Designation: F3120/F3120M – 20

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 civil aviation authority (CAA) body concerning the use of this specification as part of a certification plan. For information on which CAA regulatory bodies have accepted this specification (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 are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F3060 Terminology for Aircraft

F3061/F3061M Specification for Systems and Equipment in Small Aircraft

F3066/F3066M Specification for Aircraft Powerplant Installation Hazard Mitigation

F3082/F3082M Specification for Weights and Centers of Gravity of Aircraft

F3093/F3093M Specification for Aeroelasticity Requirements

F3117/F3117M Specification for Crew Interface in Aircraft

F3173/F3173M Specification for Aircraft Handling Characteristics

F3179/F3179M Specification for Performance of Aircraft

F3180/F3180M Specification for Low-Speed Flight Characteristics of Aircraft

F3230 Practice for Safety Assessment of Systems and Equipment in Small Aircraft

F3231/F3231M Specification for Electrical Systems for Aircraft with Combustion Engine Electrical Power Generation

F3316/F3316M Specification for Electrical Systems for Aircraft with Electric or Hybrid-Electric Propulsion

2.2 *Federal Standards:*[3]

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

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

14 CFR Part 33 Rule 68 Airworthiness Standards: Induction System Icing

2.3 *Other Standards:*

EUROCAE ED-103 Minimum Operational Performance Standard for Inflight Icing Detection Systems

[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 standards Document Summary page on the ASTM website.

[3] Available from U.S. Government Publishing Office (GPO), 732 N. Capitol St., NW, Washington, DC 20401, http://www.gpo.gov.

FAA AC 25-28 Compliance of Transport Category Airplanes with Certification Requirements for Flight in Icing Conditions[4]
MIL-STD-210 Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment[5]
NACA TN 3984 Statistical Study of Aircraft Icing Probabilities at the 700- and 500-Millibar Levels Over Ocean Areas in the Northern Hemisphere[6]
SAE AS403A Stall Warning Instrument[7]
SAE AS5498 Minimum Operational Performance Specification for Inflight Icing Detection Systems
SAE AS5562 Ice and Rain Minimum Qualification Standards for Pitot and Pitot-static Probes[7]

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.

4.2 *Similarity*—It is acceptable to show that any/all of the requirements in this document are met by similarity using data from previous certification projects if the data from that project is valid for the design being certified.

TABLE 1 Types of Aircraft Operational Requirements

Operational Requirements	Required Sections
Aircraft is approved for visual flight rules (VFR) operations	6.1.1, 6.2.1, 7.2, 7.3, and Section 10.
Aircraft is approved for instrument flight rules (IFR) operations	6.1.1, 6.2.1, 7.2, 7.3, 8.1, 8.2, 8.3, and Section 10 considering the icing conditions specified in 11.1 and 11.2
Aircraft is approved for flight in the icing conditions of 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 11.1, 11.2, and A2.4. For Section 8, consideration of the icing conditions of 11.5 must be shown
Aircraft is approved for flight in the icing conditions of 11.1 and 11.2 along with portions of 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 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 11.5 must be shown
Aircraft is approved for flight in the icing conditions of 11.1 and 11.2 along with all of 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 11.1, 11.2, and 11.4. For Section 8, consideration of the icing conditions of 11.5 must be shown

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 Specification F3117/F3117M. This means must be designed to function in the icing conditions specified in Section 11 for which approval is sought.

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 11.1 and 11.2 must be considered, assuming a minimum of a 5 min exposure at the critical, continuous maximum icing conditions of 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 11.1 and 11.2 must be considered, assuming a minimum of a 5 min exposure at the critical, continuous maximum icing conditions of 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.

[4] Available from Federal Aviation Administration (FAA), 800 Independence Ave., SW, Washington, DC 20591, http://www.faa.gov.
[5] Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, http://quicksearch.dla.mil.
[6] Available from National Aeronautics and Space Administration (NASA), 300 E. Street SW, Suite 5R30, Washington, DC 20546, https://ntrs.nasa.gov/.
[7] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, https://www.sae.org.

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 airframe 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 Annex A1.

6.3.2.3 Be shown acceptable for continued in-service use.

6.3.3 Engine ingestion of shed ice during flight test demonstrations must not result in more damage than the engine was satisfactorily demonstrated to withstand during testing for engine type certification.

6.4 *Ice Protection System (IPS) 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 flight standards defined in Annex A1) must be mitigated through the system safety requirement as defined in Specification F3061/F3061M. 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.

6.5 *Ice Shedding Analysis:*

6.5.1 Experience from prior engine ice ingestion certification testing indicates that high aspect ratio ice slabs typically break into smaller pieces during ingestion resulting in individual pieces that are typically one-third to one-half the original size.

6.5.1.1 Aspect ratio is defined as the ratio of the maximum dimension over the minimum dimension. Typical engine ingestion certification ice slabs have aspect ratios greater than 24.

6.5.1.2 Industry experience also indicates that general airframe shapes (radome, base of windshield, and antennas) typically experience similar or greater breakup due to the rapid deceleration as they enter the airstream. However, aspect ratios and results are more variable than the engine testing experience.

6.5.2 Thin airframe ice shapes or single horn ice shapes with similar aspect ratios to the engine ice ingestion certification shapes can assume a breakup to one-third of the original maximum dimension.

6.5.3 Radome, or double horn ice shapes from leading edges or antennas can assume a break-up to one-half the original maximum dimension.

6.5.4 For aircraft with aft mounted engines with potential for ice shedding from a wing leading edge, a maximum spanwise dimension equivalent to the engine inlet highlight area should be considered.

6.5.5 The resulting ice shape effects can be compared by volume, or by comparing the mass or kinetic energy effects to the aircraft engine certification ice ingestion or hail ingestion certification test results.

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 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 IPS 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 11.1 and 11.2.

7.2.2 In the icing conditions of 11.4 for which approval is sought.

7.2.3 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 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.

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/h (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	Mean Effective Particle Diameter	Demonstration
Rime ice condition	0 °F to 15 °F (–18 °C to –9 °C)	Liquid – 0.3 g/m^3 at 15 °F (–9 °C) linearly decreasing to 0.19 g/m^3 at 0 °F (–18 °C)	15–25 microns	By test, analysis or combination of the two
Glaze ice condition	20 °F to 30 °F (–7 °C to –1 °C)	Liquid – 0.3 g/m^3	15–25 microns	By test, analysis or combination of the two
Large droplet condition	15 °F to 30 °F (–9 °C to –1 °C)	Liquid – 0.3 g/m^3	100 microns (minimum)	By test, analysis or combination of the two

8. Instrumentation Ice Protection

8.1 If certification for 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 11.1 and 11.2.

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

8.1.1.3 In addition to the requirements of 8.1.1.1 and 8.1.1.2, for airplanes with $M_{MO} > 0.6$ and a maximum certified altitude above 25 000 ft, the mixed phase and ice crystal conditions defined in 11.5 under normal operating conditions.

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

8.2 If a flight instrument pitot probe heating system is installed to meet the requirements specified in 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 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 instead 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 aircraft flight manual (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 qualification of the angle of attack/stall warning sensor did not include the deicing demonstration of SAE AS403A, an alert must be provided similar to the alert required for pilot probe ice protection in 8.2.2.1.

8.4.2 For airplanes with $M_{MO} > 0.6$ and a maximum certified altitude above 25 000 ft, the mixed phase and ice crystal conditions defined in 11.5 for pressure sensing angle of attack devices, and trailing vane type angle of attack sensors without a heated faceplate, must be addressed.[8]

8.5 For any temperature probe used for setting engine thrust or power on airplanes certified for flight into known icing conditions, these probes must comply with one of 8.5.1 through 8.5.3. If service history shows unresolved icing related events, or if there is no service history for the previously certified engine/probe combination, 8.5.4 through 8.5.6 must be met.

8.5.1 The probes were certified with the engine at a certification basis that included the mixed phase and ice crystal conditions of 11.5.

[8] In-service events indicate increased risk of ice crystal ingestion/melt/refreeze between the rotating and non-rotating parts for vane type angle of attack sensors that do not incorporate sufficient heat in the faceplate.

8.5.1.1 As installed, the concentration factor must be shown to be no higher than that demonstrated for the Part 33 or CS-E engine certification.

8.5.2 The probes are not susceptible to blockage by ice crystals by design. This must be demonstrated by either:

8.5.2.1 Service history; or

8.5.2.2 Tests in the ice crystal conditions defined in 11.5, including all appropriate concentration factors.

8.5.3 The probes are similar to other designs, used under similar engine inlet conditions, in certified application with no ice crystal events in service, and the following must be similar to the previously certified design:

8.5.3.1 Inlet conditions, including mass airflow, and installation of the temperature probes, including local concentration factor of ice crystals;

8.5.3.2 Software logic used to monitor temperature signals (including for ice crystal blockage) and select the temperature for engine thrust setting; and

8.5.3.3 Flight envelope (altitude, temperature, airspeed).

8.5.4 The system design must mitigate the threat of ice crystal blockage by full authority digital engine control (FADEC) logic or flight crew warning indications, or both, or other similar means.

8.5.5 The amount of thrust loss due to temperature probe icing must be less than 3 % at the take-off and go-around power settings unless it is shown a larger loss of thrust is acceptable. The value of 3 % is the interpretation of "serious loss of power or thrust" for compliance to induction system icing requirements in past engine 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 9.1.9.

9.1.1 Analyses must be performed to establish, on the basis of the aircraft's operational needs, the coverage and adequacy of the IPS 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 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 or water catch analysis, or both, 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 IPS.

(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 median volumetric diameter (MVD) may be used in the chordwise protection analysis, however ice accretion that may result using Langmuir E or using local collection efficiencies below 0.1, or both, 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) IPSs.

(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 A2.1.1.3.

9.1.2 When performing the system safety analysis required in Specification F3061/F3061M for the IPSs and airplane systems; 9.1.2.1 – 9.1.2.3 must be met.

9.1.2.1 Substantiation of the hazard classification of IPS failure conditions shall be accomplished through analysis or simulated failure ice shape flight testing, or both.

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 IPS power sources must meet the system safety analysis and power source capacity requirements of Specification F3061/F3061M.

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 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 F3231/F3231M or Specification F3316/F3316M, the operation of IPSs and airplane systems must be

TABLE 4 Probability of Encountering Icing

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

Airworthiness Level (in accordance with Specification F3061/F3061M)	Continuous Maximum and Intermittent Maximum Icing Conditions	Supercooled Large Drop Icing Conditions
1	10^{-1} per flight hour[A]	10^{-2} per flight hour[B]
2		
3		
4	1	

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

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 4.2, in addition to the analysis and physical evaluation prescribed in 9.1.1 through 9.1.6, the effectiveness of the IPS 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 IPS 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 IPS 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 A means must be provided for determining the formation of ice on the critical parts of the aircraft when required for activation of IPSs, or for exiting severe icing conditions.

9.1.9.1 For all phases of flight in which the IPS is allowed to be operated, one of the following methods of icing detection and activation of the airframe IPS must be provided:

(i) A primary ice detection system that automatically activates, or alerts the flightcrew to activate, the airframe IPS.

(ii) 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 IPS with or without an advisory ice detection system.

(iii) 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 IPS.

9.1.9.2 An advisory ice detection system that automatically activates, or alerts the flightcrew to activate the airframe ice protection may be used to supplement 9.1.9.1 *(ii)* or *(iii)*.

9.1.9.3 For the cues in 9.1.9.1 *(ii)* or *(iii)*, adequate lighting must be provided for the use of this means during night operation.

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

(ii) Lighting must be sufficient to allow all required flightcrew to observe the ice accretion in their normal seated position.

(iii) A flashlight or other portable illumination source is not permitted to provide external lighting.

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

9.1.9.5 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.

9.1.9.6 A primary or advisory ice detection system must comply with Annex A4.

9.1.10 After the initial activation of the airframe IPS:

9.1.10.1 The IPS must be designed to operate continuously; or

9.1.10.2 The airplane must be equipped with a system that automatically cycles the IPS; or

9.1.10.3 An ice detection system must be provided to alert the flightcrew each time the IPS must be cycled.

9.1.11 The following weight and center of gravity limitations (Specification F3082/F3082M Load Distribution Limits section and Weight Limits section) must be considered for flight into known icing aircraft.

9.1.11.1 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.

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

9.1.12 The AFM must contain information for the safe operation of the aircraft in icing conditions.

9.1.12.1 The limitations section of the AFM must include:

(1) A statement similar to the following: "In icing conditions the airplane and its IPSs 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 ice contaminated tailplane stall (ICTS).

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

(6) IPSs:

(a) For airplanes without a primary ice detection system, the AFM Limitations shall require activation of IPSs 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 IPSs, 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 supercooled large droplets (SLD) envelope in 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 air traffic control (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).

9.1.12.2 The procedures section of the AFM must include:

(1) Pre-flight checks of IPSs 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 11.4.

9.1.12.3 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 IPS operation or ice accretions, or both, 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) En route 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.

9.1.13 The airframe IPS 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 IPS 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.

9.1.13.1 For airframe IPSs inhibited above 30 000 ft, the applicant must show compliance to the flight characteristic requirements in A1.1.1 with either the critical ice accretions defined in 9.1.13.5 or with simulated failure ice shapes defined in A2.3.

9.1.13.2 For airframe IPS 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.

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

9.1.13.4 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.

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

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

9.1.13.6 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 IPSs*—Operating limitations and kinds of operation placards must specifically prohibit operation into known icing conditions.

10.2 *Aircraft With Inadvertent Encounter IPSs:*

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

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/F3061M. 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/F3061M 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 IPS. 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 (LWC), 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 LWC with drop diameter and altitude is determined from Fig. 1 and Fig. 2.

11.1.2 The cloud LWC for continuous maximum icing conditions of a horizontal extent, other than 17.4 nautical miles, is determined by the value of LWC 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 LWC, 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 LWC with drop diameter and altitude is determined from Fig. 4 and Fig. 5.

11.2.2 The cloud LWC for intermittent maximum icing conditions of a horizontal extent, other than 2.6 nautical miles, is determined by the value of cloud LWC 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 LWC 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 SLD icing conditions consist of freezing drizzle and freezing rain occurring in or below, or both, stratiform clouds. SLD icing conditions are defined by the parameters of altitude, vertical and horizontal extent, temperature, LWC, and water mass distribution as a function of drop diameter distribution.

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 LWC: Fig. 7. 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.

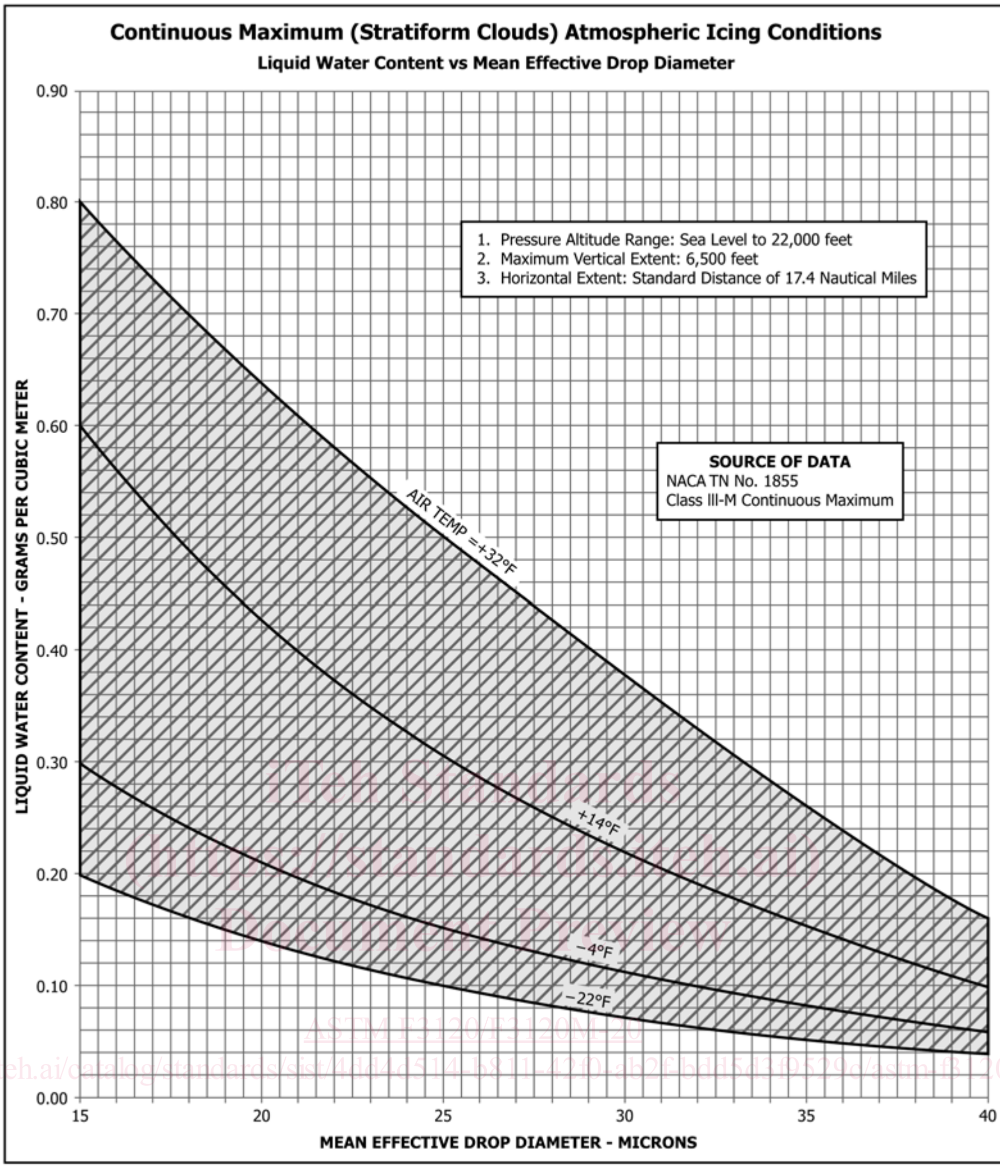

FIG. 1 Continuous Maximum (Stratiform Clouds) Icing Conditions – LWC versus Mean Effective Drop Diameter

11.4.2.4 Total LWC: Fig. 10. 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 LWC 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 LWC 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 = LWC 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 11.2, including the extension to –40 °C, and the MIL Standard 210 hot day envelope. The ice crystal icing envelope is depicted in Fig. 14.

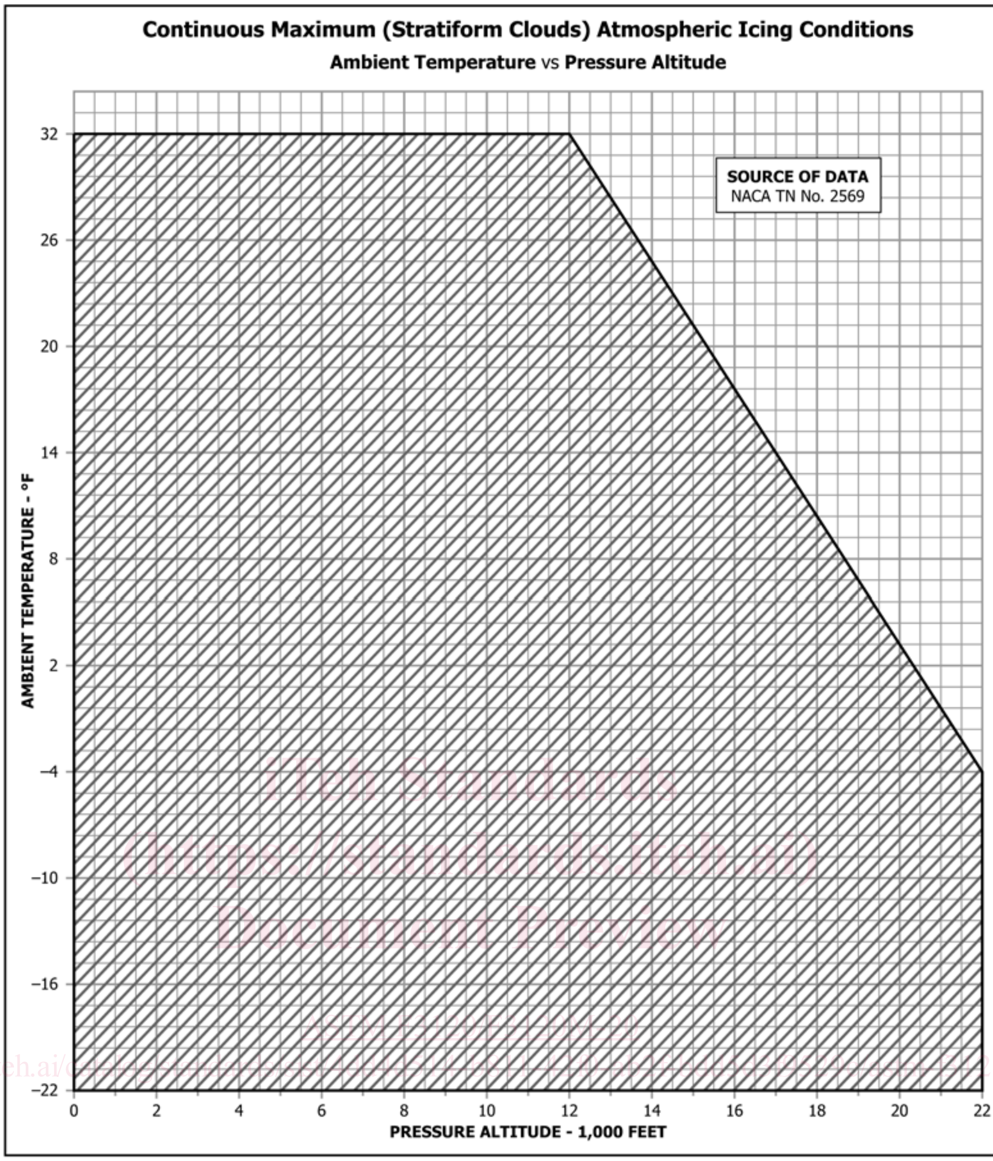

FIG. 2 Continuous Maximum (Stratiform Clouds) Icing Conditions – Ambient Temperature versus Pressure Altitude

TABLE 5 Supercooled Liquid Portion of TWC

Temperature Range – °C	Horizontal Cloud Length – Nautical Miles	LWC – g/m^3
0 to −20	</= 50	</=1.0
0 to −20	Indefinite	</=0.5
< −20		0

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 microns 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 in accordance with Fig. 16.

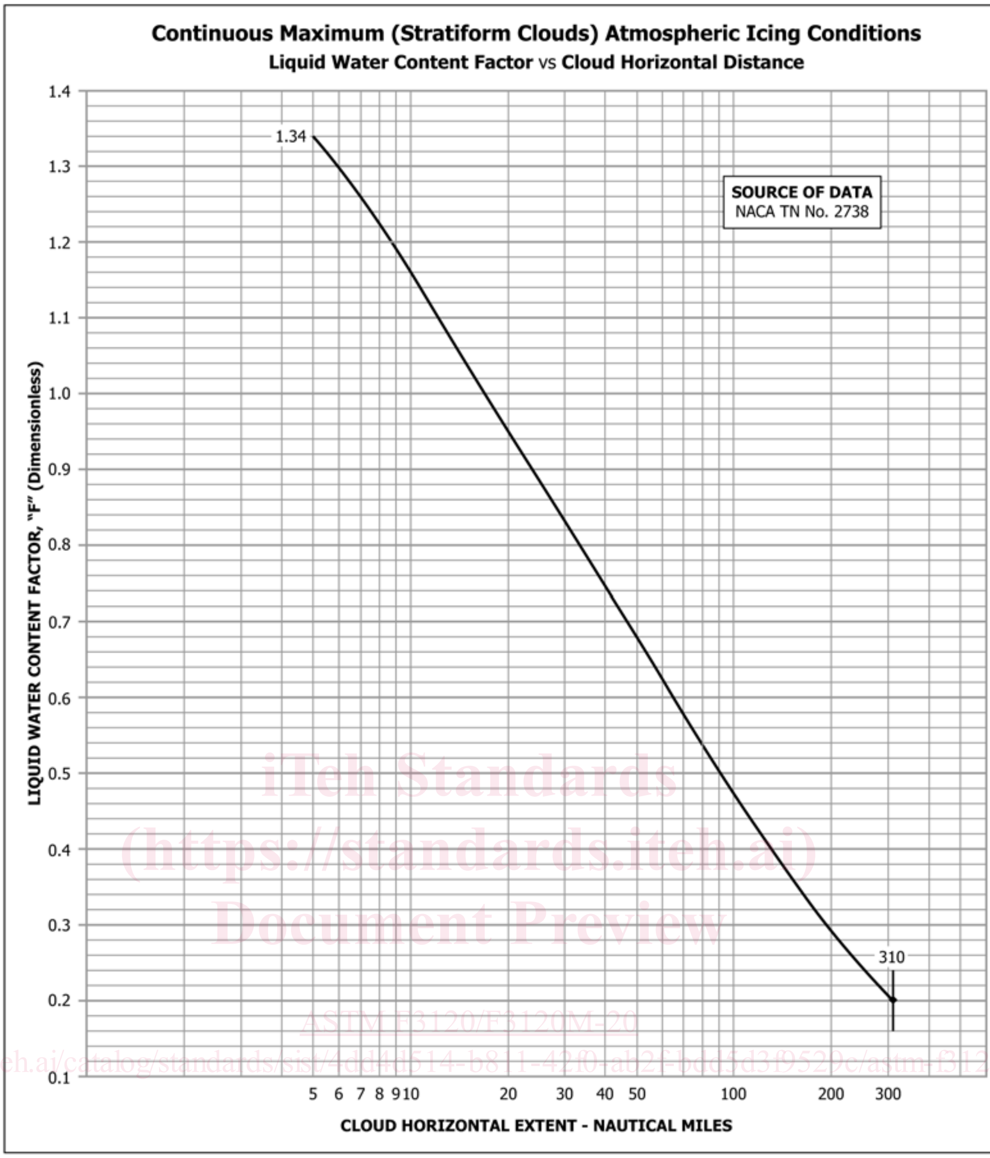

FIG. 3 Continuous Maximum (Stratiform Clouds) Icing Conditions – LWC versus Cloud Horizontal Distance

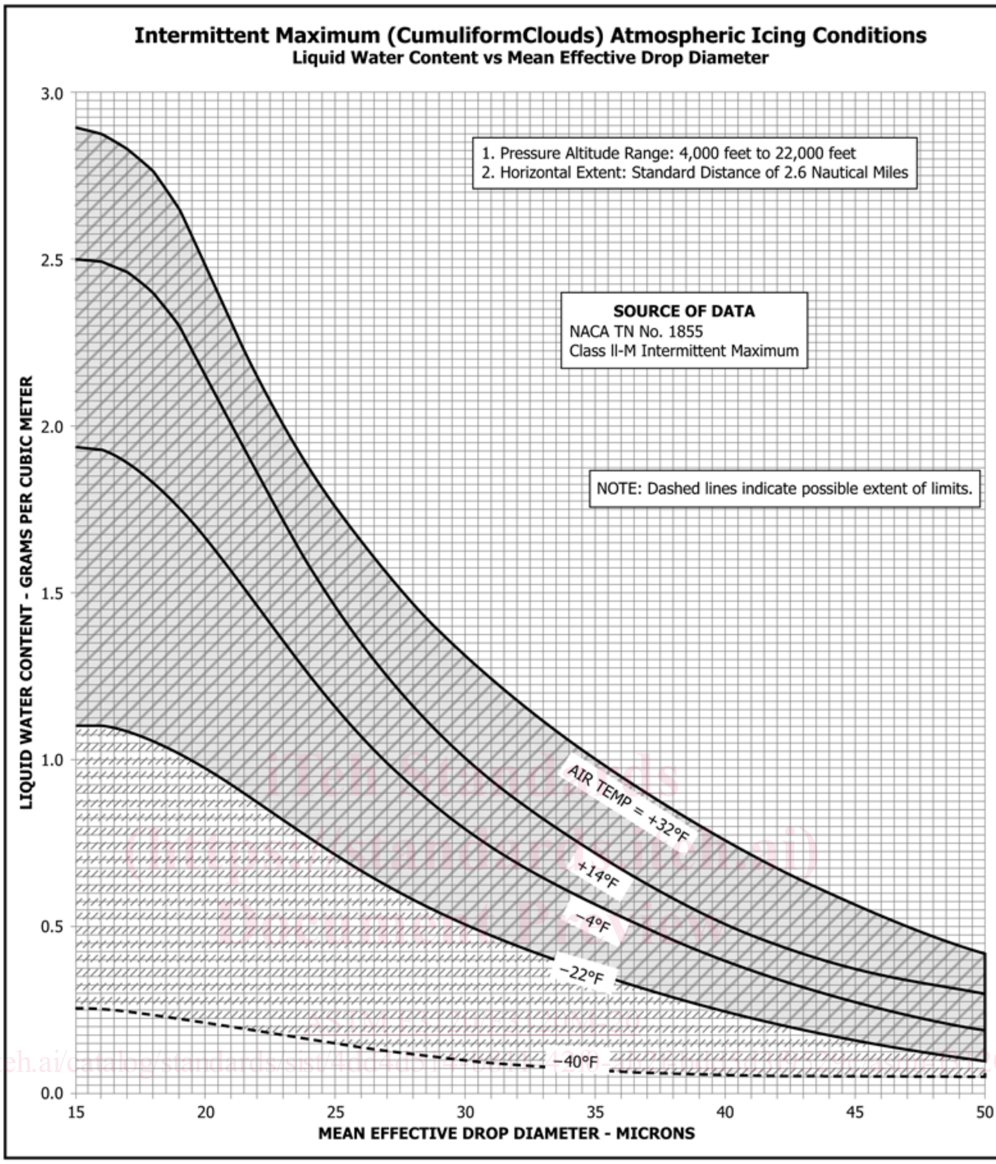

FIG. 4 Intermittent Maximum (Cumuliform Clouds) Icing Conditions – LWC versus Mean Effective Drop Diameter