Standard Specification for Ice Protection for General Aviation Aircraft[1]

This standard is issued under the fixed designation F3120/F3120M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers international standards for ice protection aspects of airworthiness and design for "general aviation" aircraft.

1.2 The applicant for a design approval must seek the individual guidance of their respective CAA body concerning the use of this standard as part of a certification plan. For information on which CAA regulatory bodies have accepted this standard (in whole or in part) as a means of compliance to their Small Aircraft Airworthiness regulations (hereinafter referred to as "the Rules"), refer to ASTM F44 webpage (www.ASTM.org/COMMITTEE/F44.htm) which includes CAA website links.

1.3 *Units*—The values are stated in units common to the field of aircraft icing. Typically SI or inch-pound units are used, but in some cases this has resulted in the use of mixed units due to the historical development of these values. In cases where values are given in one system with the other system following in brackets, the values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F3060 Terminology for Aircraft

F3061 Specification for Systems and Equipment in Small Aircraft

F3066/F3066M Specification for Powerplant Systems Specific Hazard Mitigation

F3093/F3093M Specification for Aeroelasticity Requirements

2.2 *Federal Standards:*[3]

14 CFR Part 33 (Amdt 34) Airworthiness Standards: Aircraft Engines

14 CFR Part 23 (Amdt 62) Airworthiness Standards: Normal, Utility, Aerobatic, and Commuter Category Aircraft

2.3 *Other Standard:*

SAE AS5562 Ice and Rain Minimum Qualification Standards for Pitot and Pitot-static Probes[4]

3. Terminology

3.1 Refer to Terminology F3060 for definitions of terms in this standard.

3.2 *Acronyms:*

3.2.1 *ICTS*—ice contaminated tailplane stall

3.2.2 *IPS*—ice protection system

3.2.3 *SLD*—supercooled large droplets

3.2.4 *TTO Probe*—total temperature probe

4. Applicability

4.1 *Operational Requirements*—The aircraft level of approval determines which portions of this specification are applicable for a specific project. The requirements are defined in Table 1.

5. Crew External Visibility

5.1 *Windshields and Windows*—For aircraft approved for flight in icing conditions, a means must be provided to prevent or to clear accumulations of ice from the windshield on an area sufficiently large to provide the view specified in 23.775(f). This means must be designed to function in the icing conditions specified in Section 11 for which approval is sought.

[1] This specification is under the jurisdiction of ASTM Committee F44 on General Aviation Aircraft and is the direct responsibility of Subcommittee F44.10 on General.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, http://www.access.gpo.gov.

[4] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://aerospace.sae.org.

TABLE 1 Types of Aircraft Operational Requirements

Operational Requirements	Required Sections
Aircraft is approved for VFR operations	Sections 6.1.1, 6.2.1 and 10.
Aircraft is approved for IFR operations	Sections 6.1.1, 6.2.1, 8.1, 8.2, 8.3 and 10 considering the icing conditions specified in Sections 11.1 and 11.2
Aircraft is approved for flight in the icing conditions of Sections 11.1 and 11.2	Sections 5, 6, 7, 8, and 9 (Note Annex A1 and Annex A2 are required by Section 9) considering the icing conditions specified in Sections 11.1, 11.2 and A2.4. For Section 8, consideration of the icing conditions of Section 11.5 must be shown
Aircraft is approved for flight in the icing conditions of Sections 11.1 and 11.2 along with portions of Section 11.4	Sections 5, 6, 7, 8, and 9 (Note Annex A1 and Annex A2 are required by Section 9) considering the icing conditions specified in Sections 11.1, 11.2 and the portions of 11.4 applicable to the conditions for which approval is sought For Section 8, consideration of the icing conditions of Section 11.5 must be shown
Aircraft is approved for flight in the icing conditions of Sections 11.1 and 11.2 along with all of Section 11.4	Sections 5, 6, 7, 8, and 9 (Note Annex A1 and Annex A2 are required by Section 9) considering the icing conditions specified in Sections 11.1, 11.2 and 11.4. For Section 8, consideration of the icing conditions of Section 11.5 must be shown

6. Ice Shedding

6.1 *Engine Inlet Ice Ingestion*—The ingestion of ice into the engine inlet must be considered by taking into account ice accumulation levels on the engine, inlet system, or airframe components for each turbine engine installation defined in accordance with Specification F3066/F3066M as follows:

6.1.1 For VFR only or VFR and IFR only aircraft, ice accumulations representative of an inadvertent encounter and subsequent exit from icing conditions specified in Sections 11.1 and 11.2 must be considered, assuming a minimum of a five minute exposure at the critical, continuous maximum icing conditions of Section 11.1.

6.1.2 For aircraft approved for flight in icing conditions, ice accumulations must be representative of the icing conditions in Section 11 for which approval is sought. The ice accumulations must be consistent with the icing exposures used for assessment of the aircraft performance and flight characteristics in Annex A1.

6.2 *Propeller Ice Shedding*—The formation and shedding of hazardous ice accumulation levels must be considered for each propeller installation defined in accordance to Specification F3066/F3066M as follows:

6.2.1 For aircraft with pusher propellers VFR only or VFR and IFR only aircraft, airframe ice accumulations of an inadvertent encounter and subsequent exit from icing conditions specified in Sections 11.1 and 11.2 must be considered, assuming a minimum of a five minute exposure at the critical, continuous maximum icing conditions of Section 11.1.

6.2.2 For aircraft approved for flight in icing conditions, airframe ice accumulations must be representative of the icing conditions in Section 11 for which approval is sought. The ice accumulations must be consistent with the icing exposures used for assessment of the aircraft performance and flight characteristics in Annex A1.

6.3 *Airframe Ice Shedding*—Ice accumulation levels and damage criteria that must be considered with respect to airframe ice shedding are as follows:

6.3.1 For aircraft approved for flight in icing conditions, airframe ice accumulations must be representative of the icing conditions in Section 11 for which approval is sought. The ice accumulations must be consistent with the icing exposures used for assessment of the aircraft performance and flight characteristics in Annex A1.

6.3.2 Any damage resulting from ice shedding:

6.3.2.1 Must not significantly affect the airframe's structural integrity.

6.3.2.2 Must not degrade performance and flight characteristics below levels required in 14 CFR Part 23 Amend 62 referenced in Section 2.

6.3.2.3 Be shown acceptable for continued in-service use.

6.4 *Ice Protection System Failure Considerations*—Hazards associated with the potential shedding of ice from normally protected surfaces that can result in engine ingestion or significant airframe damage (beyond levels required to meet 14 CFR Part 23 Amend 62 performance and flight characteristics) shall be mitigated through the safety analysis process as defined in Specification F3061. Ice accumulations must be representative of the icing conditions in Section 11 for which approval is sought using exit scenarios as described in A2.3. Consideration of system failures after an unintentional encounter outside of the approved icing conditions of Section 11 is not required.

7. Engine Installation and Induction System Ice Protection

7.1 *Propellers*—For aircraft approved for flight in icing conditions, propellers and other components of complete engine installations defined in accordance with Specification F3066/F3066M must meet the requirements of Section 7.1.1 through 7.1.2.

7.1.1 Ice accumulations must be representative of the icing conditions in Section 11 for which approval is sought. The ice accumulations must be consistent with the icing exposures used for assessment of the aircraft performance and flight characteristics in Annex A1.

7.1.2 An analysis shall be provided that:

7.1.2.1 Substantiates the chordwise and spanwise ice protection coverage.

7.1.2.2 Substantiates the ice protection system thermal energy rates or fluid rates.

7.1.2.3 Calculates intercycle ice accretions for propeller deice systems and shows resulting efficiency losses. The use of Fig. A1.1 or Fig. A1.2, as appropriate for the icing condition being addressed, is also acceptable in place of the analysis.

7.2 *Turbine Engines in Flight*—Each turbine engine and its air inlet system must operate throughout its flight power range as described in Specification F3066/F3066M:

7.2.1 In the icing conditions specified in Section 11 for which approval is sought.

7.2.2 In both falling and blowing snow conditions of Table 2 within the limitations established for the airplane for such operation.

7.3 *Turbine Engines on Ground*—Each turbine engine and its air inlet system must operate at idle on the ground as described in Specification F3066/F3066M.

7.3.1 In the rime and glaze icing conditions defined in Table 3.

7.3.2 For aircraft approved for operation in the icing conditions of Section 11.4, the large droplet condition as defined in Table 3 also applies.

7.3.3 In both falling and blowing snow of Table 2 within the limitations established for the airplane for such operation.

8. Instrumentation Ice Protection

8.1 If certification for instrument flight rules (IFR) or flight in icing conditions is requested, each airspeed system must have a heated pitot probe or an equivalent means of preventing malfunction due to icing.

8.1.1 The following icing conditions must be addressed:

8.1.1.1 For IFR certified airplanes, the continuous maximum and intermittent maximum icing conditions defined in Sections 11.1 and 11.2.

8.1.1.2 For flight into icing certified airplanes the icing conditions defined in Sections 11.1 through 11.4 for which certification is sought.

8.1.1.3 In addition to the requirements of Sections 8.1.1.1 and 8.1.1.2, for airplanes with V_{NE} or $V_{MO} \geq 250$ KCAS (and $M_{MO} \geq 0.6$) and a maximum certified altitude above 25 000 ft, the mixed phase and ice crystal conditions defined in Section 11.5.

8.1.2 Pitot probes which comply with SAE AS5562 meet the requirements of Section 8.1.1.

8.1.3 The following installation factors must be considered:

8.1.3.1 It shall be shown that qualification tests of the pitot probe utilize a concentration factor that is equal to or exceeds the concentration factor of the probe installed on the airplane.

8.1.3.2 For flight into icing certified airplanes, in the icing conditions for which certification is sought, it must be shown that any ice accretions on the airframe, forward of pitot probes, does not significantly affect airspeed indications.

TABLE 2 Falling and Blowing Snow Criteria for Turbine Aircraft Engines

Parameter	Description
Snow Condition	A "wet, sticky snow" which accumulates on unheated exterior and interior surfaces subject to impingement
Concentration	0.9 g/m^3 Liquid Water Equivalent or Equivalent to Rainfall of 2.5 mm/hr (Represents heavy snow with a visibility of ¼ mile or less)
Wind Velocity	Greater than 15 knots
Static Air Temperature	–4°C to 0°C (25°F to 32°F)

TABLE 3 Ground Icing Conditions for Turbine Aircraft Engines

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

8.2 If a flight instrument pitot probe heating system is installed to meet the requirements specified in Section 8.1, an alerting system must be provided to alert the flight crew when that pitot probe heating system is not operating.

8.2.1 The alert provided must conform to a "Caution" alert that is in clear view of a flightcrew member.

8.2.2 The alert required by 8.2 must be triggered in either of the following conditions:

8.2.2.1 The pitot heating system is switched "off"; except as provided in Sections 8.2.3 or 8.2.4.

8.2.2.2 The pitot heating system is switched "on" and any pitot probe heating element is inoperative.

8.2.3 The alert may be inhibited automatically by system design for the following conditions:

8.2.3.1 Ground operations.

8.2.3.2 In-flight at ambient temperature of +5°C or greater.

8.2.4 A placard or flight manual procedure that prescribes when to operate the pitot heating system may be used in lieu of 8.2.1 thru 8.2.3 if the airplane:

8.2.4.1 Is not certified for flight in icing conditions,

8.2.4.2 Does not have a service ceiling or maximum operating altitude above 18 000 ft, and

8.2.4.3 Is not certified as a level 4 aircraft.

8.3 If a static pressure system is necessary for the functioning of instruments, systems, or devices on airplanes certified for flight in instrument meteorological or icing conditions, each static pressure port must be designed or located in such a 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 of Section 11. Protecting the static pressure port(s) from the effects of ice accumulation, or utilizing an alternate source of static pressure that is protected from such effects may be necessary to comply with this requirement.

8.3.1 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 pressure system by more than 50 ft, a correction card for the alternate static pressure system must be made available to the pilot.

8.3.2 If an alternate source of static pressure is utilized, an indication or AFM procedure must be provided when switching to the alternate static pressure source is required in flight.

8.4 Angle of attack and stall warning devices on airplanes certified for flight into icing conditions are required to show by analysis and test that the respective heating systems are adequate throughout the icing conditions in Section 11 for which approval is sought.

8.4.1 If certification has been accomplished on prior type certificated aircraft whose designs are thermodynamically and aerodynamically equivalent to those used on a new aircraft design, certification may be accomplished by similarity provided any differences in the installation of these components is accounted for.

8.4.2 For airplanes with V_{NE} or $V_{MO} \geq 250$ KCAS (and $M_{MO} \geq 0.6$) and a maximum certified altitude above 25 000 ft, the mixed phase and ice crystal conditions defined in Section 11.5 for pressure sensing angle of attack devices must be addressed.

8.5 If engine inlet TTO probes are installed and provide data for thrust setting on airplanes certified for flight into known icing conditions, these probes must comply with one of Section 8.5.1 through Section 8.5.3. If service history shows unresolved icing related events, Section 8.5.4 through Section 8.5.6 must be met.

8.5.1 The probes were certified with the engine at FAA Part 33 Amendment 34 or higher.

8.5.2 The probes are not susceptible to blockage by ice crystals by design (e.g., are not heated).

8.5.3 The probes are similar to other designs which have no ice crystal events in service.

8.5.4 The system design mitigates the threat of ice crystal blockage by FADEC logic and flight crew warning indications or other similar means.

8.5.5 Show the amount of thrust loss due to TTO icing is less than 3 % at the take-off and go-around power settings. The value of 3 % is the interpretation of "serious loss of power or thrust" for compliance to FAA Part 33 Rule 68, Induction system icing, in past certification projects.

8.5.6 The AFM shall include any required statements and procedures associated with the requirements of 8.5.5.

9. Flight Into Icing Conditions

9.1 Certification for flight into icing conditions must comply with the requirements of 9.1.1 through 9.1.10.

9.1.1 Analyses must be performed to establish, on the basis of the aircraft's operational needs, the coverage and adequacy of the ice protection system for the various components of the aircraft as follows: *(1)* the icing conditions defined in Section 11 for which approval is sought, which shall include a 45 min hold with no horizontal extent correction; and *(2)* the flight conditions that provide the maximum water catch.

9.1.1.1 For airframe areas left unprotected, supporting data and rationale must be provided for allowing them to remain unprotected. Appendix X1 contains a list of areas that shall be considered. The performance and flight characteristics requirements of Section 9.1.6 and the shedding requirements of Section 6 shall be considered when determining airframe areas to be left unprotected.

9.1.1.2 A drop impingement and/or water catch analysis shall be accomplished, of the wing, horizontal and vertical stabilizers, and any other leading edges or protuberances that may require protection as applicable for the type of ice protection system.

(1) The analysis must consider all the airplane's flight configurations, phases of flight, and operating envelopes (including airspeeds, altitudes, and angles of attack).

(2) This analysis is needed to establish the chordwise extents of the areas to be protected or the potential for any impingement aft of the protected areas.

(3) A Langmuir A distribution at 40 µ MVD may be used in the chordwise protection analysis, however ice accretion that may result using Langmuir E and/or using local collection efficiencies below 0.1 shall be accounted for in defining critical ice accretions.

(4) This type of analysis also determines the quantity of heat (or flow rate for fluid systems) required for thermal (or fluid) ice protection systems.

(5) Analysis codes may be used provided they have been found acceptable by the governing civil aviation authority, or will be validated during subsequent tests. See Section A2.1.1.3.

9.1.2 When performing the system safety analysis required in Specification F3061 for the ice protection systems and airplane systems; 9.1.2.1 – 9.1.2.3 must be met.

9.1.2.1 Substantiation of the hazard classification of ice protection system failure conditions shall be accomplished through analysis and/or simulated failure ice shape flight testing.

9.1.2.2 Table 4 provides the probability of encountering the icing conditions in Section 11 for an airplane certified for flight in icing conditions.

9.1.2.3 Ice protection system power sources must meet the system safety analysis and power source capacity requirements of Specification F3061.

9.1.3 Critical ice shape accumulations on antennas, masts, or other components attached externally to the aircraft must not result in hazards, such as damage to these external components, or damage from ice shedding into the engines or impacting the airframe (reference Section 6).

9.1.3.1 Similarity to prior design, flight tests in simulated or natural icing conditions, critical shape impact assessments, or use of artificial ice shapes to assess bending or vibration characteristics of external components are all acceptable methods when properly substantiated.

9.1.4 When performing the flutter analysis required in Specification F3093/F3093M, any mass accumulations on unprotected and protected surfaces, including any accretions that could develop on control surfaces, must be considered. Ice

TABLE 4 Probability of Encountering Icing

NOTE 1—Probabilities should not be reduced based on phases of flight.

Airworthiness Level (per F3061)	Continuous Maximum and Intermittent Maximum Icing Conditions	Supercooled Large Drop Icing Conditions
1 2 3 4	10^{-1} per flight hour[A] 1	10^{-2} per flight hour[B]

[A] Based on NACA TN 3984 icing observations.
[B] Reference FAA AC 25-28 "Probability of Encountering Appendix O Conditions".

accretions to consider must include the holding and failure shapes defined in Annex A2.

9.1.5 When performing the electrical load analysis required in Specification F3061 the operation of ice protection systems and airplane systems must be considered throughout the airplane flight envelope under conditions requiring operation of the systems.

9.1.5.1 If applicable, a load shedding sequence must 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.

9.1.6 The performance and flight characteristics requirements of Annex A1 must be met.

9.1.7 Except as provided by Section 9.1.9, in addition to the analysis and physical evaluation prescribed in Sections 9.1.1 through 9.1.6, the effectiveness of the ice protection system as a whole and its components must be shown by flight tests of the aircraft or its components in measured natural atmospheric icing conditions.

9.1.8 One or more of the following tests, as found necessary to determine the adequacy of the ice protection system and airplane systems must be accomplished.

9.1.8.1 Laboratory dry air or simulated icing tests, or a combination of both, of the components or models of the components;

9.1.8.2 Flight dry air tests of the ice protection system as a whole, or its individual components;

9.1.8.3 Flight test of the aircraft or its components in measured simulated icing conditions;

9.1.8.4 Flight test of the aircraft in a cold soak condition following exposure to liquid precipitation to evaluate the following systems:

(1) Pneumatic systems susceptible to accumulations of ambient moisture.

(2) Angle of attack sensors.

9.1.9 If certification for flight into icing conditions has been accomplished on prior type certificated aircraft whose designs include components that are thermodynamically and aerodynamically equivalent to those used on a new aircraft design, certification of these equivalent components may be accomplished by similarity to meet the requirements in Section 9.1.1 and Section 9.1.7, provided that the applicant accounts for any differences in installation of these components.

9.1.10 A means must be provided for determining the formation of ice on the critical parts of the aircraft when required for activation of ice protection systems, or for exiting severe icing conditions.

9.1.10.1 For all phases of flight in which the ice protection system is allowed to be operated, 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.

(2) 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.

(3) 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.

(4) An advisory ice detection system that alerts the flightcrew to activate the airframe ice protection system in addition to (2) or (3).

9.1.10.2 For the cues in 9.1.10.1, adequate lighting must be provided for the use of this means during night operation.

(1) Any illumination must be of a type that will not cause glare or reflection that would handicap crewmembers in the performance of their duties.

9.1.10.3 For aircraft equipped for a crew of two pilots, if external visual cues are required for ice protection system activation or detection of freezing drizzle, freezing rain, or severe ice accretions, they shall be provided for both pilots in their normal seating position.

9.1.10.4 The airplane must incorporate provisions to allow the flightcrew close access to the wing upper surface to facilitate a pre-takeoff contamination inspection if not possible while standing on the ground. Recessed steps and handles in the fuselage, in proximity to the wing leading edge, would be one example.

9.1.11 After the initial activation of the airframe ice protection system:

9.1.11.1 The ice protection system must be designed to operate continuously; or

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

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

9.1.12 The following weight and center of gravity limitations (23.23 and 23.25) must be considered for flight into known icing aircraft.

9.1.12.1 No changes in the airplane load distribution limits and airplane weight limits, from those for non-icing conditions, are allowed for flight in icing conditions.

9.1.12.2 The flight tests required in Annex A1 shall be conducted at the critical weight and center of gravity position.

9.1.13 The Aircraft Flight Manual must contain information for the safe operation of the aircraft in icing conditions.

9.1.13.1 The limitations section of the AFM must include:

(1) A statement similar to the following: "In icing conditions the airplane and its ice protection systems must be operated 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."

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

(3) For high speed and level 4 category airplanes, a visual and tactile inspection of the wing leading edge and upper surface in:

(a) Ground icing conditions.

(b) Conditions conducive to upper wing surface ice accretion caused by cold soak fuel, unless it is shown that the aircraft design precludes such surface ice contamination.

(4) Minimum airspeed in icing conditions for all flap settings approved for flight in icing conditions.

(5) Flap:

(a) Maximum flap deflection if required to preclude ICTS.

(b) A statement similar to "flaps must be retracted for holding or extended operations in icing conditions."

(6) Ice protection systems:

(a) For airplanes without a primary ice detection system, the AFM Limitations shall require activation of ice protection systems at first sign of ice accretion on a specified monitored or reference surface or in potential icing conditions. Potential icing conditions shall be defined as 5°C ambient temperature/ 10° total temperature in visible moisture (clouds, fog, precipitation).

(b) For airplanes with fluid ice protection systems, the AFM Limitations shall state a minimum dispatch fluid level that is at least the amount required for protection for 45 min based on the flow rate required in critical continuous maximum icing conditions, with no correction for cloud horizontal extent.

(7) A statement prohibiting flight in severe icing conditions or conditions that are determined to contain freezing rain or freezing drizzle if approval did not include neither a portion nor the whole SLD envelope in Section 11.4, along with listing the following visual cues to identify these conditions:

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

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

(c) Accumulation of ice on the propeller spinner or engine nacelle farther back than normally observed.

(d) Accumulation of ice on cockpit side windows.

(e) Visible rain at temperatures below +5°C OAT.

(f) Droplets that splash or splatter on impact at temperatures below +5°C OAT.

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

(8) A statement that if the airplane encounters severe icing conditions or conditions that are determined to contain freezing rain or freezing drizzle, for which the airplane is not approved, the pilot must immediately exit them by changing altitude or course, or landing. If necessary, request ATC priority to exit the SLD conditions or declare an emergency. Additionally the following procedures must be included in the AFM limitations section:

(a) The autopilot must be disconnected. If the autopilot is engaged, hold the control wheel firmly and disengage the autopilot.

(b) If the flaps are extended, do not retract them until the airframe is clear of ice or airplane has landed.

(c) Avoid abrupt and excessive maneuvering.

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

(e) Report these weather conditions to ATC.

(9) All wing ice inspection lights must be operable prior to flight into known or forecast icing at night. This supersedes any relief provided by the Master Minimum Equipment List (MMEL).

9.1.13.2 The procedures section of the AFM must include:

(1) Pre-flight checks of ice protection systems prior to flights in known or forecast icing. Pre-flight procedures of fluid anti ice/deice systems shall be referenced in the Limitations section. Fluid systems, even when operational, may require time to "prime" the panels.

(2) Recovery procedure for stall warning, and low airspeed awareness system activation if applicable, that emphasizes reduction in angle of attack.

(3) Exiting SLD, if approval did not include either a portion or the whole envelope of Section 11.4.

9.1.13.3 The performance section of the AFM must include the following in the same format as non-icing performance data:

(1) Stall speed increase due to critical ice accretion and corrections on reference landing approach speed, V_{REF}.

(2) Effects of ice protection system operation and/or ice accretions, if applicable, on takeoff speeds and performance.

(3) Balked landing climb data, and approach climb data if required to be determined, with critical ice accretions.

(4) Enroute climb performance if the service ceiling with critical ice accretions is less than 22 000 ft.

(5) Landing distance data if reference landing approach speed, V_{REF} in icing conditions is higher than non-icing.

9.1.14 The airframe ice protection system must be designed and certified to the icing conditions of Section 11 for which approval is sought and be available above 30 000 ft. If the system is inhibited above 30 000 ft or if the airframe ice protection system performance is intentionally reduced to meet power availability requirements for altitudes above 30 000 ft, it must be shown that the airplane can operate safely in icing conditions at altitudes above 30 000 ft, or approval for flight in icing shall be restricted to operations below that altitude.

9.1.14.1 For airframe ice protection systems inhibited above 30 000 ft, the applicant must show compliance to the flight characteristic requirements in Annex A1.1.1 with either the critical ice accretions defined in Section 9.1.14.5 or with simulated failure ice shapes defined in Annex A2.3.

9.1.14.2 For airframe ice protection system with intentionally reduced performance to meet power availability requirements for altitudes above 30 000 ft, the applicant may show that the critical protected surface ice accretion above 30 000 ft is less critical than the critical protected surface ice that exists in Section 11 icing conditions for which approval is sought. "Less critical" must account for size, chord location, and shape of runback ice.

9.1.14.3 Analysis, validated by test, may be used to determine the wing runback ice that exists above 30 000 ft on thermal systems.

9.1.14.4 Dry air flight tests above 30 000 ft shall validate the internal heat model and empirical data must validate the external heat model. A pressurized icing tunnel or sea level tunnel with scaling for altitude may be acceptable sources of empirical data.

9.1.14.5 The critical ice accretion above 30 000 ft must consider:

(1) Unprotected surfaces, A transit (climb, cruise, or descent) through the more critical of Section 11.1 or 11.2 icing conditions.

(2) Protected surfaces: A transit (climb, cruise, or descent) at altitudes between 30 000 ft and the maximum operating altitude through the more critical of Section 11.1 or 11.2 icing conditions.

9.1.14.6 For turbojet engines mounted behind the wing, the applicant must show that shedding of ice accretions above 30 000 ft will not result in a loss of engine thrust. All the protected surface ice accretion shall be considered to shed at once. For example, an airplane in which the airframe ice protection is inhibited above 30 000 ft, all the ice will shed at once when the system is activated during descent through 30 000 ft.

10. Aircraft Not Approved for Flight in Icing

10.1 *Aircraft Without Airframe Ice Protection Systems*—Operating limitations and kinds of operation placards must specifically prohibit operation into known icing conditions.

10.2 *Aircraft With Inadvertent Encounter Ice Protection Systems:*

10.2.1 Ice protection systems that are installed on aircraft not approved for flight in icing are defined as inadvertent ice protection systems. These systems are neither designed, nor approved for flight in known icing conditions and are subject to the same operating limitations as aircraft without ice protection systems.

10.2.2 The installation of the system (not operating) must not degrade performance and flight characteristics below levels required in 14 CFR Part 23 Amend 62, referenced in Section 2.

10.2.3 If the operation of the system can affect the requirements of 14 CFR Part 23 Amend 62, referenced in Section 2, it must be demonstrated that there are no hazardous effects with system operation (for example, deicer inflation, fluid dispersion, hot bleed air effects).

10.2.4 The systems must meet the systems level requirements as defined in Specification F3061. However since the aircraft is not approved for flight in icing, the system hazard classification is "no safety effect".

10.2.5 Other systems requirements from Specification F3061 must be met similar to other non essential equipment. This includes consideration of potential effects on essential equipment and the potential for hazards due to system failures not related to icing effects.

10.2.6 Since this aircraft is prohibited from flight in icing, the ice protection effectiveness of the system when operating normally must not create a greater hazard than the same aircraft operating with no ice protection system. For example on systems where runback ice can be developed, it must be demonstrated than the effect of the runback is no greater than the potential effect of the same aircraft inadvertently encountering icing conditions.

10.2.7 AFM must include the system description and system operating information and provide guidance on operating the aircraft within the limitations of the approval (for example, not approved for flight into icing, abnormal procedures for inadvertent encounters).

10.2.8 AFM shall include warning information on the potential effects of inadvertent ice accumulations such as: the stall speeds may increase; stall warning may not be reliable; there are potential performance effects of ice accumulations, monitor airspeed; and any specific autopilot use instructions while exiting icing conditions.

11. Atmospheric Icing Conditions

11.1 The maximum continuous intensity of atmospheric icing conditions (Continuous Maximum Icing) is defined by the variables of the cloud liquid water content, the mean effective diameter of the cloud droplets, the ambient air temperature, and the inter-relationship of these three variables as shown in Fig. 1. The limiting icing envelope in terms of altitude and temperature is given in Fig. 2.

11.1.1 The inter-relationship of cloud liquid water content with drop diameter and altitude is determined from Fig. 1 and Fig. 2.

11.1.2 The cloud liquid water content for continuous maximum icing conditions of a horizontal extent, other than 17.4 nautical miles, is determined by the value of liquid water content of Fig. 1, multiplied by the appropriate factor from Fig. 3.

11.2 The intermittent maximum intensity of atmospheric icing conditions (Intermittent Maximum Icing) is defined by the variables of the cloud liquid water content, the mean effective diameter of the cloud droplets, the ambient air temperature, and the interrelationship of these three variables as shown in Fig. 4. The limiting icing envelope in terms of altitude and temperature is given in Fig. 5.

11.2.1 The inter-relationship of cloud liquid water content with drop diameter and altitude is determined from Fig. 4 and Fig. 5.

11.2.2 The cloud liquid water content for intermittent maximum icing conditions of a horizontal extent, other than 2.6 nautical miles, is determined by the value of cloud liquid water content of Fig. 4 multiplied by the appropriate factor in Fig. 6.

11.3 The maximum intensity of atmospheric icing conditions for takeoff (Takeoff Maximum Icing) is defined by the cloud liquid water content of 0.35 g/m^3, the mean effective diameter of the cloud droplets of 20 microns, and the ambient air temperature at ground level of –9°C. The Takeoff Maximum Icing conditions extend from ground level to a height of 1500 ft above the level of the takeoff surface.

11.4 Supercooled large drop (SLD) icing conditions consist of freezing drizzle and freezing rain occurring in and/or below stratiform clouds. SLD icing conditions are defined by the parameters of altitude, vertical and horizontal extent, temperature, liquid water content, and water mass distribution as a function of drop diameter distribution.

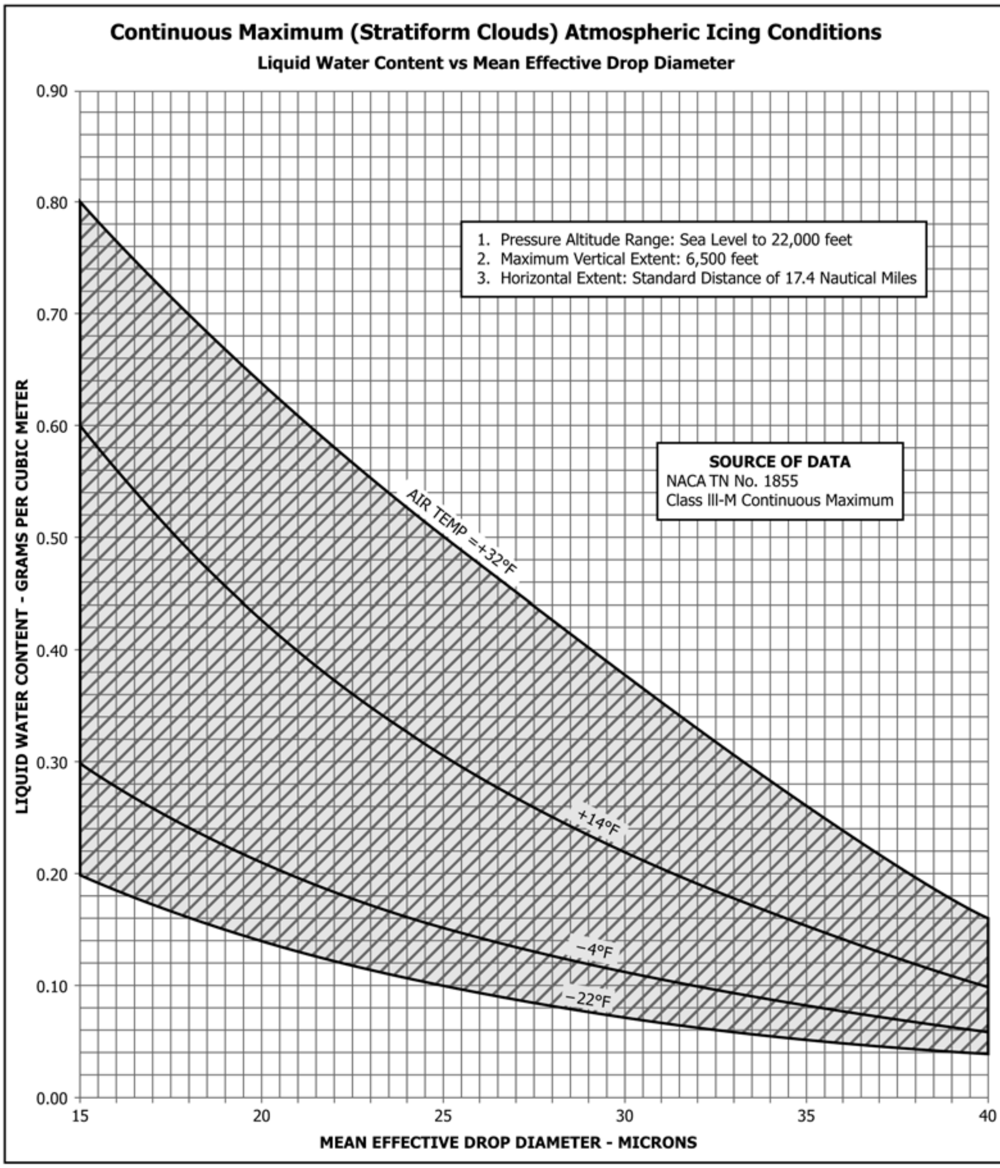

FIG. 1 Continuous Maximum (Stratiform Clouds) Icing Conditions – Liquid Water Content vs. Mean Effective Drop Diameter

11.4.1 *Freezing Drizzle*—Conditions with spectra maximum drop diameters from 100 µm to 500 µm.

11.4.1.1 Pressure altitude range: 0 to 22 000 ft MSL.

11.4.1.2 Maximum vertical extent: 12 000 ft.

11.4.1.3 Horizontal extent: standard distance of 17.4 nautical miles.

11.4.1.4 Total liquid water content: Fig. 7. Liquid water content (LWC) in grams per cubic meter (g/m^3) based on horizontal extent standard distance of 17.4 nautical miles.

11.4.1.5 Drop diameter distribution: Fig. 8.

11.4.1.6 Altitude and temperature envelope: Fig. 9.

11.4.2 *Freezing Rain*—Conditions with spectra maximum drop diameters greater than 500 µm.

11.4.2.1 Pressure altitude range: 0 to 12 000 ft MSL.

11.4.2.2 Maximum vertical extent: 7000 ft.

11.4.2.3 Horizontal extenet: standard distance of 17.4 nautical miles.

11.4.2.4 Total liquid water content: Fig. 10. Liquid water content (LWC) in grams per cubic meter (g/m^3) based on horizontal extent standard distance of 17.4 nautical miles.

11.4.2.5 Drop diameter distribution: Fig. 11.

11.4.2.6 Altitude and temperature envelope: Fig. 12.

11.4.3 *Horizontal Extent*—The liquid water content for freezing drizzle and freezing rain conditions for horizontal extents other than the standard 17.4 nautical miles can be determined by the value of the liquid water content determined from Fig. 7 or Fig. 10, multiplied by the factor provided in Fig. 13 which is defined by the equation $S = 1.266 - 0.213 \log10(H)$ where S = liquid water content scale factor (dimensionless) and H = horizontal extent in nautical miles.

11.5 *Mixed Phase and Ice Crystal Icing Envelope (Deep Convective Clouds)*—Ice crystal conditions exist within the Intermittent Maximum Icing envelope defined in Section 11.2,

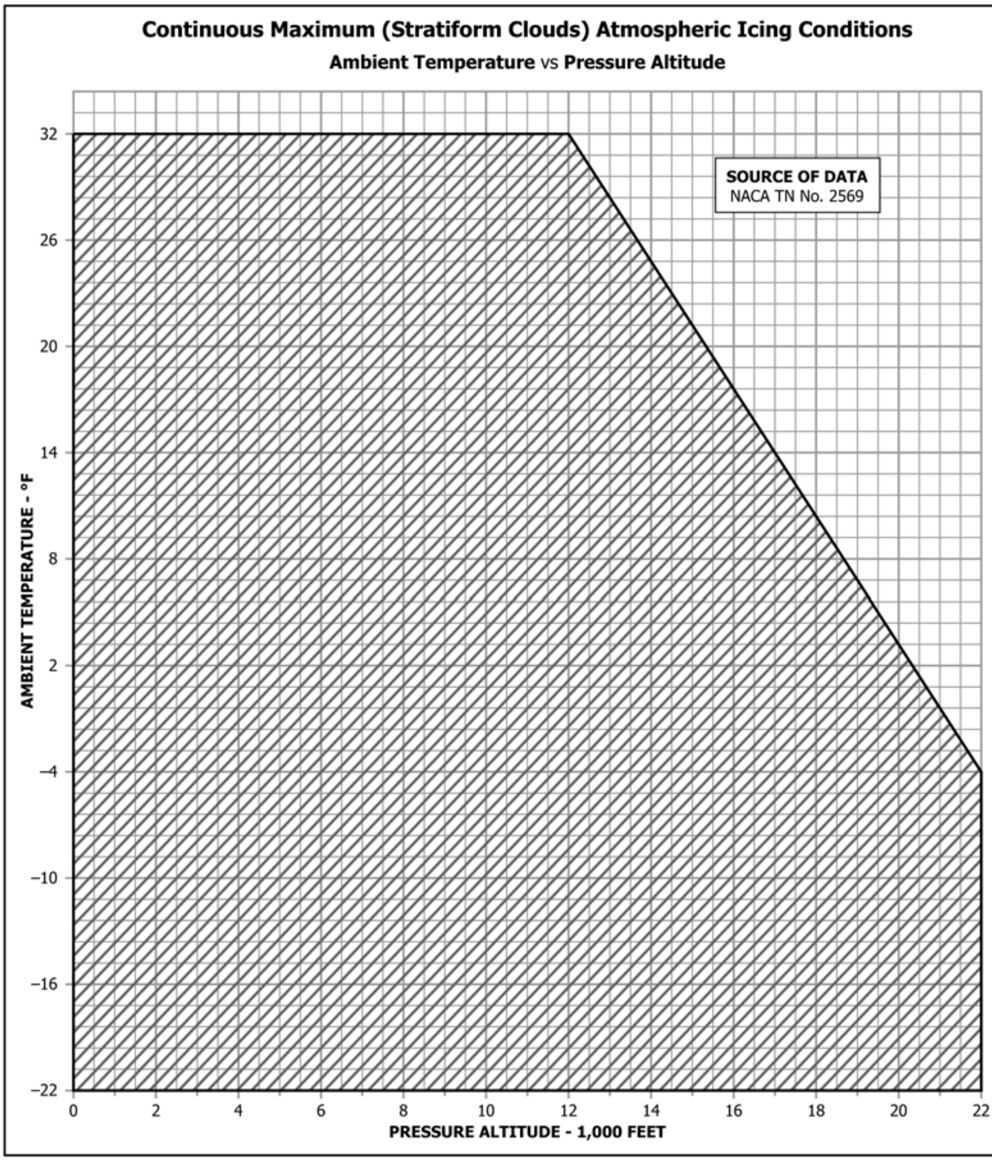

FIG. 2 Continuous Maximum (Stratiform Clouds) Icing Conditions – Ambient Temperature vs. Pressure Altitude

including the extension to –40°C, and the Mil Standard 210 hot day envelope. The ice crystal icing envelope is depicted in Fig. 14.

11.5.1 Within the envelope, total water content (TWC) in g/m^3 has been determined based upon the adiabatic lapse defined by the convective rise of 90 % relative humidity air from sea level to higher altitudes and scaled by a factor of 0.65 to a standard cloud length of 17.4 nautical miles. Fig. 15 displays TWC for this distance over a range of ambient temperatures within the boundaries of the ice crystal envelope specified in Fig. 14. Ice crystal size median mass dimension (MMD) range is 50 to 200 microns (equivalent spherical size) based upon measurements near convective storm cores. The TWC can be treated as completely glaciated (ice crystal) except as noted in Table 5: Supercooled Liquid Portion of TWC.

11.5.2 The TWC levels displayed in Fig. 15 represent TWC values for a standard exposure distance (horizontal cloud length) of 17.4 nautical miles that must be adjusted with length of icing exposure per Fig. 16.

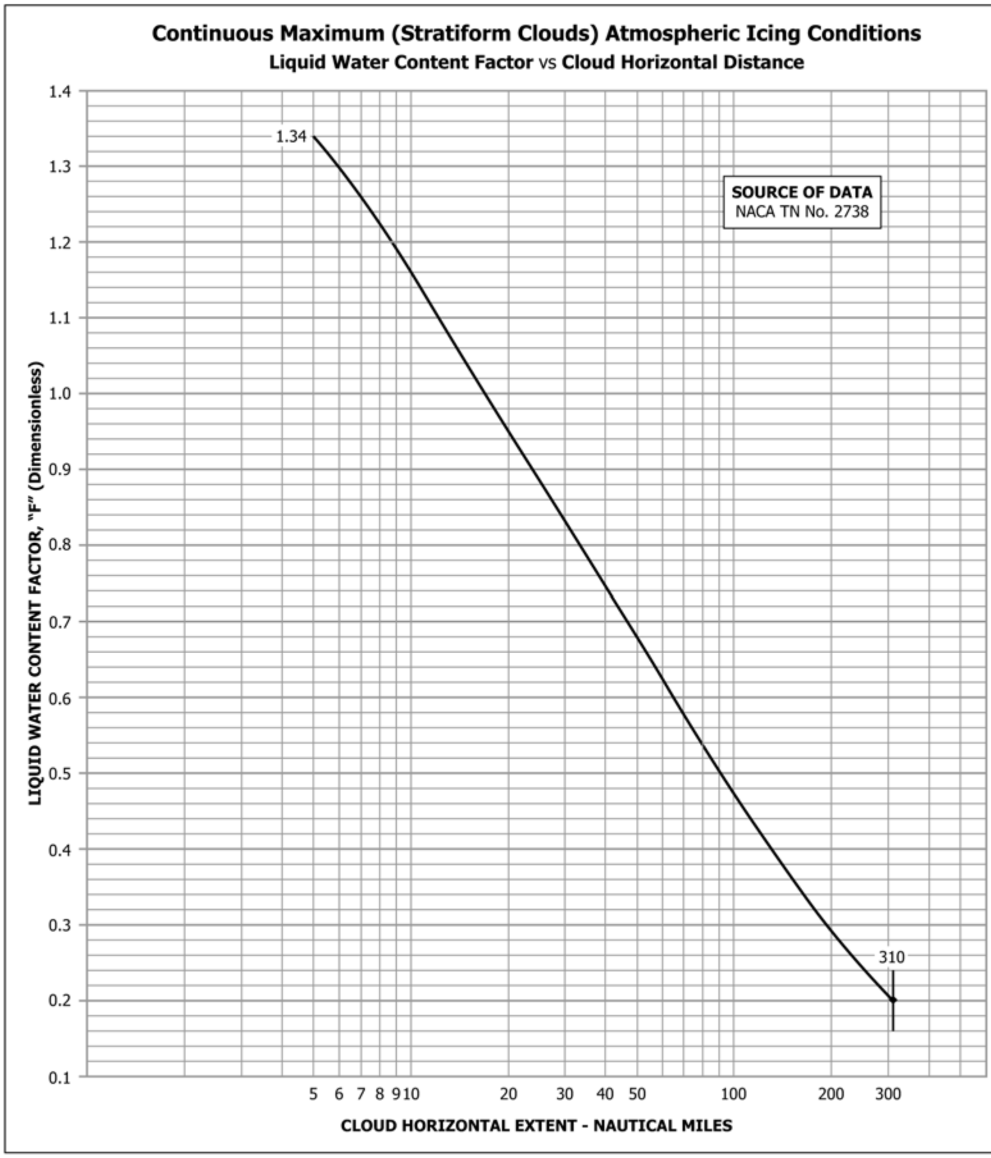

FIG. 3 Continuous Maximum (Stratiform Clouds) Icing Conditions – Liquid Water Content vs. Cloud Horizontal Distance

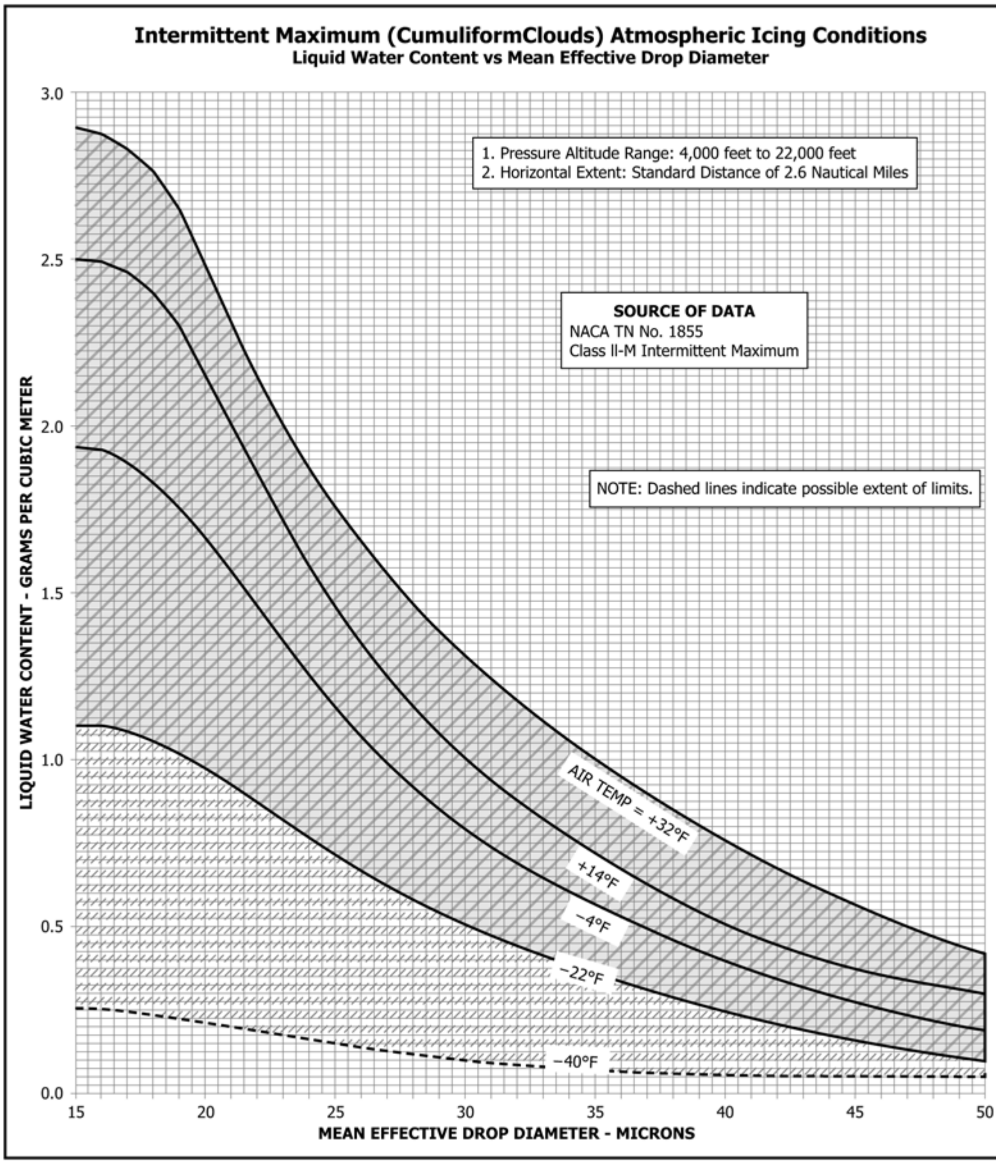

FIG. 4 Intermittent Maximum (Cumuliform Clouds) Icing Conditions – Liquid Water Content vs. Mean Effective Drop Diameter

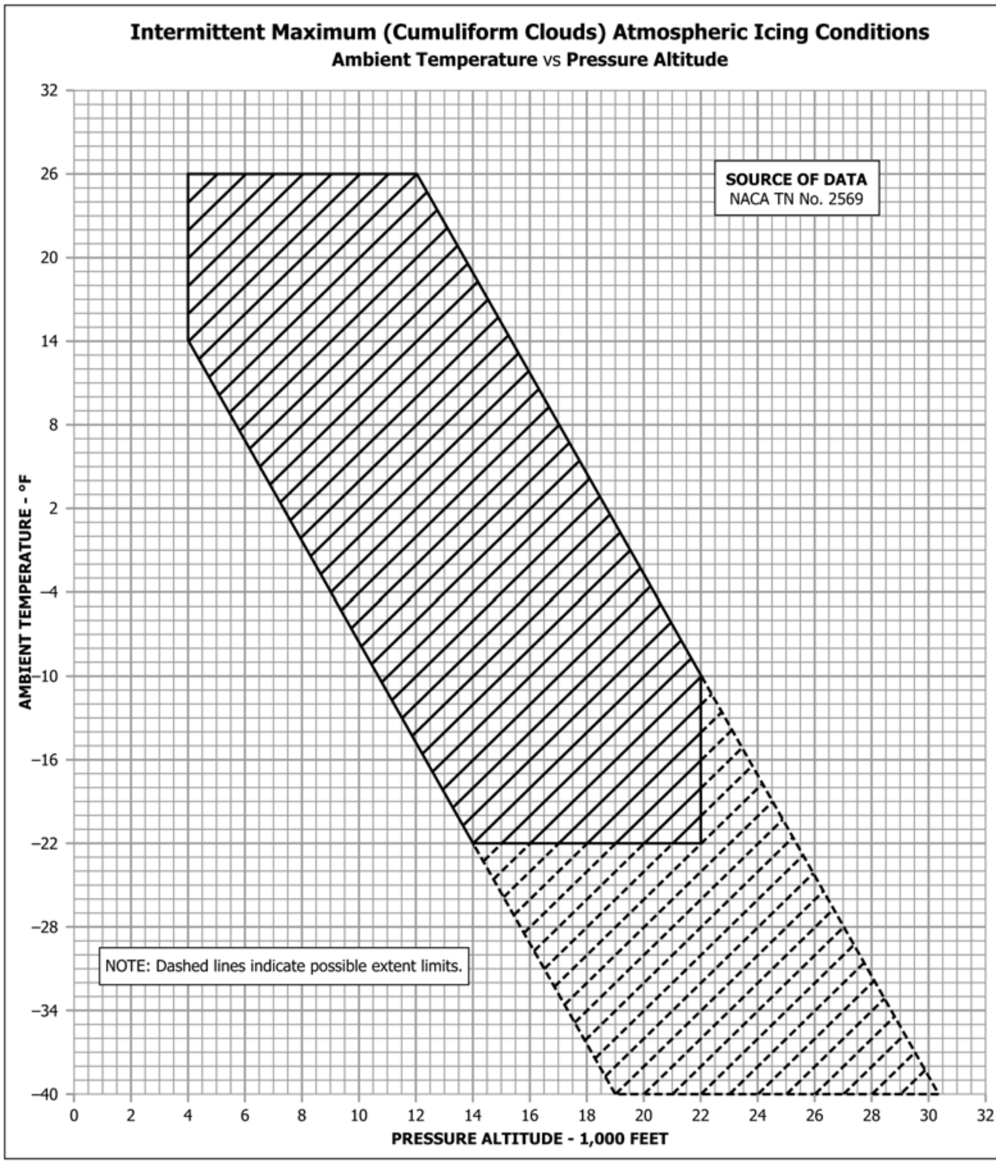

FIG. 5 Intermittent Maximum (Cumuliform Clouds) Icing Conditions – Ambient Temperature vs. Pressure Altitude

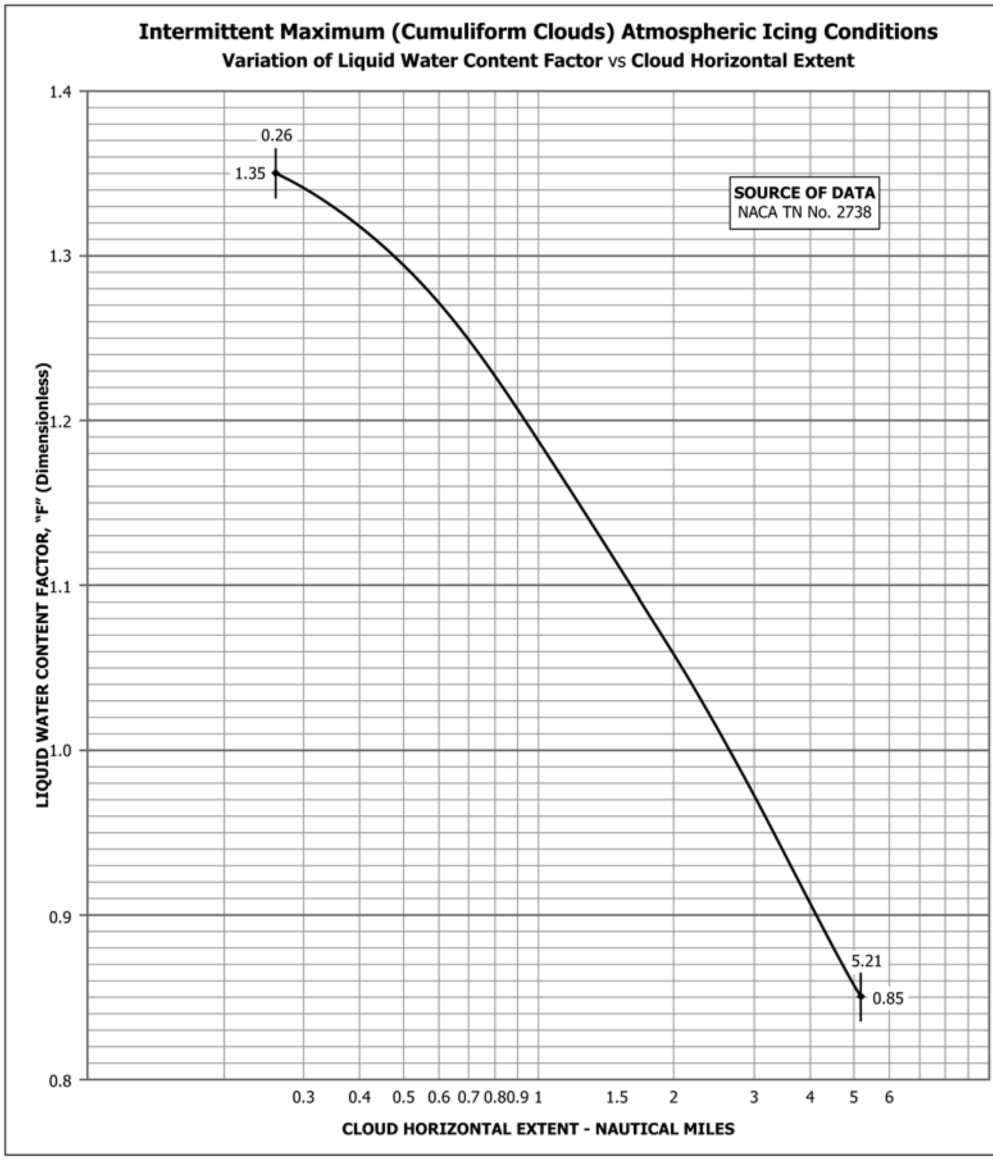

FIG. 6 Intermittent Maximum (Cumuliform Clouds) Icing Conditions – Variation of Liquid Water Content Factor with Cloud Horizontal Extent

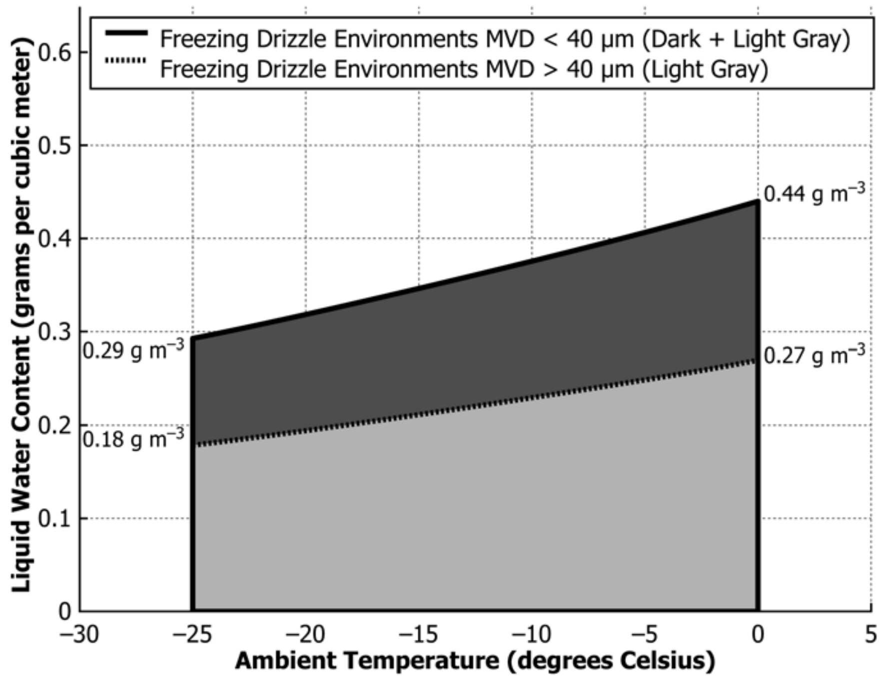

FIG. 7 Freezing Drizzle, Liquid Water Content

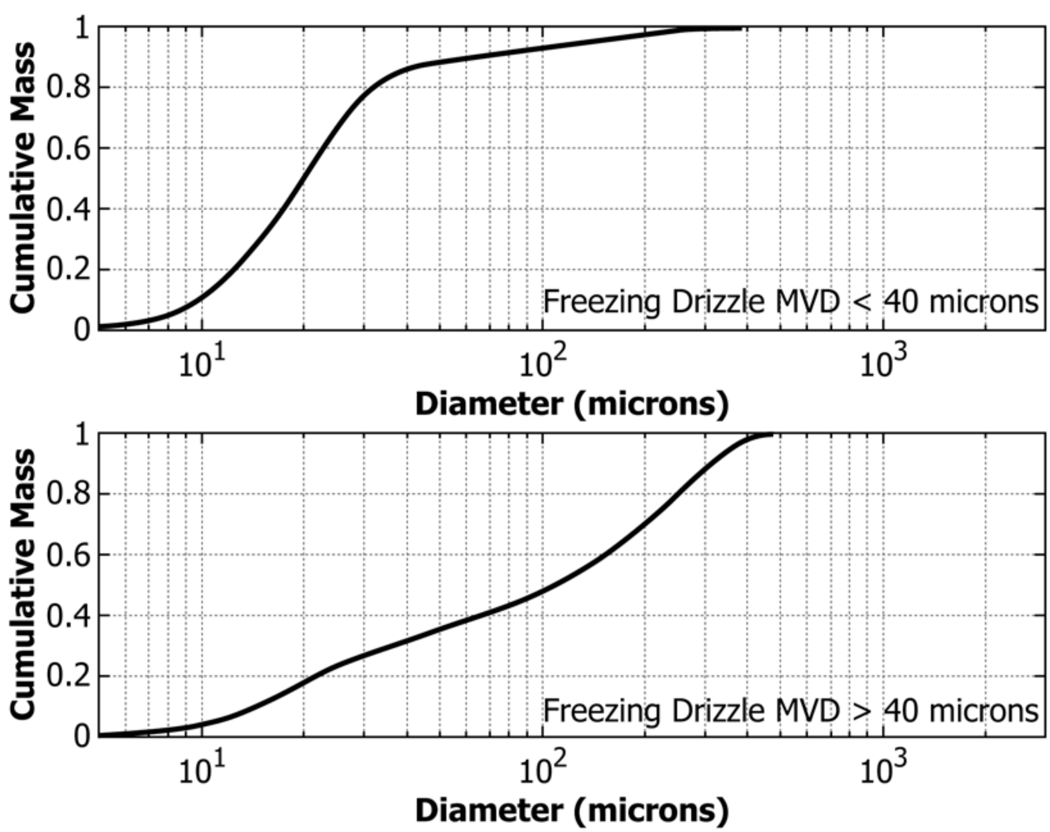

FIG. 8 Freezing Drizzle, Drop Diameter Distribution

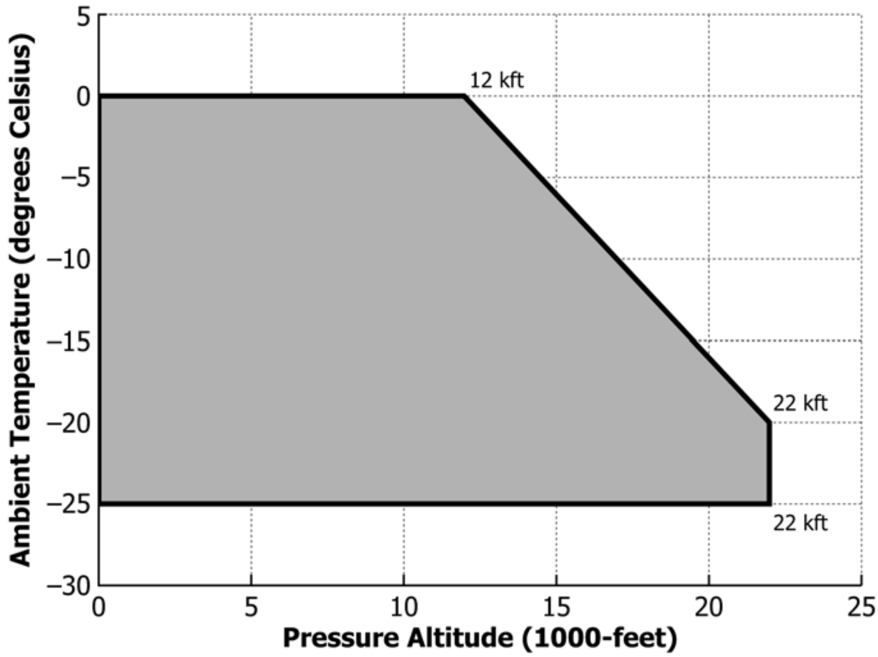

FIG. 9 Freezing Drizzle, Temperature and Altitude

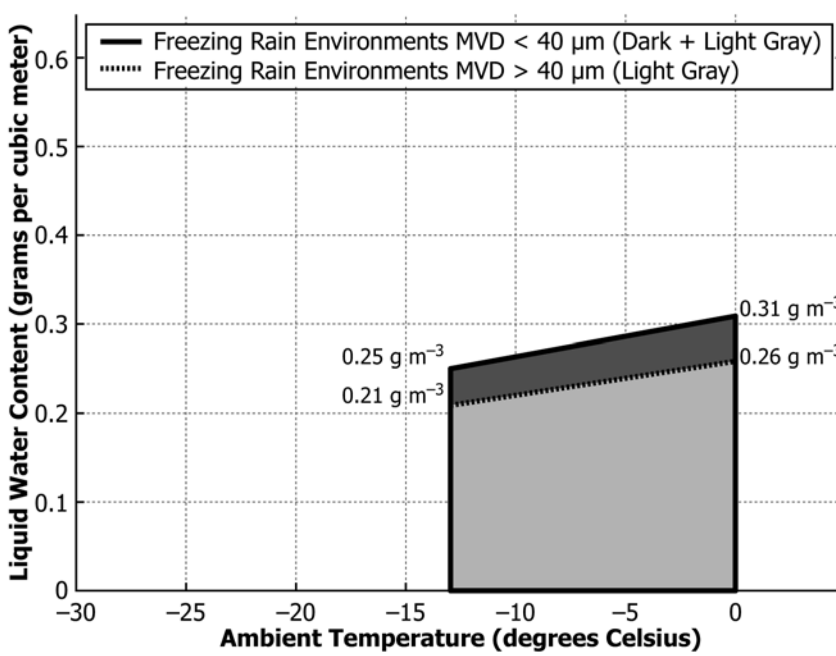

FIG. 10 Freezing Rain, Liquid Water Content

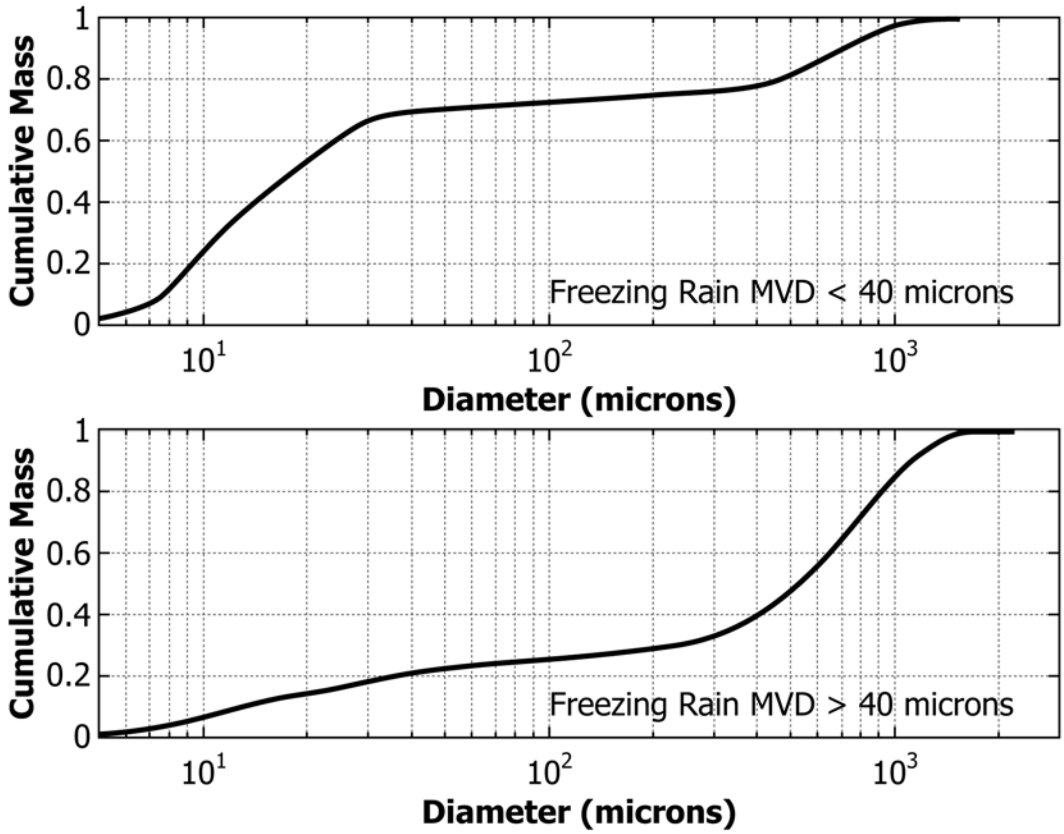

FIG. 11 Freezing Rain, Drop Diameter Distribution

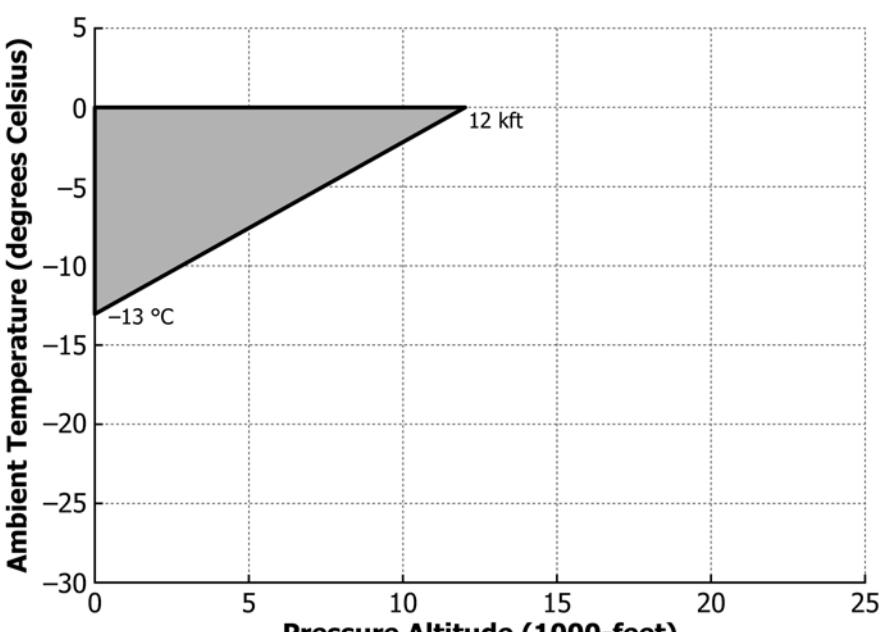

FIG. 12 Freezing Rain, Temperature and Altitude

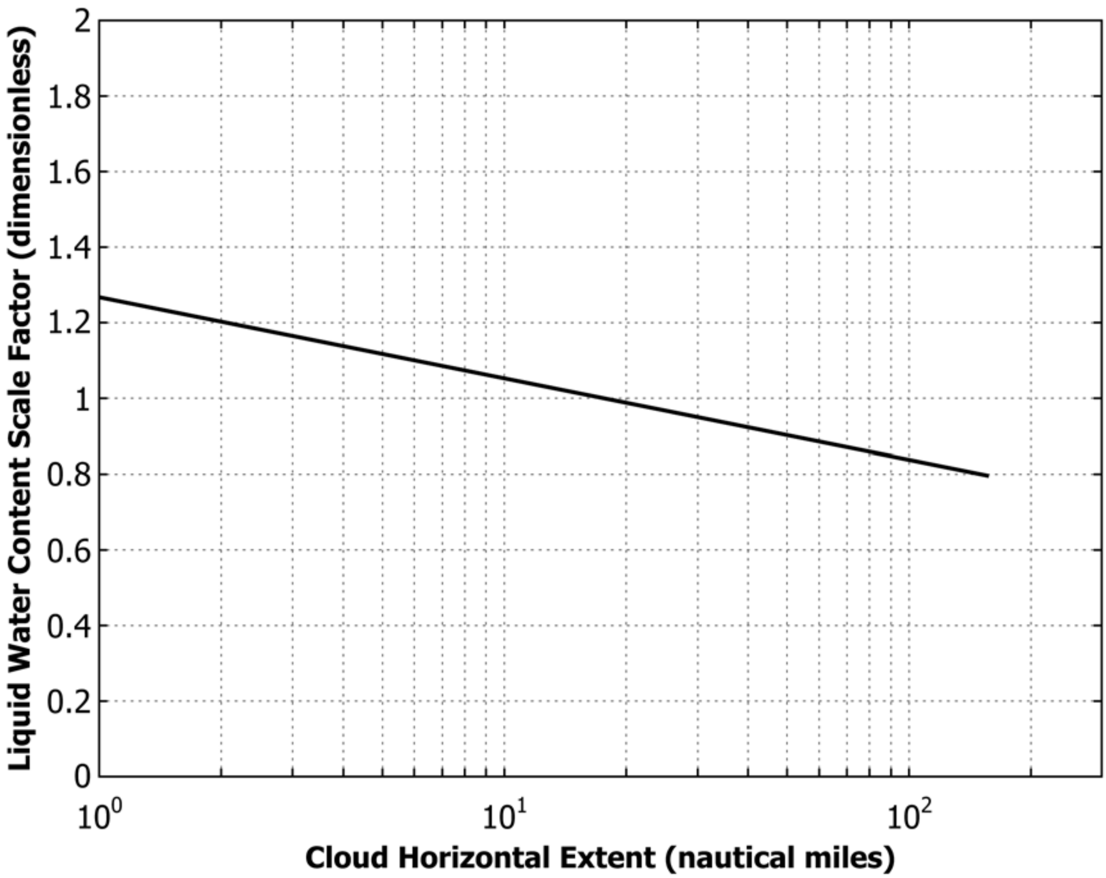

FIG. 13 Horizontal Extent, Freezing Drizzle and Freezing Rain

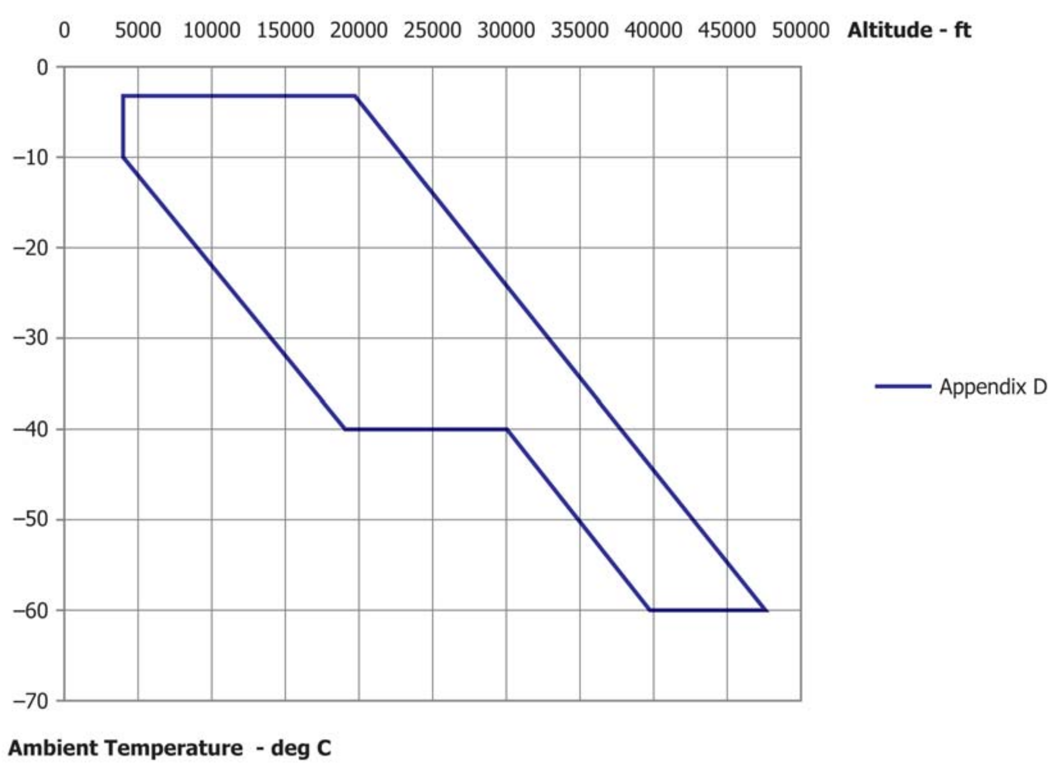

FIG. 14 Convective Cloud Ice Crystal Envelope

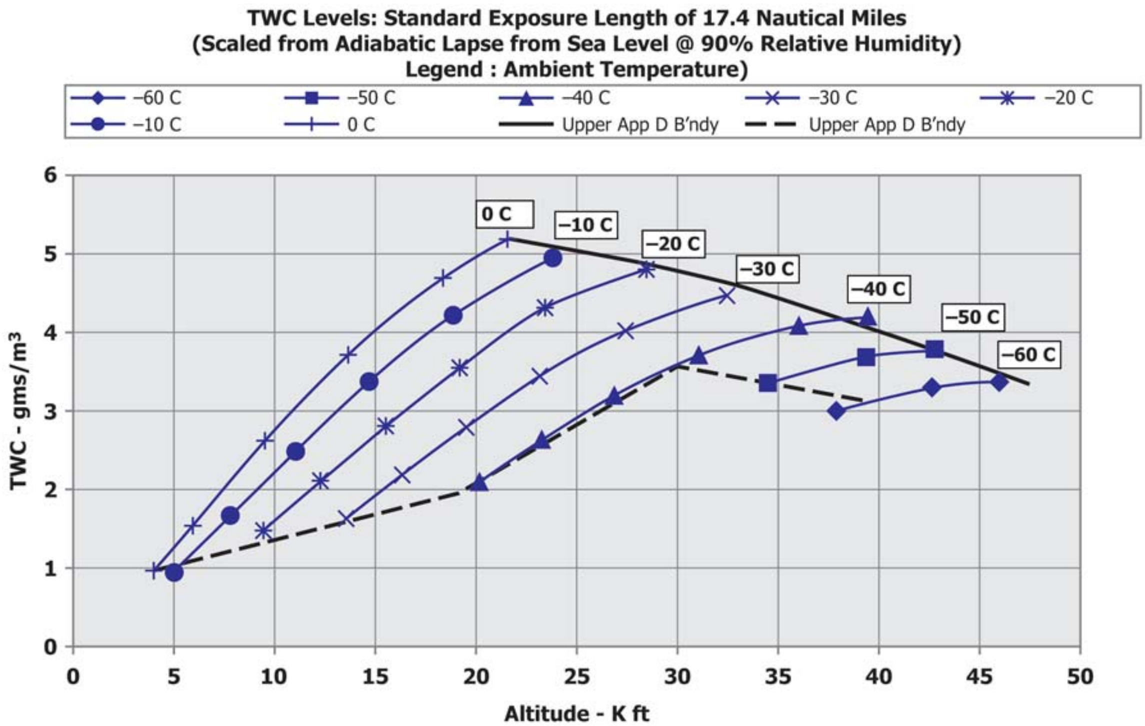

FIG. 15 Total Water Content

TABLE 5 Supercooled Liquid Portion of TWC

Temperature Range – °C	Horizontal Cloud Length – Nautical Miles	LWC – g/m³
0 to –20	</= 50	</=1.0
0 to –20	Indefinite	</=0.5
< –20		0

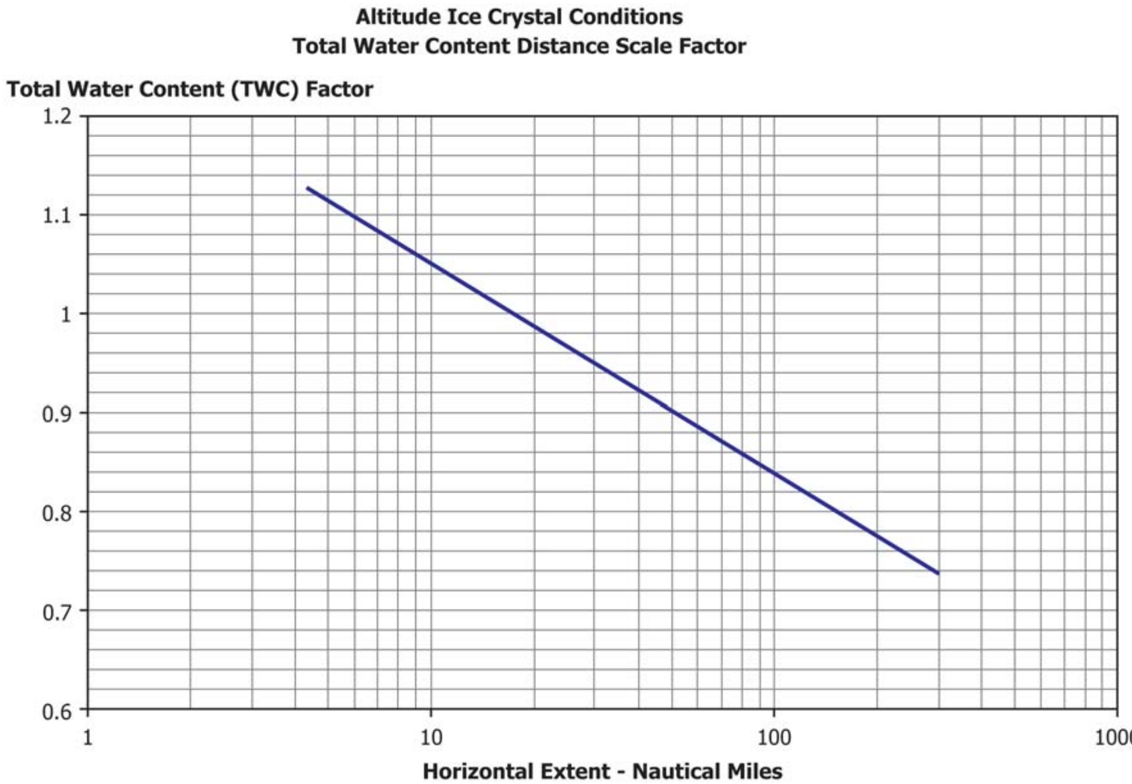

FIG. 16 Exposure Length Influence on TWC

ANNEXES

(Mandatory Information)

A1. PERFORMANCE AND FLIGHT CHARACTERISTICS REQUIREMENTS IN ICING

A1.1 It shall be demonstrated by flight test, except where it is stated analysis may be acceptable, that the aircraft is capable of operating safely during normal Ice Protection System (IPS) operation. Assume 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. Flight testing with simulated ice shapes on lifting surfaces, combined with a drag analysis of other components, may be used to show compliance. Ice shapes may be used on other components in lieu of a drag analysis. Critical ice accretions are defined in Annex A2 of this standard.

A1.1.1 The following performance portions of 14 CFR Part 23 Amend 62 must be demonstrated.

A1.1.1.1 *General*—14 CFR Part 23 Amend 62, General section of Performance Requirements (23.45) except:

(1) It can be assumed that ice accretion will not be present on the airframe at static temperatures warmer than +5°C.

(2) For deicing systems, the average drag increment determined over the deicing cycle may be used for performance calculations.

(3) Propeller efficiency loss shall be the value in Fig. A1.1 or Fig. A1.2, as appropriate for the icing condition being addressed, 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 the appropriate Figure.

A1.1.1.2 *Stalling Speed*—14 CFR Part 23 Amend 62, Stalling Speeds section (23.49).

(1) Each flap setting approved for icing must be evaluated.

(2) Effect of pneumatic boot inflation must be evaluated.

A1.1.1.3 *Takeoff Speeds*—14 CFR Part 23 Amend 62, Takeoff Speeds section (23.51) for high speed Level 3 multiengine airplanes and all Level 4 airplanes, the takeoff safety speed in icing conditions, V2, and takeoff rotation speed VR, must be established for critical takeoff ice accretion if the stall speed VS1 due to takeoff ice accretion exceeds that for non-icing by the greater of 3% or 3 KCAS at maximum takeoff weight.

A1.1.1.4 *Takeoff Performance*—14 CFR Part 23 Amend 62, Takeoff Performance section (23.53) the effect of operating ice protection systems that are approved for takeoff must be established.

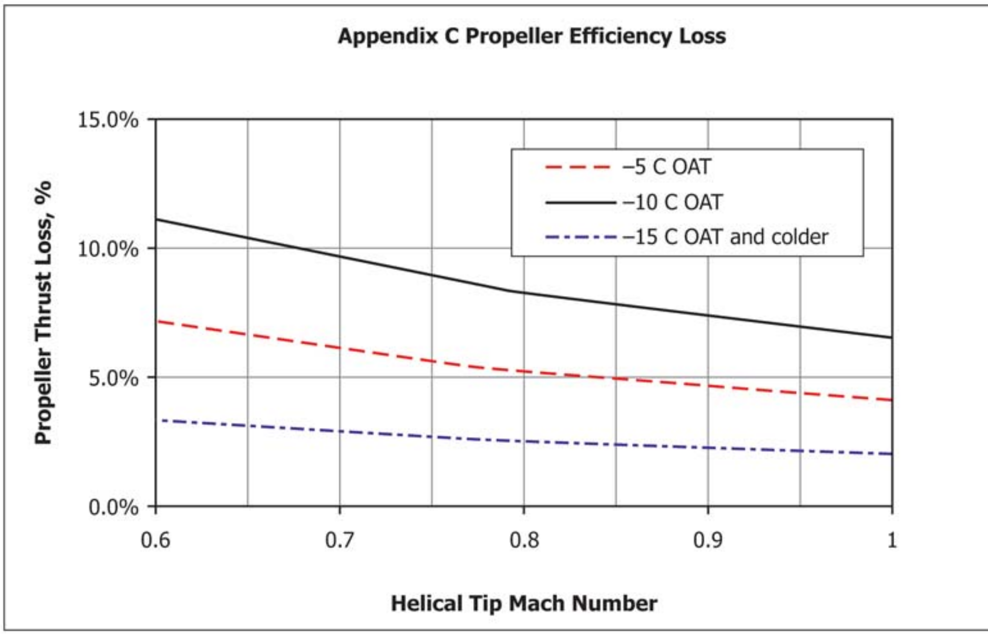

FIG. A1.1 Propeller Efficiency Loss in Icing Conditions

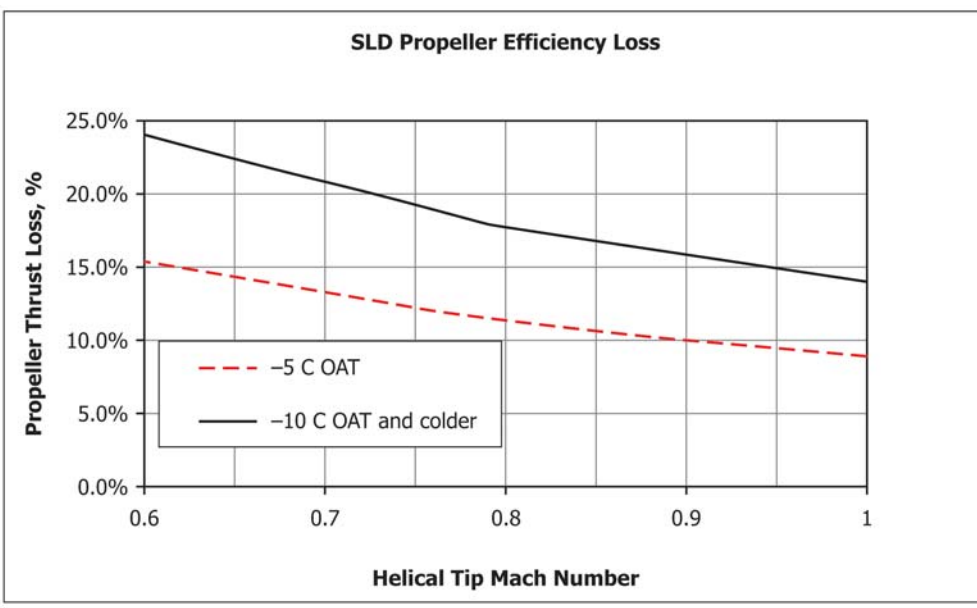

FIG. A1.2 Propeller Efficiency Loss in SLD Conditions

A1.1.1.5 *Takeoff Path*—Takeoff Path section (23.57) for high speed Level 3 multiengine airplanes and all Level 4 airplanes, the effect of takeoff ice accretion on takeoff path must be established if the degradation of climb gradient due to takeoff ice is greater 0.4%.

A1.1.1.6 *Climb*—Table A1.1 defines the climb requirements from 14 CFR Part 23 Amend 62 which must be met.

A1.1.1.7 *Landing*—Table A1.2 defines the landing requirements from 14 CFR Part 23 Amend 62 which must be met.

A1.1.2 The airplane must meet the requirements of A1.1.2.1 through A1.1.2.6, without requiring exceptional piloting skill, alertness, or strength, at:

(1) The critical weight and center of gravity determined during non-icing tests.

(2) The critical altitude. The maximum demonstration altitude need not exceed 30 000 ft unless operation of the airframe ice protection system is prohibited above 30 000 ft, or if the airframe ice protection system performance is intentionally reduced to meet power availability limits for altitudes above 30 000 ft.

(3) The critical airspeed, unless specified otherwise in the following paragraphs, except airspeed need not exceed the lesser of 250 KCAS, V_{MO}/M_{MO}, or an airspeed at which it can be demonstrated ice no longer remains on the airplane.

TABLE A1.1 Climb Flight Test Requirements from Part 23 Amend 62

Part 23 Amend 62 section title	Test	Applicability
Climb after Partial Loss of Thrust section as applicable to high speed level 3 multiengine and all level 4 airplanes (23.67(c)(d))	One engine inoperative climb	High speed Level 3 multiengine airplanes and all Level 4 airplanes
Enroute Climb/ Descent section (23.69)	Enroute climb/descent	Aircraft whose service ceiling with critical ice accretions is less than 22 000 ft
Balked Landing section (23.77)	Balked landing	All

TABLE A1.2 Landing Flight Test Requirements from Part 23 Amend 62

Part 23 Amend 62 section number	Test	Comment
Reference Landing Approach Speed section (23.73)	Reference landing approach speed, V_{REF}	V_{REF}, in icing conditions, may be the non-icing V_{REF} if at maximum landing weight the calculated V_{REF} for icing is not more than 4 KCAS higher than the non-icing V_{REF}
Landing Distance section (23.75)	Landing distance	A suitable analysis may be acceptable.

(4) The configurations specified in 14 CFR Part 23 Amend 62, unless specified otherwise in the following paragraphs, and maximum flap need not exceed the maximum flap deflection that will be specified in the AFM for flight in icing conditions.

A1.1.2.1 Table A1.3 and Table A1.4 defines the controllability and stalls requirements which must be met.

A1.1.2.2 In addition to the requirements in A1.1.2.1 the following stall warning requirements must be met.

(1) Stall warning shall be provided by the same means in icing conditions as in non-icing conditions.

(2) Each flap setting approved for icing must be evaluated.

(3) Annunciation must be provided to the pilot that the icing stall warning schedule, if different than the non-icing schedule, is active if AFM limitations or procedures are changed from non-icing.

(4) The airplane shall be free of buffet and stall warning in level altitude, 40° bank turns at:

TABLE A1.3 Controllability and Stalls Flight Test Requirements from Part 23 Amend 62

Part 23 Amend 62 section title	Test
Control Forces section (23.143)	Control forces
Longitudinal Control section (23.145)	Longitudinal control except the maneuvering capability of 1.5 g to provide a margin to recover from upset or inadvertent speed increase, power-off glide, and zero rate of descent tests are not required
Minimum Control Speed section (23.149(c))	Minimum control speed in the landing configuration test only

TABLE A1.4 Controllability and Stalls Flight Test Requirements from Part 23 Amend 62

Part 23 Amend 62 section title	Test
Stalls section (23.201 and 23.203)	Wing Level Stall and Turning Flight (Accelerated turning stalls in the Turning Flight and Accelerated Turning Stalls section is not required)
Stall Warning section (23.207)	Stall warning. See additional standards in A1.1.2.2

(a) Minimum holding airspeed, flaps and gear retracted, and

(b) V_{REF} in icing, flaps in maximum landing position approved for icing, and gear extended.

A1.1.2.3 Table A1.5 defines the stability requirements which must be met. The flight conditions which must be shown are:

(1) Minimum holding airspeed, flaps and gear retracted.

(2) V_{REF} in icing, flaps in maximum landing position approved for icing, and gear extended.

(3) Any other flight condition with marginal results in non-icing conditions.

A1.1.2.4 The airplane must be demonstrated to be not susceptible to ice contaminated tailplane stall (ICTS) by the following:

(1) 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 travel or other design characteristic of the flight control system, and it shall be possible to promptly recover from the maneuver without exceeding a pull control force of 50 lb.

(2) Any changes in force that the pilot must apply to the pitch control to maintain speed with increasing sideslip angle shall 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.

(3) The ICTS susceptibility tests must be accomplished at the following range of conditions:

(a) Speeds from 1.2 VS1 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 (VFE) or Landing Gear Extended Speed (VLE), as applicable, during the maneuver.

(b) Power or thrust from flight idle to maximum go-around.

TABLE A1.5 Stability Flight Test Requirements from 14 CFR Part 23 Amend 62

14 CFR Part 23 Amend 62 section title	Test
Static Longitudinal Stability section (23.173)	Static longitudinal stability
Static Directional and Lateral Stability section (23.177(d)(1)(2))	Static lateral/directional stability during steady heading sideslips tests only (rapid entry tests are not required)

A1.1.2.5 It shall be possible to readily arrest and reverse roll rate using only lateral control input, and the lateral control force shall not reverse with increase of control deflection. Bank to bank rolls of ⅓, ⅔ and full lateral control deflection shall be used to demonstrate this requirement.

A1.1.2.6 Table A1.6 defines the remaining flight and ground characteristics which must be met. The tests may be accomplished concurrently with other tests, between tests, or during approach and landing, if applicable.

A1.1.3 An automatic pilot system shall be capable of operation in the icing conditions approved for operating that airplane. As a minimum, the following flight tests must be accomplished:

A1.1.3.1 Autopilot shall smoothly roll into and out of turns without large overshoots in bank angle or during roll out on headings at maximum angle of bank turn allowable by the autopilot in one direction and then rapid reversal of angle of bank in the other direction.

A1.1.3.2 If the autopilot has the ability to fly a coupled instrument approach and/or go-around, conduct the following maneuvers per the appropriate AFM procedures:

(1) Coupled approach using all approved flap selections.

(2) Go-around using all approved flap selections.

(3) Glideslope capture from above the glidepath, if applicable.

A1.1.3.3 Low speed characteristics shall 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 shall be evaluated in a 1 to 2 knot/s deceleration in altitude hold, in straight and turning (maximum autopilot bank) flight, recovering one second after stall warning using AFM procedures. If AFM procedures do not exist, recovery shall be conducted by minimizing altitude loss.

A1.1.4 If compliance to the requirements of this Annex are shown by simulated ice shapes, the following limited performance and flight characteristics must be demonstrated after accreting ice during a natural ice flight test at the conditions specified in Table A1.7.

A1.1.4.1 Level, 40° banked turns.

TABLE A1.6 Miscellaneous Flight and Ground Characteristics Test Requirements from 14 CFR Part 23 Amend 62

14 CFR Part 23 Amend 62 section title	Test
Control During Landings section (23.153)	Control during landings
Elevator Control Force in Maneuvers section (23.155)	Elevator control force in maneuvers
Rate of Roll section (23.157(c))	Rate of roll in approach configuration test only
Trim Requirements section (23.161)	Trim
Dynamic Stability section (23.181)	Dynamic stability
Longitudinal Stability and Control along with Directional Stability and Control sections (23.231 and 23.233)	Ground handling characteristics
Vibration and Buffeting section (23.251(a)(b))	Vibration and buffeting (test specific to airplanes with MD greater then M 0.6 is not required)

TABLE A1.7 Ice Shape Definition for Natural Ice Flight Test

Configuration	Trim Airspeed	Ice Accretion	
		Protected Surface	Unprotected Surface
Flaps up, gear up	Minimum holding	Critical ice shape with normal IPS operation per AFM procedures	Equivalent to 45-minute hold at critical conditions, may be truncated to 2 inches at outboard wing tip
Landing flaps, gear down	Icing V_{REF}		Time to accrete 0.5 inch on outboard wing tip

A1.1.4.2 Bank-to-bank rapid rolls, 30° – 30°.

A1.1.4.3 Climb or level performance check.

A1.1.4.4 Autopilot tests (to include extended operation during hold to check for control anomalies caused by control surface ice accretion.

A1.1.4.5 Straight stall (1 knot/s deceleration rate, wings level, power off, may recover at first indication of stall).

A1.2 *Flight Characteristics with Pre-Activation Ice*—The following shall be shown by flight test, except where it is stated analysis may be acceptable, to show that the aircraft is capable of operating safely prior to activation of the ice protection system. Flight testing with simulated ice shapes on lifting surfaces may be used to show compliance. Critical ice accretions are defined in Annex A2 of this standard.

A1.2.1 *Longitudinal Control*—The airplane is controllable in a pull-up maneuver up to 1.5 g load factor; and there is no pitch control force reversal during a pushover maneuver down to 0.5 g load factor.

A1.2.2 *Low Airspeed Awareness*—There shall be an indication to the pilot of impending stall, with sufficient margin in straight flight to allow the pilot to prevent stalling.

A1.2.2.1 Compliance with this requirement must be demonstrated in straight flight with the speed reduced at one knot per second, with recovery initiated not less than either of the following:

(1) One second after activation of a stall warning system that is used for compliance to A1.1.1.2; or

(2) Three seconds after activation of a low airspeed awareness system.

A1.2.2.2 The low airspeed system in paragraph *(2)* of A1.2.2.1.

(1) May be based on airspeed alone; and

(2) Must have a visual and either aural or tactile alert.

A1.2.2.3 Recovery shall be per AFM procedures.

A1.2.2.4 Flight testing to show compliance to A1.2.2 is not required if:

(1) The stall warning system of section A1.2.2.1*(1)* annunciates one KCAS above an icing stall speed that can be assumed to be 15 % greater than non-icing stall speed at maximum landing weight; or

(2) The low airspeed awareness system of section A1.2.2.1*(2)* annunciates three KCAS above an icing stall speed that can be assumed to be 15 % greater than non-icing stall speed at maximum landing weight.

A1.3 *Failure of an Ice Protection System*—Flight investigations must 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.

A1.3.1 The following tests shall be accomplished with the simulated failure ice shapes defined in Annex A2.

A1.3.1.1 Longitudinal control tests of A1.2.1 of this Annex.

A1.3.1.2 Lateral control during 40° bank turns and 30° – 30° bank-to-bank rolls.

A1.3.1.3 Decelerate to stall warning (natural acceptable) and recover after not less than 1 second, or demonstrate minimum safe airspeed with asymmetric failure.

A1.3.1.4 Demonstrate an approach and landing.

A1.3.2 If loss of all windshield IPS is probable or remote, an approach and landing must be demonstrated.

A1.4 *Supercooled Large Drop (SLD) Icing Condtions (Aircraft not approved for SLD)*—For aircraft not seeking approval for any portion of Section 11.4, flight investigations shall be conducted to verify that the aircraft can meet the following requirements for supercooled large drop (SLD) icing conditions.

A1.4.1 The airplane shall meet the following requirements with the SLD "detect and exit" ice accretions defined in Annex A2.4.

A1.4.1.1 *Lateral Control*—Section A1.1.2.5 of this Annex.

A1.4.1.2 *Low Airspeed Awareness*—There shall be an indication to the pilot of impending stall, with sufficient margin in straight flight to allow the pilot to prevent stalling when the pilot starts a recovery maneuver not less than three seconds after the onset of stall warning (5 s if the indication is based on airspeed and not angle of attack).

(1) Compliance with this requirement must be demonstrated in straight flight with the speed reduced at rates not exceeding 1 knot/s.

(2) The indication must have a visual and either aural or tactile alert. A stall warning system may comply with this requirement.

(3) Recovery shall be per AFM procedures.

A1.4.2 The above testing shall be used to establish AFM safe minimum operational speeds for an SLD encounter for all flap deflection approved for such an encounter.

A1.4.3 Results of the failure shape testing of Section A1.3 of this Annex shall be used to establish any AFM procedures for maximum flap deflection after an SLD encounter.

A1.5 *Supercooled Large Drop (SLD) Icing Condtions (Aircraft with partial SLD approval)*—For aircraft seeking approval for portions of Section 11.4, flight investigations shall be conducted to verify that the aircraft can meet the following requirements for supercooled large drop (SLD) icing conditions which they are not certified to operate in.

A1.5.1 The airplane shall meet the following requirements with the SLD "detect and exit" ice accretions defined in Annex A2.5.

A1.5.1.1 *Lateral Control*—Section A1.1.2.5 of this Annex.

A1.5.1.2 *Low Airspeed Awareness*—There shall be an indication to the pilot of impending stall, with sufficient margin in straight flight to allow the pilot to prevent stalling when the pilot starts a recovery maneuver not less than three seconds after the onset of stall warning (5 seconds if the indication is based on airspeed and not angle of attack).

(1) Compliance with this requirement must be demonstrated in straight flight with the speed reduced at rates not exceeding 1 knot/s.

(2) The indication must have a visual and either aural or tactile alert. A stall warning system may comply with this requirement.

(3) Recovery shall be per AFM procedures.

A1.5.2 The above testing shall be used to establish AFM safe minimum operational speeds for an unapproved SLD encounter for all flap deflection approved for such an encounter.

A1.5.3 Results of the failure shape testing of Section A1.3 of this Annex shall be used to establish any AFM procedures for maximum flap deflection after an unapproved SLD encounter.

A2. CRITICAL ICE ACCRETIONS

A2.1 Critical ice accretions for normal IPS operations are defined in A2.1.1 through A2.1.4.

A2.1.1 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 as defined in Annex A1 for icing conditions. Applicants must demonstrate that:

A2.1.1.1 The full range of atmospheric icing conditions for which approval is sought specified in Section 11 have been considered including liquid water content, temperature and flight conditions (configuration, speed, angle-of-attack, and altitude).

A2.1.1.2 Ice accretions on mechanical deicing systems shall consider high water catch conditions (high true airspeed, high LWC), low shedding performance conditions (low calibrated airspeed, cold ambient temperature), and runback conditions (total temperature near freezing).

A2.1.1.3 Critical ice accretions may be determined by analyses if validated for the specific function (for example, unprotected 2D surface, unprotected 3D surface, ice shedding at low airspeed and cold OAT, runback ice on mechanical systems, runback location and shape on running wet systems.

A2.1.2 Table A2.1 defines the critical ice accretions for normal IPS operation on unprotected and protected surfaces (if any ice accretions) for each phase of flight in the cloud icing conditions of Section 11 for which approval is sought.

A2.1.3 In order to reduce the number of ice accretions to be considered when demonstrating compliance with the requirements of Section 9.1.6:

A2.1.3.1 Any of the ice accretions defined for one flight phase may be used for any other flight phase for the same icing conditions, or ice accretions may be "enveloped" to one ice accretion, 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.

A2.1.3.2 The ice accretion that has the most adverse effect on stall angle of attack may be used for airplane performance tests provided any difference in performance is conservatively taken into account.

A2.1.4 If mechanical deice ice protection systems result in a ridge behind the protected area in some icing conditions defined in Section 11 for which certification is requested, this ice shape must be flown in addition to the critical intercycle/residual ice shape.

A2.2 Critical ice accretions prior to IPS activation are defined in A2.2.1 through A2.2.7.

A2.2.1 Low airspeed awareness and susceptibility to ICTS are evaluated with pre-activation ice accretion. Pre-activation ice is a function of how ice accretion is detected.

A2.2.2 Table A2.2 defines pre-activation ice prior to IPS activation.

TABLE A2.1 Ice Accretions for Normal IPS Operation

Flight Phase	Cloud Icing Conditions of Section 11
Takeoff Ground Roll	None. AFM limitation requires airplane free of contamination for takeoff.
Takeoff	Ice accreted from lift-off to 400 ft
Final Takeoff	Ice accreted from lift-off to 1500 ft
Enroute	Ice accreted during the en-route phase of flight, only applicable to airplanes with a service ceiling in icing below 22 000 ft.
Holding	Ice accreted during a 45 min hold with no reduction for horizontal cloud extent (that is, the hold is conducted entirely within the 17.4 nautical mile standard cloud extent).
Approach	Ice accreted in 5 min in approach configuration on protected surfaces, holding ice on unprotected surfaces.
Landing	Approach ice plus: Ice accreted in 5 min in landing configuration on protected surfaces, holding ice on unprotected surfaces.

TABLE A2.2 Definition of Ice Accretion Prior to IPS Activation

Continuous Maximum Cloud Icing Conditions of Section 11.1	
Means of Ice Detection	Pre-activation Ice Time
Primary IDS and Automatic IPS Activation	IDS response time
Primary IDS and Manual IPS Activation	IDS response time plus 10 s
Advisory Ice Detection System	IDS response time plus 30 s
Outside air temperature and visible moisture	30 s
Visual cue of first sign of ice accretion	2 min, unless another time is defined in accordance with Section A2.2.5
Outside air temperature and visible moisture combined with Primary or Advisory IDS	No pre-activation ice testing is required

A2.2.3 Pre-activation ice after IPS activation shall also be added to the accretion in Table A2.2 and evaluated if ice protection system effectiveness is delayed either due to system architecture or IPS performance, and this ice accretion is not shown by analysis or test to be less conservative than critical normal IPS ice accretion.

A2.2.4 Pre-activation ice shall be determined in holding configuration at minimum holding airspeed.

A2.2.5 Ice detection time for visual cues may be reduced to a time less than two minutes if:

A2.2.5.1 The ice detection means is demonstrated in day and night conditions, considering clear ice,

A2.2.5.2 The visual cue is in the pilot's primary field of view, and

A2.2.5.3 The time shall not be less than one minute.

A2.2.6 In low freezing fractions conditions, applicant must show that a primary or advisory ice detection 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.

A2.2.7 Defined outside air temperature in Table A2.2 shall be a minimum of 5°C.

A2.3 The critical ice accretions for failure of the IPS shall be ice accreted during a 22.5 min hold at minimum holding airspeed plus 10 knots with no reduction for horizontal cloud extent; or an ice accretion based on a realistic exit scenario that accounts for the time it takes:

A2.3.1 For the system to annunciate the failure (for example, one deicing boot cycle);

A2.3.2 For the pilot to decide on a course of action and notify Air Traffic Control (ATC) (for example, 2 min); and for the pilot to decide on a course of action and notify Air Traffic Control (ATC) (for example, 2 min); and

A2.3.3 To exit the icing conditions (46 nm for probable or remote failures).

A2.4 For aircraft not approved for operation in the icing conditions of Section 11.4, "Detect and exit" ice accretion for SLD conditions shall be determined empirically, or by analysis validated on a similar design, on the upper wing surface in holding configuration at holding airspeed. The following conditions shall be used:

A2.4.1 Liquid water content (LWC) of 0.3 g/m^3.

A2.4.2 Median volumetric diameter (MVD) of 105 µm.

A2.4.3 Critical total temperature between –4.4°C [24°F] and 2.2°C [36°F].

A2.4.4 Duration defined in Table A2.3.

A2.5 For aircraft approved for operation in a portion of the icing conditions of Section 11.4, "Detect and exit" ice accretion for encounters with conditions not approved shall be determined empirically, or by analysis validated on a similar design, on the upper wing surface in holding configuration at holding airspeed.

A2.5.1 The full range of atmospheric icing conditions of Section 11.4 which are not approved shall be evaluated to determine the critical ice shape with no reduction for horizontal cloud extent.

A2.5.2 The duration defined in Table A2.3 shall be used.

TABLE A2.3 Duration for "Detect and Exit" of SLD

Means of SLD Detection	Duration
Generic SLD Cues in AFM	16 min
Substantiated visual cues	The sum of: (1) Detection time[A] (2) 2 min (ATC clearance) (3) Time to transit 17.4 nm
SLD detection system	The sum of: (1) Detection time of the system at the total temperature that provide the critical ice accretion (2) 2 min (ATC clearance) (3) Time to transit 17.4 nm

[A] 3 min 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); 5 min for a visual reference located on a wing, wing mounted engine, or wing tip.

APPENDIX

(Nonmandatory Information)

X1. GUIDANCE FOR ICE PROTECTION SYSTEMS

X1.1 The following surfaces shall be considered to meet the requirements of 9.1.1.1.

X1.1.1 Radome.

X1.1.2 Leading edges of wings.

X1.1.3 Leading edges of high lift devices and control surfaces.

X1.1.4 Leading edges of control surface balance areas, if not shielded (such as aileron and elevator horns).

X1.1.5 Accessory cooling air intakes

X1.1.6 Antennas and masts.

X1.1.7 External tanks and fairings.

X1.1.8 External hinges, tracks, door handles, and entry steps.

X1.1.9 Landing gear.

X1.1.10 Retractable forward landing lights.

X1.1.11 Ram air turbines.

X1.1.12 Ice inspection lights, if required.

X1.1.13 Vortex generators and other flow control devices like stall strips, vorilons, and fences.

X1.1.14 Other structural protuberances that are exposed to icing conditions.

X1.1.15 Fuel tank vents.

X1.2 *Electromagnetic Compatibility*—The effect, if any, of ice protection system operation on other airplane systems must be determined per the requirements of Specification F3061.