As defined in table XXX.

b. Number of ice shapes to flight test. The number of ice shapes can be reduced as follows:

1. "Final takeoff ice" may be used for "takeoff ice" if shown to be more critical (chord location of ice due to high flap deflection may have to be addressed).

2. The "enroute ice" accretion may be used for "final takeoff" or "takeoff" if shown to be more critical (chord location of ice due to high flap deflection may have to be addressed).

3. The ice accretion(s) that has the most adverse effect on stall and handling qualities may be used for airplane performance tests provided any difference in performance is conservatively taken into account.

4. The applicant should evaluate the proposed cold weather operations procedures and determine if any untreated surfaces can accrete ice, such as upper fuselage. The drag due to ice accretion on these surfaces may be analytically calculated.

5. Either the critical freezing drizzle or freezing rain may be tested, if substantiated to be more critical. Note that the vertical extent of FZDZ is larger than FZRA.

c. Assumptions. For both unprotected and protected parts, the ice accretion for the takeoff phase must be determined for the icing conditions defined in paragraph 2.a. above, using the following assumptions:

1. The airfoils, control surfaces, and, if applicable, propellers are free from frost, snow, or ice at the start of takeoff;

2. The test program assumes Type II, III or IV fluids are approved for the airplane and these fluids keep the lifting surfaces clean until lift-off;

3. The ice accretion begins at liftoff;
4. The critical ratio of thrust/power-to-weight;
5. Failure of the critical engine occurs at V_{EF}; and
6. Crew activation of the ice protection system is in accordance with a normal operating procedure provided in the Airplane Flight Manual, except that after beginning the takeoff roll, it must be assumed that the crew takes no action to activate the ice protection system until the airplane is at least 400 feet above the takeoff surface.
7. FAA approved takeoff performance data assumes a clean, dry runway.

d. Flight tests. The table below provides guidance for each of the applicable Subpart B regulations.

23.45	**General (performance)**	**Applicable.**
23.49(a) and (b)	Stall speed	Tested in same manner as Appendix C ice shapes in following configurations: High lift devices retracted configuration, "Final Take-off Ice." High lift devices retracted configuration, "En-route Ice." Holding configuration, "Holding Ice." Lowest lift take-off configuration, "Holding Ice." Highest lift take-off configuration, "Take-off Ice."
23.51	Takeoff speeds	The values of V_{MCG} and V_{MC} determined for non-icing conditions may be used. The value of V_{S1} must be based on “Takeoff Ice”, if required per the rule.
23.53	Takeoff performance	Takeoff performance is determined with engine power losses associated with ice protection equipment that is not prohibited for takeoff.
23.55	Accelerate-stop distance	The effect of any increase in V_1 due to take-off in icing conditions may be determined by a suitable analysis.
23.57	Takeoff path	The effect of the take-off speed increase, thrust loss, and drag increase on the take-off path may be determined by a suitable analysis.
23.59	Takeoff distance and takeoff run	The effect of the take-off speed increase, thrust loss, and drag increase on the take-off distance and run may be determined by a suitable analysis.
23.61	Takeoff flight path	The effect of the speed increase for icing, thrust loss, and drag increase on the take-off flight path may be determined by a suitable analysis.
23.63	Climb: general	Climb speeds are based on V_{S1} determined with applicable ice accretion.

23.45	**General (performance)**	**Applicable.**
23.65	Climb: AEO	Approved take-off lift configurations, "Takeoff Ice." Not applicable if stall speed and climb requirement icing/non-icing differences comply with regulation.
23.66	Takeoff climb: OEI	Approved take-off lift configurations, "Takeoff Ice."
23.67	Climb: One engine inoperative	Not applicable if stall speed and climb requirements of regulation are complied with.
23.67(a)	GW<6000 Normal, Utility, & Acro	High lift devices retracted configuration, "Final Takeoff Ice."
23.67(b)(1)	GW>6000 Normal, Utility, & Acro	Lowest lift take-off configuration, "Takeoff Ice."
23.67(b)(2)	GW>6000 Normal, Utility, & Acro	High lift devices retracted configuration, "Final Takeoff Ice."
23.67(c)(1)	TO GD Commuter	Highest lift take-off configuration, landing gear extended, "Takeoff Ice."
23.67(c)(2)	TO GU Commuter	Lowest lift take-off configuration, landing gear retracted, "Takeoff Ice."
23.67(c)(3)	Climb OEI Final TO Commuter	High lift devices retracted configuration, "Final Takeoff Ice."
23.67(c)(4)	Climb OEI Approach Commuter	NOTE 2
23.69(a)	Enroute flight path AEO	Evaluated with “Enroute Ice.” Climb speeds are based on V_{S1} determined with “Enroute Ice.” Not applicable if climb speed and service ceiling icing/non-icing comply with regulation.
23.69(b)	Enroute flight path OEI	Evaluated with “Enroute Ice.” Climb speeds are based on V_{S1} determined with “Enroute Ice.”
23.71	Glide: Single engine airplanes	Evaluated with “Enroute Ice.”
23.73	Reference landing approach speed	Not applicable.
23.75	Landing distances	Not applicable.
23.77	Landing climb AEO	Not applicable.
23.141	Flight characteristics: General	Applicable as defined in guidance for following sections.
23.143(a)	Safely controllable & maneuverable	Applicable for appropriate flight phases

Appendix 9

23.45	**General (performance)**	**Applicable.**
23.143(b)	Smooth transitions in conditions	It must be possible to make a smooth transition from one flight condition to another (including turns and slips) without danger of exceeding the limit load factor, under any probable operating condition. AEO only. May be evaluated concurrently with other flight tests.
23.143(b)	Sudden failure of engine	Not applicable.
23.143(c)	Control force limits	Applicable
23.143(d)	ICTS	Zero g pushovers and sideslip evaluated at: Approved take-off lift configurations, V_{50} or V_2, "Takeoff Ice." Lowest lift take-off configuration, all-engines-operating initial climb speed, "Final Takeoff Ice" High lift devices retracted configuration, enroute climb speed, "Enroute Ice"
23.143(e)	Control – pre-activation ice	Not applicable.
23.143(f)	Control – detect & exit	Not applicable.
23.143(g)	Lateral control evaluation	Approved take-off lift configurations, V_{50} V_2, "Takeoff Ice." Lowest lift take-off configuration, all-engines-operating initial climb speed, "Final Takeoff Ice" High lift devices retracted configuration, enroute climb speed, "Enroute Ice"
23.145(a)	Pitch down capability	Highest lift take-off configuration, "Takeoff Ice." Highest lift take-off configuration, "Final takeoff Ice." High lift devices retracted configuration, "Enroute Ice"
23.145(b)(1)	Flap extension	Not applicable.
23.145(b)(2)	Go-around	Not applicable.

23.45	**General (performance)**	**Applicable.**
23.145(b)(3)	GA w/complete flap retract– no loss of altitude	Not applicable.
23.145(b)(4)	TO power	Not applicable.
23.145(b)(5)	Control power w/flaps extended	Not applicable.
23.145(b)(6)	Flap retraction	Highest lift take-off configuration, "Takeoff Ice." Highest lift take-off configuration, "Final takeoff Ice."
23.145(c)	1.5g capability above Vmo/Mmo	Not required.
23.145(d)	Power off glide gear and flap extended	Not required.
23.145(e)	Landing with primary FCS failure	Not required.
23.147(a)	Directional control - OEI	Evaluated with “Enroute Ice.”
23.147(b)	Sudden engine failure – 2 sec delay	Evaluated with “Enroute Ice.”
23.147(c)	Control with primary lateral FCS failure	Not required.
23.149	Minimum control speed	Compliance to paragraph (b) can be shown by showing simulated engine failures at V2 are controllable with all approved takeoff high lift configurations with “Takeoff Ice.”
23.151	Acrobatic maneuvers	Required for acrobatic and utility airplanes if such maneuvers are not prohibited in Appendix O conditions.
23.153	Control during landings	Not applicable.
23.155	Elevator control force in maneuvers	Applicable with “Enroute Ice. Evaluation limited to 250 KCAS, Vne, or an airspeed shown to have no ice accretion.
23.157	Rate of roll	Approved take-off lift configurations, 1.2V_S or 1.1V_{MC}, whichever is higher, "Final Takeoff Ice."
23.161	Trim	Evaluated concurrently with other tests.
23.171	General (stability)	Applicable.
23.173	Static longitudinal stability	Applicable.

Appendix 9

23.45	**General (performance)**	**Applicable.**
23.175	Demonstration of Static Long. Stab.	Only paragraph (a) is applicable, evaluated with “Enroute Ice”.
23.177	Static lateral-directional stability	Approved take-off lift configurations, V_{50} or V_2, "Takeoff Ice." Lowest lift take-off configuration, all-engines-operating initial climb speed, Final Takeoff Ice” High lift devices retracted configuration, enroute climb speed, “Enroute Ice”
23.181	Dynamic stability	Provided that there are no marginal compliance aspects with the non-contaminated airplane, it is not necessary to demonstrate dynamic stability in specific tests. Qualitative evaluations should be combined with the other testing. Any tendency to sustain oscillations in turbulence or difficulty in achieving precise attitude control should be investigated.
23.201 & 23.203	Stall characteristics	Applicable. One kt/sec wings level and turning stalls only. No accelerated turning stall. Configurations evaluated: All approved take-off lift configurations, "Takeoff Ice." Lowest lift take-off configuration, “Final Takeoff Ice” High lift devices retracted configuration, “Enroute Ice”
23.207(a)	Stall warning clear & distinctive	Applicable.
23.207(b)	Stall warning means	Applicable.
23.207(c)	Stall warning margin 5 KCAS	Stall warning should be assessed in conjunction with stall speed testing and stall characteristics testing.

23.45	**General (performance)**	**Applicable.**
23.207(d)	Maneuver margin	Airplane should be free of buffet and stall warning in following level altitude turns at specified bank: Approved take-off lift configurations, V_{50} or V_2, 40° bank, "Takeoff Ice." Approved take-off lift configurations, V_{50} or V_2, 30° bank, simulated thrust for OEI, "Takeoff Ice." Lowest lift take-off configuration, all-engines-operating initial climb speed, 40° bank, Final Takeoff Ice" High lift devices retracted configuration, minimum enroute climb speed, "Enroute Ice"
23.207(e)	Stall warning in accelerated turning stalls	Not required.
23.207(f)	Stall warning - acrobatic	Applicable if acrobatic category.
23.207(g)	Stall warning – pre-activation ice	Not applicable.
23.207(h)	Stall warning – detect and exit	Not required.
23.207(i)	Means of stall warning same in icing	Applicable. Means of stall warning in Appendix O same as non-icing and Appendix C.
23.207(e)	Stall warning 1.5g turns 2 kt/sec	Shouldn't be required to be consistent with current part 23 practice
23.207(f)	Acrobatic airplane stall warning	
23.221	Spinning	Not required.
23.231	Ground and water Longitudinal S&C	Applicable – no dedicated tests
23.233	Ground and water Directional S&C	Applicable – no dedicated tests. Crosswind capability can be determined similar to Appendix C.
23.235	Operation on unpaved surfaces	Not required.
23.237	Operation on water	Applicable – no dedicated tests

Appendix 9

23.45	**General (performance)**	**Applicable.**
23.239	Spray characteristics	Not required.
23.251	Vibration & buffeting	Applicable. Evaluation limited to 250 KCAS, V_{ne}, or an airspeed shown to have no ice accretion.
23.253	High speed characteristics	Not required.

3. Flight tests with Ice shapes simulating residual takeoff and climb ice accretion.

a. After takeoff into freezing drizzle or freezing rain conditions, several scenarios that result in additional ice accretions are possible:

1. The airplane has to immediately return and land; or
2. The airplane subsequently encounters Appendix C icing conditions; for which it is approved for flight in and is not required to exit;
3. The airplane encounters Appendix O conditions in a subsequent flight phase and must exit.

b. In the last two scenarios, ice may or may not sublimate off, depending on the flight and ambient conditions. It is possible that freezing rain ice accretions may be removed, if one assumes that a warm layer exists above the freezing rain. For an airplane that has to return and land, there is a high probability that not only will the takeoff ice accretions remain on the airplane, but additional ice will accrete. To address these scenarios, the applicant should show that:

1. The additional Subpart B requirements associated with holding, approach and landing phases are shown with the "Enroute" ice calculated for takeoff in Appendix O; and
2. Unless the applicant can empirically substantiate that Appendix O takeoff ice accretion will always shed under any foreseeable scenario, the applicant should conduct the flight tests in 1. above with Appendix C or Appendix O detect and exit ice shapes that are empirically determined by combining the critical Appendix O takeoff ice accretion ("Enroute") followed by the respective Appendix C or Appendix O detect and exit ice accretion (critical of approach or landing, as defined in Table XX of this AC, but holding need not be considered).

4. Natural icing flight tests

a. Appendix O Conditions. Takeoffs should be accomplished in Appendix O conditions to demonstrate that the airplane can safely takeoff in Appendix O conditions.

1. Appendix O Conditions. It is not necessary to quantify the conditions with airplane mounted equipment. Airport observations are sufficient. The following conditions should be demonstrated as a minimum:

(a) Moderate freezing drizzle
(b) Light freezing rain

2. Airplane Configuration

(a) Nominal weight and CG.

b. Ground Deicing/Anti-Icing Fluids. Type II and Type IV fluids have resulted in modifications of takeoff procedures due to changes in lift losses, control forces, or rotation characteristics. Assessment of the fluids prior to testing in natural freezing drizzle or freezing rain should be considered.

c. Demonstration Objectives. The following should be evaluated

1. Takeoff performance
2. Longitudinal controllability at rotation and during climb
3. Lateral/directional controllability during climb
4. Flap and gear operation

Part 23 SLD ARC REPORT
APPENDIX E – OPERATIONS COST SURVEY

This appendix provides information received by the ARC relative to surveys distributed by the operations sub-group.

Regional Air Cargo Carriers Association (RACCA) Survey

With respect to operation in ground icing conditions	Yes	No	extra
if the appropriate anti-icing procedures and time limits are followed, is your operation currently approved to takeoff in freezing drizzle?	1	4	
if the appropriate anti-icing procedures and time limits are followed, is your operation currently approved to takeoff in light freezing rain?	2	3	
Presuming that you're considering a new aircraft	**Yes**	**No**	**extra**
would a newly certificated airplane in which takeoff or flight in freezing drizzle was prohibited by an operating limitation have a significantly negative effect on the airplane's viability in your operation?	3	2	
would a newly certificated airplane in which takeoff or flight in freezing rain was prohibited by an operating limitation have a significantly negative effect on the airplane's viability in your operation?	3	2	
would a newly certificated airplane in which takeoff or flight in freezing drizzle was prohibited by an operating limitation bias you against purchasing it?	4	1	
would a newly certificated airplane in which takeoff or flight in light freezing rain was prohibited by an operating limitation bias you against purchasing it?	3	1	not so much as freezing drizzle

Aircraft Owner and Pilots Association (AOPA) Survey

1. Is your aircraft equipped with a de-ice/anti-ice system?

#	Answer		Response	%
1	Yes		25	78%
2	No		7	22%
	Total		32	100%

2. Is your aircraft certified for flight into known icing conditions?

#	Answer		Response	%
1	Yes		21	88%
2	No		3	13%
	Total		24	100%

3. What type of operations do you use your aircraft for?

#	Answer		Response	%
1	Personal		2	10%
2	Business		4	19%
3	Both Personal and Business		15	71%
	Total		21	100%

4. Do you utilize de-ice/anti-ice fluid and hold-over times in your winter operations?

#	Answer		Response	%
1	Yes		11	52%
2	No		9	43%
3	Not Sure		1	5%
	Total		21	100%

5. Do your operations allow for takeoff in freezing drizzle/light freezing rain?

#	Answer		Response	%
1	Yes		6	50%
2	No		5	42%
3	Not Sure		1	8%
	Total		12	100%

6. Approximately how many times does this occur per year?

#	Answer		Response	%
1	0		0	0%
2	1		2	33%
3	2		2	33%
4	3-5		1	17%
5	6-10		0	0%
6	More than 10		1	17%
	Total		6	100%

7. On average, what is the cost (in dollars) of a canceled flight to you or your company?

Text Response
1000.00
3 TO 5 THOUSAND $

8. During winter operations, do your operations allow for landing in freezing drizzle/light freezing rain?

#	Answer		Response	%
1	Yes		9	45%
2	No		8	40%
3	Not Sure		3	15%
	Total		20	100%

9. Approximately how many times does this occur per year?

#	Answer		Response	%
1	0		1	11%
2	1		2	22%
3	2		3	33%
4	3-5		2	22%
5	6-10		0	0%
6	More than 10		1	11%
	Total		9	100%

10. If a divert is required, what is your average distance to an alternate airport?

#	Answer		Response	%
1	0-50 nm		5	26%
2	51-100 nm		12	63%
3	101-150 nm		1	5%
4	More than 150 nm		0	0%
5	Not sure		1	5%
	Total		19	100%

11. What is your average total fuel flow per hour in gallons?

Text Response
85
45
70
40
60
75
75
85
200
78
75 gph
90
65 GAL JET A
100
63
160
65
80
70

12. If you were in the market for a new aircraft, would you reconsider the purchase if that aircraft (certified for FIKI) carried a limitation that takeoffs and landings in freezing drizzle or freezing rain were prohibited?

#	Answer		Response	%
1	Yes		16	55%
2	No		6	21%
3	Not Sure		7	24%
	Total		29	100%

National Air Transportation Association (NATA) Survey

Do you operate FAR Part 23 airplanes under Part 135?		
Answer Options	Response Percent	Response Count
Yes	100.0%	6
No	0.0%	0
	answered question	6
	skipped question	0

What type(s) of Part 23 certificated airplanes do you operate? (Please check all that apply.)		
Answer Options	Response Percent	Response Count
Single-Engine Piston	0.0%	0
Multi-Engine Piston	66.7%	2
Single-Engine Turboprop	66.7%	2
Multi-Engine Turboprop	33.3%	1
Turbojet	33.3%	1
	answered question	3
	skipped question	3

Are any your Part 23 aircraft airplanes with a de-ice or anti-ice system certified for flight into known icing conditions?		
Answer Options	Response Percent	Response Count
Yes	100.0%	3
No	0.0%	0
	answered question	3
	skipped question	3

Do you utilize de-ice / anti-ice fluid on your Part 23 airplanes?		
Answer Options	Response Percent	Response Count
Yes	100.0%	3
No	0.0%	0
	answered question	3
	skipped question	3

Do you have OpsSpec authority to use an approved deicing/anti-icing program that complies with 121.629(c)?		
Answer Options	Response Percent	Response Count
Yes	33.3%	1
No	66.7%	2
	answered question	3
	skipped question	3

Does your operation allow for takeoff in (check all that apply):		
Answer Options	Response Percent	Response Count
Light freezing drizzle	66.7%	2
Freezing drizzle	66.7%	2
Light freezing rain	66.7%	2
Freezing rain	66.7%	2
None of the above	33.3%	1
	answered question	3
	skipped question	3

When utilizing your Part 23 airplane(s), how often on average, during the past five winter seasons, have takeoffs in freezing precipitation occurred?		
Answer Options	Response Percent	Response Count
0-3	0.0%	0
4-6	0.0%	0
7-10	0.0%	0
11-15	0.0%	0
More than 15	100.0%	2
	answered question	2
	skipped question	4

When utilizing your Part 23 airplane(s), how often on average, during the past five winter seasons, have you been unable to dispatch those airplane(s) because of freezing precipitation?

Answer Options	Response Percent	Response Count
0-3	0.0%	0
4-6	50.0%	1
7-10	0.0%	0
11-15	0.0%	0
More than 15	50.0%	1
	answered question	2
	skipped question	4

How often on average, during the past five winter seasons, did you have to divert your Part 23 airplane(s) because of freezing precipitation at the destination?

Answer Options	Response Percent	Response Count
0-3	50.0%	1
4-6	0.0%	0
7-10	50.0%	1
11-15	0.0%	0
More than 15	0.0%	0
	answered question	2
	skipped question	4

How often on average, during the past five winter seasons, did your Part 23 airplane(s) divert because of icing conditions encountered en-route?		
Answer Options	Response Percent	Response Count
0-3	50.0%	1
4-6	50.0%	1
7-10	0.0%	0
11-15	0.0%	0
More than 15	0.0%	0
	answered question	2
	skipped question	4

How often on average, during the past five winter seasons, have you been unable to dispatch your Part 23 airplane because of freezing precipitation?		
Answer Options	Response Percent	Response Count
0-3	100.0%	2
4-6	0.0%	0
7-10	0.0%	0
11-15	0.0%	0
More than 15	0.0%	0
	answered question	2
	skipped question	4

How often on average, during the past five winter seasons did you have to divert your Part 23 aircraft because of freezing precipitation at the destination?		
Answer Options	Response Percent	Response Count
0-3	50.0%	1
4-6	50.0%	1
7-10	0.0%	0
11-15	0.0%	0
More than 15	0.0%	0
	answered question	2
	skipped question	4

How often on average, during the past five winter seasons did your Part 23 aircraft divert because of icing conditions encountered en-route?		
Answer Options	Response Percent	Response Count
0-3	50.0%	1
4-6	50.0%	1
7-10	0.0%	0
11-15	0.0%	0
More than 15	0.0%	0
	answered question	2
	skipped question	4

In what FAA region do you conduct most of your operations?		
Answer Options	Response Percent	Response Count
Alaska	0.0%	0
Southwest	0.0%	0
Northwest Mountain	0.0%	0
New England	0.0%	0
Western Pacific	0.0%	0
Eastern	0.0%	0
Great Lakes	66.7%	2
Southern	33.3%	1
Central	0.0%	0
Hawaii	0.0%	0
	answered question	3
	skipped question	3

Part 23 Icing Accident Survey

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FAA-SAD P-23 Icing ARC

Differences Between P23 & P25

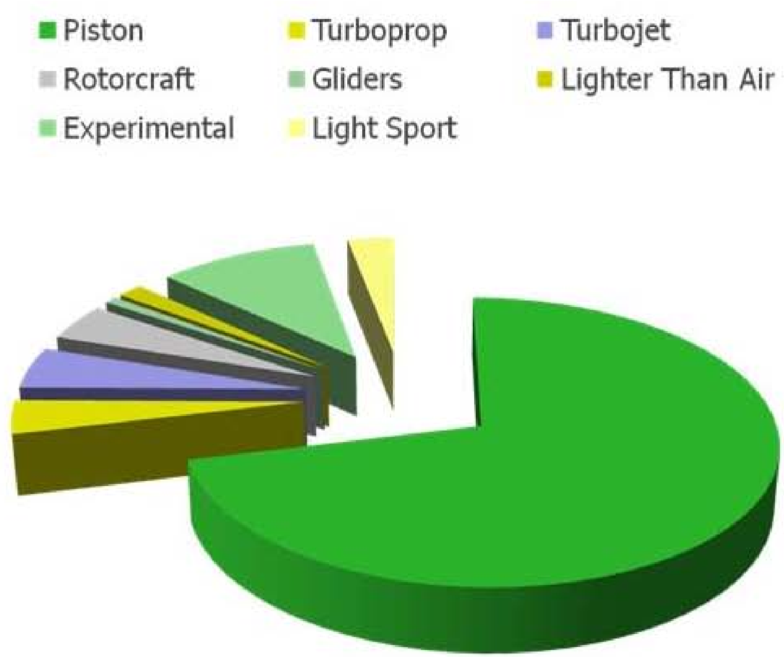
- Part 23 has many times more accidents each year when compared to part 25
  - Training grounds for new pilots
  - Less regulation on private use
  - Fewer professional flight crews
  - Fewer type rating required aircraft
  - Etc.
- Number of accidents allows for statistically relevant analysis not possible in part 25

FAA-SAD P-23 Icing ARC

U.S. Active Aircraft

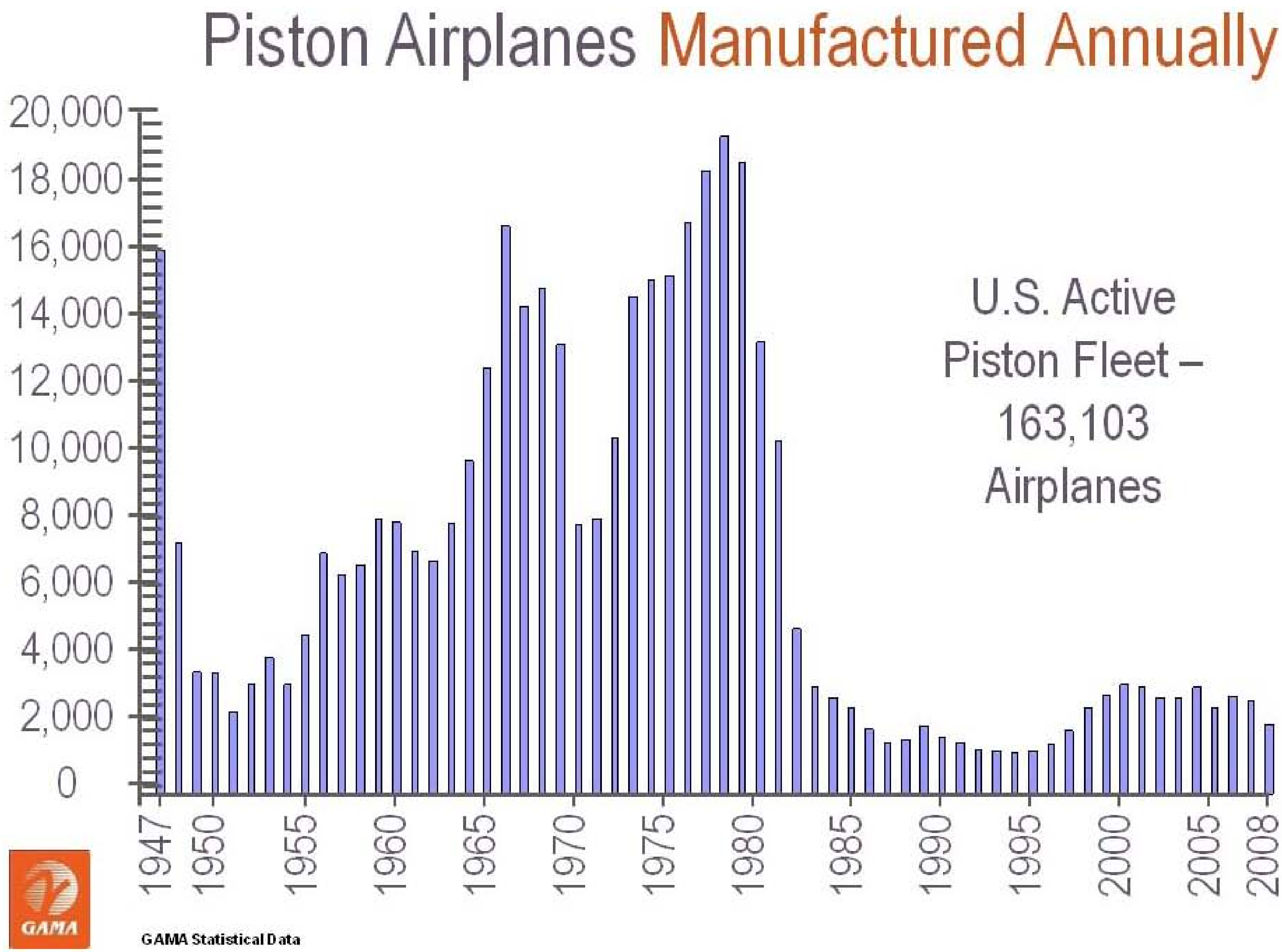
Active Aircraft

- 320,000 Worldwide
- 228,000 U.S.
- 163,103 U.S. Piston
- 145,497 U.S. Single Piston
- 17.515 U.S. Twin Piston



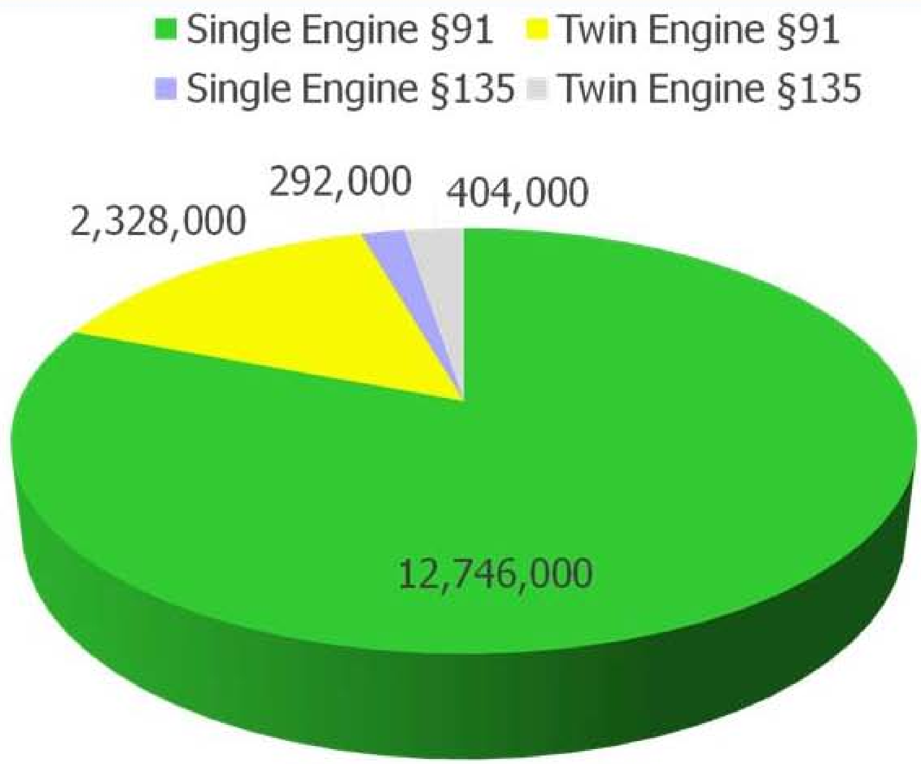
Source: FAA

FAA-SAD P-23 Icing ARC


Piston Airplanes Manufactured Annually
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1947
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2008
U.S. Active Piston Fleet – 163,103 Airplanes
GAMA
GAMA Statistical Data

GAMA

2008 U.S. Active Piston Fleet Hours



FAA-SAD P-23 Icing ARC

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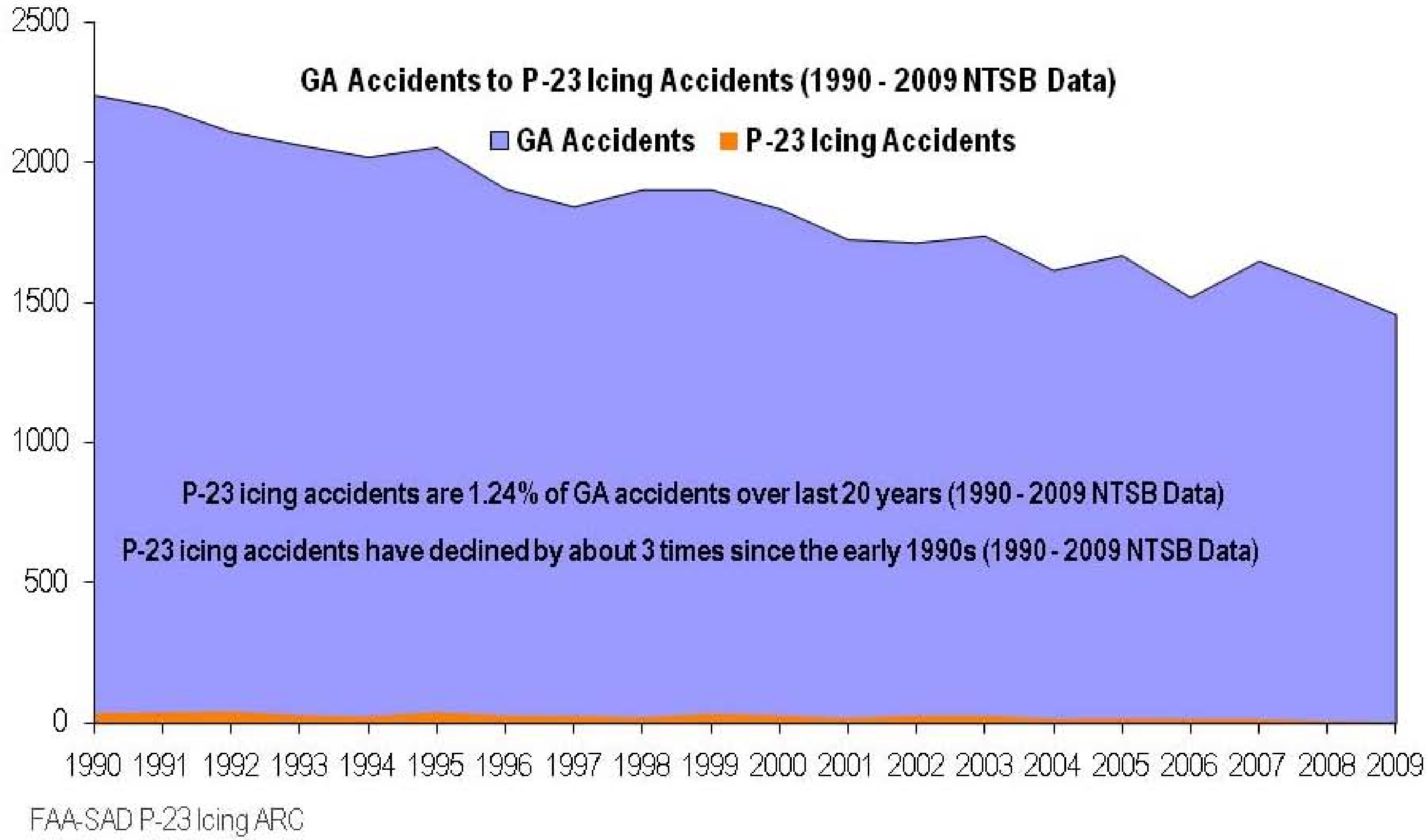
Population of Data

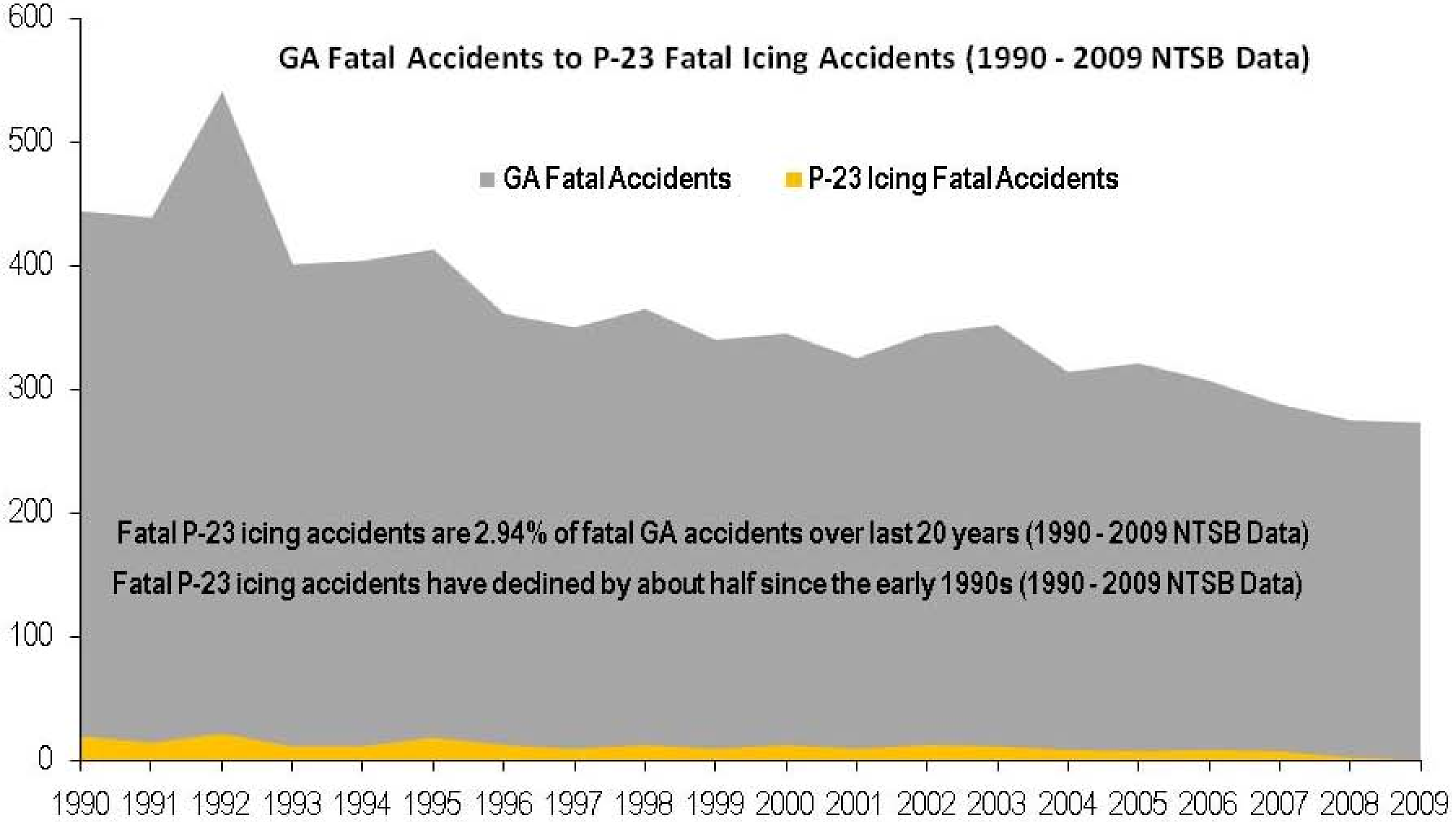
- NTSB Icing Accidents 1990 – 2009
  - Data set provided to GAO during 2010 independent review of icing accidents
  - NTSB data from 1988+ is standardized
    - Common accident themes
    - Frequency of events
- 457 "Icing Accidents" from 1990 – 2009
  - Fatal – 212
  - Serious Injury – 51
  - Minor Injury – 48
  - No Injury - 146

FAA-SAD P-23 Icing ARC

Total GA Accidents to P-23 Icing Accidents



Fatal GA Accidents to Fatal P-23 Icing Accidents



FAA-SAD P-23 Icing ARC

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Common Themes

- Major Themes:
  - Non-FIKI aircraft into forecast icing conditions
  - Attempted flight with ground ice & frost
  - Loss of forward visibility
  - Stall on Landing to Some Accumulations
  - Induction System Icing
  - SLD overwhelms de/anti-Ice systems

FAA-SAD P-23 Icing ARC

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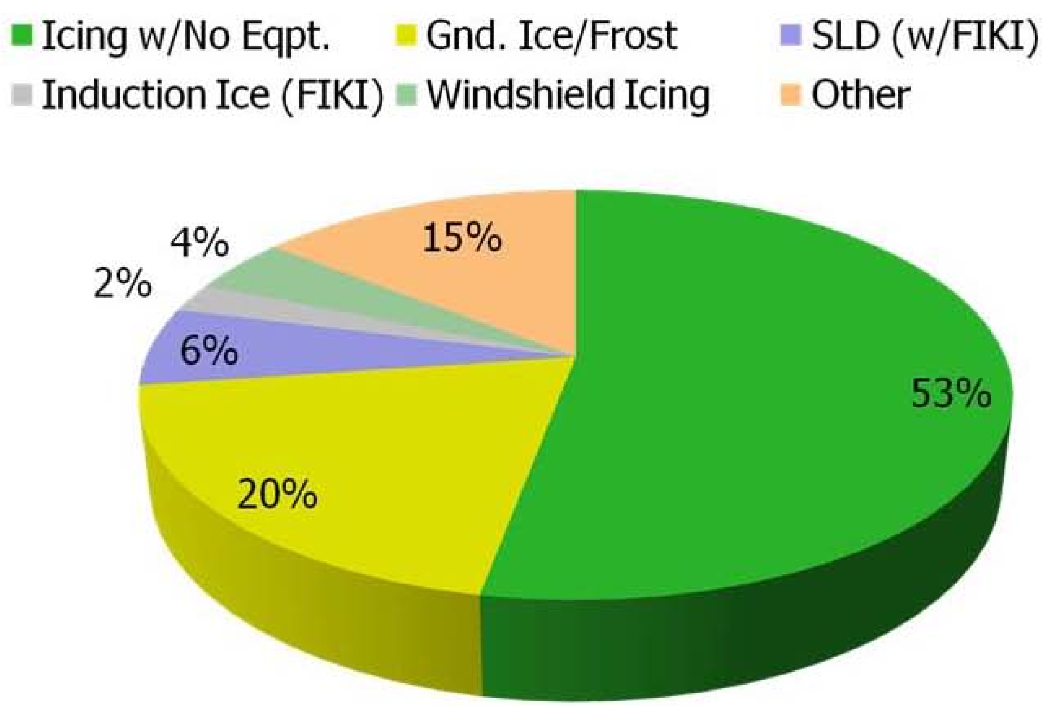
"Other" Icing Accidents

- Stall on Approach Due to Some Ice
- Frozen Pitot/Static
- Anti/De-Ice System Failures
- Didn't Use Anti-Ice System
- Loss of Traction on Landing
- Didn't Maintain Minimum Icing Airspeed
- Unknown

FAA-SAD P-23 Icing ARC

1990-2001 §23 Icing Accident Causes (257 Total)



FAA-SAD P-23 Icing ARC

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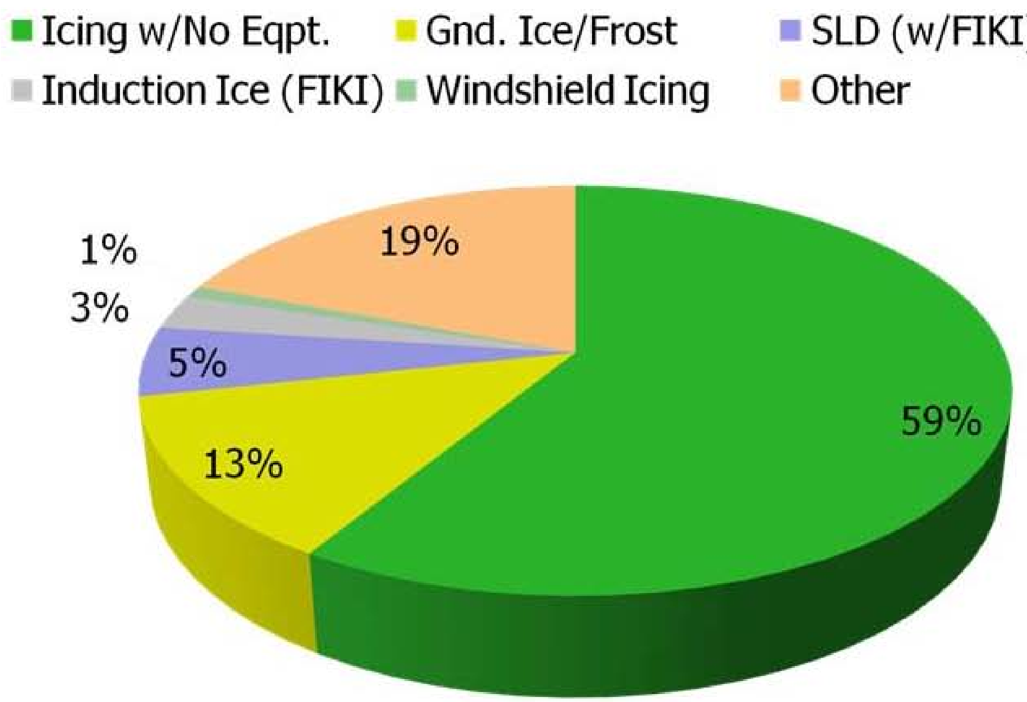
1990-2001 §23 Fatal Icing Accident Causes (109 Total)



FAA-SAD P-23 Icing ARC

"Other" Icing Accidents

- Stall on Approach Due to Some Ice
- Frozen Pitot/Static
- Anti/De-Ice System Failures
- Didn't Use Anti-Ice System
- Loss of Traction on Landing
- Didn't Maintain Minimum Icing Airspeed
- Unknown

FAA-SAD P-23 Icing ARC

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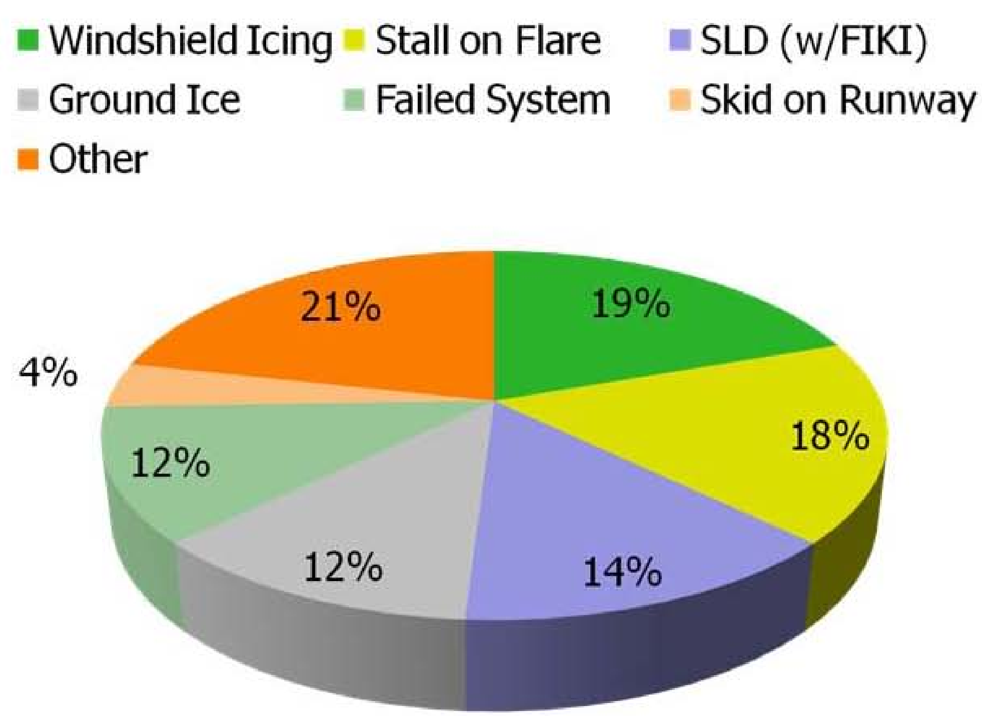
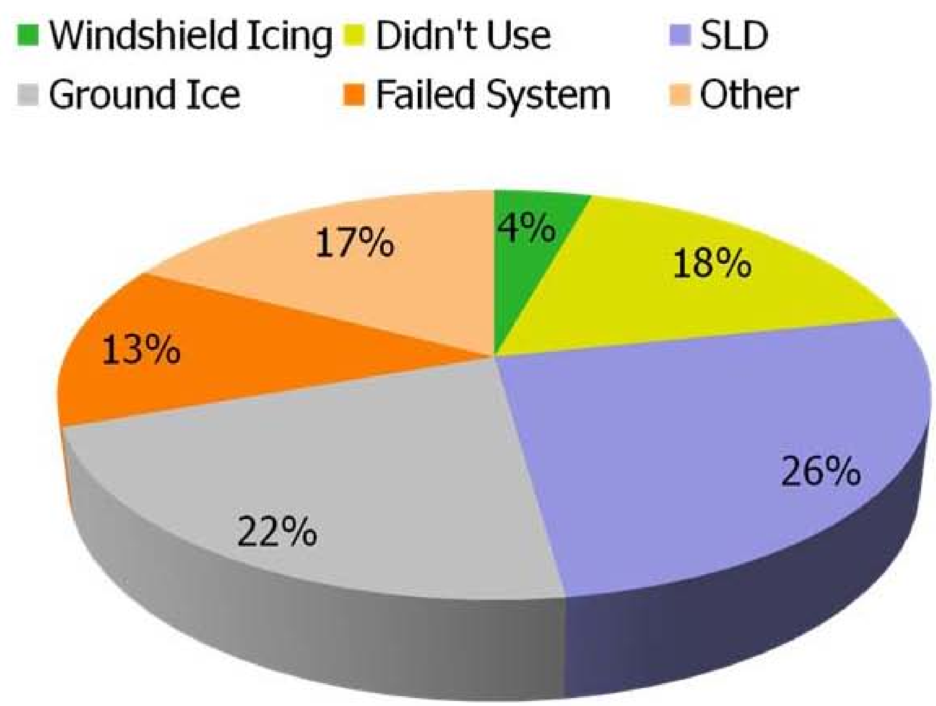
1990-2001 §23 FIKI Icing Accident Causes (51 Total)



FAA-SAD P-23 Icing ARC

1990-2001 §23 Fatal FIKI Approved Icing Accident Causes (23 Total)



FAA-SAD P-23 Icing ARC

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Operational Rule Effectiveness

- Operational Issues
  - Large Safety Benefit (Existing Fleet so Large)
  - More Difficult to Control than Design
    - Assume 30% Effective Peak (Ramp Up/Ramp Down)
- Majority of Accidents are Operational Issues
  - 53% Flight into icing w/no equipment
    - Education Campaign (30% Effective) = 15% Reduction in Icing Accidents Immediately
  - 20% Ground icing takeoffs
    - Education Campaign (30% Effective) = 6% Reduction in Icing Accidents Immediately

FAA-SAD P-23 Icing ARC

Design Rule Effectiveness

- Design Rule Effectiveness
  - Smaller Safety Benefit
  - More Definite Results
  - Slower Benefit (New Models to Existing Models)
    - Existing Fleet 228,000 Airplanes
    - 1% retirement/year
    - New Non-FIKI – 1333/year
    - New FIKI (SLD Proof) – 1616 per year
    - New Designs Adopted @ 10%/year to year 10

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Design Rule Effectiveness

- SLD Represents 6% of Accidents Today
  - "Bulletproof" Design (100% effective, Typical Production Rates, 10% New Design Adoption/Year)

Year	Total Icing Accident Reduction	Fatal Icing Accident Reduction	FIKI Icing Accident Reduction	Fatal FIKI Accident Reduction
1	0%	0%	0%	0%
5	0%	0%	0.1%	0.1%
10	0.2%	0.1%	0.4%	0.7%
15	0.4%	0.3%	0.9%	1.6%
20	0.6%	0.5%	1.3%	2.5%

FAA-SAD P-23 Icing ARC

Suggested Direction

- Auto Ice Detection Represents 18% of Fatal FIKI Accidents Today
  - "Bulletproof" Design (100% effective, Typical Production Rates, 10% New Design Adoption/Year)

Year	Fatal FIKI Accident Reduction
1	0%
5	0.1%
10	.5%
15	1.1%
20	1.7%

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Design Rule Effectiveness

- Failure Detection Represents 12% of FIKI Equipped Accidents Today
  - "Bulletproof" Design (100% effective, Typical Production Rates, 10% New Design Adoption/Year)

Year	FIKI Icing Accident Reduction	Fatal FIKI Accident Reduction
1	0%	0%
5	0.1%	0.1%
10	0.3%	0.3%
15	0.7%	0.7%
20	1.1%	1.1%

FAA-SAD P-23 Icing ARC

Summary Chart

- Reductions in Total Icing Accidents (23 per year)

Year	Flight into Icing w/o Equip.	Takeoff w/Ground Frost	SLD Icing	W/S Icing
1	5%	2%	0%	0%
5	10%	4%	0%	0.1%
10	15%	6%	0.2%	0.7%
15	10%	4%	0.4%	1.6%
20	5%	2%	0.6%	2.5%
Total 20yr	47	19	1	4

= Operational Changes

= Design Changes

FAA-SAD P-23 Icing ARC

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Summary Chart

- Reductions in Fatal Icing Accidents (10 per year)

Year	Flight into Icing w/o Equip.	Takeoff w/Ground Frost	SLD Icing	W/S Icing
1	6%	1%	0%	0%
5	12%	2%	0%	0.0%
10	18%	4%	0.1%	0.0%
15	12%	2%	0.3%	0.1%
20	6%	1%	0.5%	0.1%
Total 20yr	24	4	0	0

= Operational Changes

= Design Changes

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Summary Chart

- Reductions in FIKI Approved Icing Accidents (5 per year)

Year	W/S Icing	Stall on Flare	SLD Icing	Ground Frost	Fail Detect
1	0%	0%	0%	1%	0%
5	0.1%	0.1%	0.1%	2%	0.1%
10	0.5%	0.5%	0.4%	4%	0.3%
15	1.2%	1.1%	0.9%	2%	0.7%
20	1.8%	1.7%	1.3%	1%	1.1%
Total 20yr	1	1	0	2	0

[dark grey box] = Operational Changes

[green box] = Design Changes

FAA-SAD P-23 Icing ARC

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Summary Chart

- Reductions in Fatal FIKI Approved Icing Accidents (2 per year)

Year	Auto Detect	Fail Detect	SLD Icing	Ground Frost	W/S Icing
1	0%	0%	0%	2%	0%
5	0.1%	0.1%	0.1%	4%	0%
10	.5%	0.3%	0.7%	7%	0.1%
15	1.1%	0.7%	1.6%	4%	0.2%
20	1.7%	1.1%	2.5%	0.4	1.1%
Total 20yr	0	0	0	2	0

= Operational Changes

= Design Changes

FAA-SAD P-23 Icing ARC