CS-25 AMENDMENT 16 — CHANGE INFORMATION

The Agency publishes amendments to Certification Specifications as consolidated documents. These documents are used for establishing the certification basis for applications made after the date of entry into force of the amendment.

Consequently, except for a note '[Amdt No: 25/16]' under the amended paragraph, the consolidated text of CS-25 does not allow readers to see the detailed changes introduced by the new amendment. To allow readers to also see these detailed changes this document has been created. The same format as for publication of Notices of Proposed Amendments (NPAs) has been used to show the changes:

(a) deleted text is marked with ~~strike through~~;

(b) new or amended text is highlighted in grey;

(c) an ellipsis (…) indicates that the remaining text is unchanged in front of or following the reflected amendment.

BOOK 1

SUBPART B - FLIGHT

Amend CS 25.21 as follows:

CS 25.21 Proof of compliance

…

(g) …

(1) Each requirement of this subpart, except CS 25.121(a), 25.123(c), 25.143(b)(1) and (b)(2), 25.149, 25.201(c)(2), and 25.251(b) through (e), must be met in the icing conditions specified in Appendix C. CS 25.207(c) and (d) must be met in the landing configuration in the icing conditions specified in Appendix C but need not be met for other configurations. Compliance must be shown using the ice accretions defined in part II of Appendix C, assuming normal operation of the aeroplane and its ice protection system in accordance with the operating limitations and operating procedures established by the applicant and provided in the Aeroplane Flight Manual.

(2) If the applicant does not seek certification for flight in all icing conditions defined in Appendix O, each requirement of this subpart, except CS 25.105, 25.107, 25.109, 25.111, 25.113, 25.115, 25.121, 25.123, 25.143(b)(1), (b)(2), and (c)(1), 25.149, 25.201(c)(2), 25.207(c), (d) and (e)(1), and 25.251(b) through (e), must be met in the Appendix O icing conditions for which certification is not sought in order to allow a safe exit from those conditions. Compliance must be shown using the ice accretions defined in part II, paragraphs (b) and (d) of Appendix O, assuming normal operation of the aeroplane and its ice protection system in accordance with the operating limitations and operating procedures established by the applicant and provided in the Aeroplane Flight Manual.

(3) If the applicant seeks certification for flight in any portion of the icing conditions of Appendix O, each requirement of this subpart, except paragraphs CS 25.121(a), 25.123(c), 25.143(b)(1) and (b)(2), 25.149, 25.201(c)(2), and 25.251(b) through (e), must be met in the Appendix O icing conditions for which certification is sought. CS 25.207(c) and (d) must be met in the landing configuration in the icing conditions specified in Appendix O for which certification is sought but need not be met for other configurations. Compliance must be shown using the ice accretions defined in part II, paragraphs (c) and (d) of Appendix O, assuming normal operation of the aeroplane and its ice protection system in accordance with the operating limitations and operating procedures established by the applicant and provided in the Aeroplane Flight Manual.

(~~2~~4) No changes in the load distribution limits of CS 25.23, the weight limits of CS 25.25 (except where limited by performance requirements of this subpart), and the centre of gravity limits of CS 25.27, from those for non-icing conditions, are allowed for flight in icing conditions or with ice accretion.

Amend CS 25.105 as follows:

CS 25.105 Take-off

(a) …

(2) In icing conditions, if in the configuration used to show compliance with ~~of~~ CS 25.121(b), and with the most critical of the "Take-off Ice" accretion(s) defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g):

…

Amend CS 25.111 as follows:

CS 25.111 Take-off path

…

(c) …

(5) …

(i) With the most critical of the “Take-off Ice” accretion(s) defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g), from a height of 11 m (35 ft) above the take-off surface up to the point where the aeroplane is 122 m (400 ft) above the take-off surface; and

(ii) With the most critical of the “Final Take-off Ice” accretion(s) defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g), from the point where the aeroplane is 122 m (400 ft) above the take-off surface to the end of the take-off path.

…

Amend CS 25.119 as follows:

CS 25.119 Landing climb: all-engines-operating

…

(b) In icing conditions with the most critical of the “Landing Ice” accretion(s) defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g), and with a climb speed of V_{REF} determined in accordance with CS 25.125(b)(2)(ii).

Amend CS 25.121 as follows:

CS 25.121 Climb: one-engine-inoperative

…

(b) …

(2) …

(ii) In icing conditions with the most critical of the “Take-off Ice” accretion(s) defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g), if in the configuration used to show compliance with ~~of~~ CS 25.121(b) with ~~the~~this “Take-off Ice” accretion:

…

(c) …

(2) …

(ii) In icing conditions with the most critical of the “Final Take-off Ice” accretion(s) defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g), if in the configuration used to show compliance with ~~of~~ CS 25.121(b) with the “Take-off Ice” accretion used to show compliance with CS 25.111(c)(5)(i):

…

(d) …

(2) …

(ii) In icing conditions with the most critical of the “Approach Ice” accretion(s) defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g). The climb speed selected for non-icing conditions may be used if the climb speed for icing conditions, computed in accordance with sub-paragraph (d)(1)(iii) of this paragraph, does not exceed that for non-icing conditions by more than the greater of 5.6 km/h (3 knots) CAS or 3%.

…

Amend CS 25.123 as follows:

CS 25.123 En-route flight paths

(b) …

(2) In icing conditions with the most critical of the “En-route Ice” accretion(s) defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g), if:

…

Amend CS 25.125 as follows:

CS 25.125 Landing

(a) …

(2) In icing conditions with the most critical of the “Landing Ice” accretion(s) defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g), if V_{REF} for icing conditions exceeds V_{REF} for non-icing conditions by more than 9.3 km/h (5 knots) CAS at the maximum landing weight.

(b) …

(2) …

(ii) …

(B) 1.23 V_{SR0} with the most critical of the "Landing Ice" accretion(s) defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g), if that speed exceeds VREF selected for non-icing conditions by more than 9.3 km/h (5 knots) CAS; and

(C) A speed that provides the manoeuvring capability specified in CS 25.143(h) with the most critical of the “~~L~~landing ~~i~~Ice” accretion(s) defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g).

…

Amend CS 25.143 as follows:

CS 25.143 Controllability and manoeuvrability - General

(c) The aeroplane must be shown to be safely controllable and manoeuvrable with the most critical of the ice accretion(s) appropriate to the phase of flight as defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g), and with the critical engine inoperative and its propeller (if applicable) in the minimum drag position:

…

(i) …

(1) Controllability must be demonstrated with the most critical of the ice accretion(s) for the particular phase of flight as defined in ~~described in~~ Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g) ~~that is most critical for the particular flight phase~~.

…

(j) For flight in icing conditions before the ice protection system has been activated and is performing its intended function, it must be demonstrated in flight with the most critical of the ice accretion(s) defined in Appendix C, part II(e), and Appendix O, part II(d), as applicable, in accordance with CS 25.21(g), that:

…

Amend CS 25.207 as follows:

CS 25.207 Stall warning

…

(b) The warning must be furnished either through the inherent aerodynamic qualities of the aeroplane or by a device that will give clearly distinguishable indications under expected conditions of flight. However, a visual stall warning device that requires the attention of the crew within the cockpit is not acceptable by itself. If a warning device is used, it must provide a warning in each of the aeroplane configurations prescribed in sub-paragraph (a) of this paragraph at the speed prescribed in subparagraphs (c) and (d) of this paragraph. Except for ~~showing compliance with~~ the stall warning ~~margin~~ prescribed in subparagraph (h)(3)(ii) of this paragraph, the stall warning for flight in icing conditions must be provided by the same means as the stall warning for flight in non-icing conditions. (See AMC 25.207(b).)

…

(e) …

(1) The ~~more~~ most critical of the take-off ice and final take-off ice accretions defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g), for each configuration used in the take-off phase of flight;

(2) The most critical of the en route ice accretion(s) defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g), for the en route configuration;

(3) The most critical of the holding ice accretion(s) defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g), for the holding configuration(s);

(4) The most critical of the approach ice accretion(s) defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g), for the approach configuration(s); and

(5) The most critical of the landing ice accretion(s) defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g), for the landing and go-around configuration(s).

…

(h) The following stall warning margin is required ~~F~~for flight in icing conditions before the ice protection system has been activated and is performing its intended function. Compliance must be shown using the most critical of~~, with~~ the ice accretion(s) defined in Appendix C, part II(e), and Appendix O, part II(d), as applicable, in accordance with CS 25.21(g). T~~t~~he stall warning margin in straight and turning flight must be sufficient to allow the pilot to prevent stalling without encountering any adverse flight characteristics when:

…

Amend CS 25.237 as follows:

CS 25.237 Wind velocities

(a) …

(3) …

(ii) Icing conditions with the most critical of the landing ice accretion(s) defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g).

Amend CS 25.253 as follows:

CS 25.253 High-speed characteristics

…

(c) *Maximum speed for stability characteristics in icing conditions*. The maximum speed for stability characteristics with the most critical of the ice accretions defined in Appendi~~x~~ces C and O, as applicable, in accordance with CS 25.21(g), at which the requirements of CS 25.143(g), 25.147(e), 25.175(b)(1), 25.177(a) through (c), and 25.181 must be met, is the lower of:

…

SUBPART D – DESIGN AND CONSTRUCTION

Amend CS 25.773 as follows:

CS 25.773 Pilot compartment view

(See AMC 25.773, AMC 25.773(b)(1)(ii), AMC 25.773(b)(4), AMC 25.773(c))

…

(b) …

(1) …

(ii) The icing conditions specified in ~~CS 25.1419~~Appendix C and the following icing conditions specified in Appendix O, if certification for flight in icing conditions is ~~requested.~~ sought:

(A) For aeroplanes certificated in accordance with CS 25.1420(a)(1), the icing conditions that the aeroplane is certified to safely exit following detection.

(B) For aeroplanes certificated in accordance with CS 25.1420(a)(2), the icing conditions that the aeroplane is certified to safely operate in and the icing conditions that the aeroplanes is certified to safely exit following detection.

(C) For aeroplanes certificated in accordance with CS 25.1420(a)(3), all icing conditions.

SUBPART E - POWERPLANT

Amend CS 25.903 as follows:

CS 25.903 Engines

(a) …

(3) Any engine not certificated to CS–E must be shown to comply with CS–E 780 or be shown to have an ice accumulation service history in similar installation locations which has not resulted in any unsafe conditions.

…

Amend CS 25.929 as follows:

CS 25.929 Propeller de-icing

(a) ~~For aeroplanes intended for use where~~ If certification for flight in icing conditions ~~may be expected~~ is sought, there must be a means to prevent or remove hazardous ice accumulations that could form in the icing conditions defined in Appendices C and O on propellers or on accessories where ice accumulation would jeopardise engine performance.

(see AMC 25.929(a))

…

Amend CS 25.1093 as follows:

CS 25.1093 ~~Air intake system de-icing and anti-icing provisions~~Powerplant Icing

…

(b) Turbine engines

~~(1) Each turbine engine must operate throughout the flight power range of the engine (including idling), without the accumulation of ice on the engine, inlet system components, or airframe components that would adversely affect engine operation or cause a serious loss of power or thrust (see AMC 25.1093 (b).) –~~

~~(i) Under the icing conditions specified in Appendix C.~~

~~(ii) Reserved~~

~~(2) Each engine must idle for 30 minutes on the ground, with the air bleed available for engine icing protection at its critical condition, without adverse effect, in an atmosphere that is at a temperature between –9º and –1ºC (15º and 30ºF) and has a liquid water content not less than 0·3 grams per cubic metre in the form of drops having a mean effective diameter not less than 20 microns, followed by a momentary operation at take-off power or thrust. During the 30 minutes of idle operation, the engine may be run up periodically to a moderate power or thrust setting.~~

Each engine, with all icing protection systems operating, must:

(1) Operate throughout its flight power range, including the minimum descent idling speeds, in the icing conditions defined in Appendices C, O and P, and in falling and blowing snow within the limitations established for the aeroplane for such operation, without the accumulation of ice on the engine, air intake system components or airframe components that would do any of the following:

(i) Adversely affect installed engine operation or cause a sustained loss of power or thrust; or an unacceptable increase in gas path operating temperature; or an airframe/engine incompatibility; or

(ii) Result in unacceptable temporary power or thrust loss or engine damage; or

(iii) Cause a stall, surge, or flameout or loss of engine controllability (for example, rollback).

(2) Idle for a minimum of 30 minutes on the ground in the following icing conditions shown in Table 1 below, unless replaced by similar test conditions that are more critical. These conditions must be demonstrated with the available air bleed for icing protection at its critical condition, without adverse effect, followed by an acceleration to take-off power or thrust, in accordance with the procedures defined in the aeroplane flight manual. During the idle operation the engine may be run up periodically to a moderate power or thrust setting in a manner acceptable to the Agency. The applicant must document the engine run-up procedure (including the maximum time interval between run-ups from idle, run-up power setting, and duration at power), the associated minimum ambient temperature, if any, and the maximum time interval. These conditions must be used in the analysis that establishes the aeroplane operating limitations in accordance with CS 25.1521.

Table 1- Icing conditions for ground tests

Condition	Total air temperature	Water concentration (minimum)	Mean effective particle diameter	Demonstration
(i) Rime ice condition	-18 to -9°C (0 to 15°F)	Liquid—0.3 g/m^3	15–25 µm	By test, analysis or combination of the two.
(ii) Glaze ice condition	-9 to -1°C (15 to 30°F)	Liquid—0.3 g/m^3	15–25 µm	By test, analysis or combination of the two.
(iii) Large drop condition	-9 to -1°C (15 to 30°F)	Liquid—0.3 g/m^3	100-3000 µm	By test, analysis or combination of the two.

SUBPART F - EQUIPMENT

Amend CS 25.1323 as follows:

CS 25.1323 Airspeed indicating system

…

(i) ~~Each system must have a heated pitot tube or an equivalent means of preventing malfunction due to icing. (See AMC to 25.1323 (i) and 25.1325(b).)~~ Reserved

…

Create a new CS 25.1324 as follows:

CS 25.1324 Flight instrument external probes

(see AMC 25.1324)

Each flight instrument external probes systems, including, but not necessarily limited to, pitot tubes, pitot-static tubes, static probes, angle of attack sensors, side slip vanes, and temperature probes, must be heated or have an equivalent means of preventing malfunction in the heavy rain conditions defined in Table 1 of this paragraph, in the icing conditions as defined in Appendices C and P, and the following icing conditions specified in Appendix O:

(a) For aeroplanes certificated in accordance with CS 25.1420(a)(1), the icing conditions that the aeroplane is certified to safely exit following detection;

(b) For aeroplanes certificated in accordance with CS 25.1420(a)(2), the icing conditions that the aeroplane is certified to safely operate in and the icing conditions that the aeroplane is certified to safely exit following detection;

(c) For aeroplanes certificated in accordance with CS 25.1420(a)(3), all icing conditions.

Table 1 – Rain test conditions

Altitude Range		Liquid Water Content	Horizontal Extent		Droplet MVD
(ft)	(m)	(g/m^3)	(km)	(NM)	(µm)
0 to 10 000	0 to 3 000	1	100	50	500 to 2 000
		6	5	3	
		15	1	0.5	

Amend CS 25.1325 as follows:

CS 25.1325 Static pressure systems

…

(b) Each static port must be designed and located ~~in such manner~~ so that:

(1) the static pressure system performance is least affected by airflow variation, or by moisture or other foreign matter, and

(2) ~~that t~~the correlation between air pressure in the static pressure system and true ambient atmospheric static pressure is not changed when the aeroplane is exposed to ~~the continuous and intermittent maximum~~ icing conditions ~~defined in Appendix C. (See AMC to 25.1323 (i) and 25.1325(b).)~~ .The static pressure system shall comply with CS 25.1324.

Amend CS 25.1326 as follows:

CS 25.1326 Flight instrument external probes ~~Pitot~~ heating ~~indication~~ systems alert

(see AMC 25.1326)

If a flight instrument external probe ~~pitot~~ heating system is installed, an ~~indication system~~ alert must be provided to ~~indicate to~~ the flight crew when ~~that~~ the flight instrument external probe ~~pitot~~ heating system is not operating or not functioning normally. The ~~indication system~~ alert must comply with the following requirements:

(a) The ~~indication~~ alert provided must ~~incorporate~~ conform to the ~~an amber light that is in clear view of a flight-crew member~~ Caution alert indications.

(b) The ~~indication~~ alert provided must be ~~designed to alert the flight crew~~ triggered if either of the following conditions exists:

(1) The flight instrument external probe ~~pitot~~ heating system is switched ‘off’.

(2) The flight instrument external probe ~~pitot~~ heating system is switched ‘on’ and ~~any pitot tube heating element~~ is not functioning normally ~~inoperative~~.

Amend CS 25.1403 as follows:

CS 25.1403 Wing ice detection lights

(see AMC 25.1403)

…

Create a new CS 25.1420 as follows:

CS 25.1420 Supercooled large drop icing conditions

(see AMC 25.1420)

(a) If certification for flight in icing conditions is sought, in addition to the requirements of CS 25.1419, the aeroplane must be capable of operating in accordance with sub-paragraphs (a)(1), (a)(2), or (a)(3) of this paragraph.

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

(i) The aeroplane must have a means to detect that it is operating in Appendix O icing conditions; and

(ii) Following detection of Appendix O icing conditions, the aeroplane must be capable of operating safely while exiting all icing conditions.

(2) Operating safely in a portion of the icing conditions defined in Appendix O as selected by the applicant.

(i) The aeroplane must have a means to detect that it is operating in conditions that exceed the selected portion of Appendix O icing conditions; and

(ii) Following detection, the aeroplane must be capable of operating safely while exiting all icing conditions.

(3) Operating safely in the icing conditions defined in Appendix O.

(b) To establish that the aeroplane can operate safely as required in sub-paragraph (a) of this paragraph, an applicant must show through analysis that the ice protection for the various components of the aeroplane is adequate, taking into account the various aeroplane operational configurations. To verify the analysis, one, or more as found necessary, of the following methods must be used:

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

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

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

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

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

(c) For an aeroplane certified in accordance with sub-paragraph (a)(2) or (a)(3) of this paragraph, the requirements of CS 25.1419 (e), (f), (g), and (h) must be met for the icing conditions defined in Appendix O in which the aeroplane is certified to operate.

SUBPART G – OPERATING LIMITATIONS AND INFORMATION

Amend CS 25.1521 as follows:

CS 25.1521 Powerplant limitations

…

(c)…

(3) Maximum time interval between engine run-ups from idle, run-up power setting, duration at power, and the associated minimum ambient temperature, if any, demonstrated for the maximum time interval, for ground operation in icing conditions, as defined in CS 25.1093(b)(2).

(~~3~~4) Any other parameter for which a limitation has been established as part of the engine type certificate except that a limitation need not be established for a parameter that cannot be exceeded during normal operation due to the design of the installation or to another established limitation.

Amend CS 25.1533 as follows:

CS 25.1533 Additional operating limitations

…

(c) For aeroplanes certified in accordance with CS 25.1420(a)(1) or (a)(2), an operating limitation must be established to:

(1) Prohibit intentional flight, including take-off and landing, into icing conditions defined in Appendix O for which the aeroplane has not been certified to safely operate; and

(2) Require exiting all icing conditions if icing conditions defined in Appendix O are encountered for which the aeroplane has not been certified to safely operate.

SUBPART J – AUXILIARY POWER UNIT INSTALLATIONS

Amend CS 25J1093(a) as follows:

CS 25J1093 Air intake system icing protection

(a) Each non-essential APU air intake system, including any screen if used, which does not comply with CS 25J1093(b) will be restricted to use in non-icing conditions, unless it can be shown that the APU complete with air intake system, if subjected to the icing conditions defined in Appendices C, O and P, will not affect the safe operation of the aeroplane.

Replace CS 25J1093(b) by the following text:

CS 25J1093 Air intake system icing protection

…

(b) For essential APUs:

Each essential APU, with all icing protection systems operating, and screen if used, must:

(1) operate throughout its flight power range in the icing conditions defined in Appendices C, O and P, and in falling and blowing snow within the limitations established for the aeroplane for such operation, without the accumulation of ice on the APU, air intake system components or airframe components that would do any of the following:

(i) Adversely affect installed APU operation or cause a sustained loss of power; or an unacceptable increase in gas path operating temperature; or an airframe/APU incompatibility; or

(ii) Result in unacceptable temporary power loss or APU damage; or

(iii) Cause a stall, surge, or flameout or loss of APU controllability (for example, rollback).

(2) operate for a minimum of 30 minutes on the ground in the icing conditions shown in Table 1 of CS 25.1093(b)(2), unless replaced by similar test conditions that are more critical. These conditions must be demonstrated with the available icing protection (if applicable) at its critical condition, without adverse effect. The applicant must document the APU minimum ambient temperature demonstrated, if any, and establish the aeroplane operating limitations.

APPENDICES

APPENDIX C

Amend Appendix C, Part II as follows:

Part II - Airframe Ice Accretions ~~for Showing Compliance with Subpart B~~

(a) *Ice accretions - General*

…

(1) Take-off Ice is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, occurring between ~~lift-off~~ the end of the take-off distance and 122 m (400 ft) above the take-off surface, assuming accretion starts at ~~lift-off~~ the end of the take-off distance in the take-off maximum icing conditions of Part I, paragraph (c) of this Appendix.

(2) Final Take-off Ice is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, between 122 m (400 ft) and either 457 m (1 500 ft) above the take-off surface, or the height at which the transition from the ~~takeoff~~take-off to the en route configuration is completed and V_{FTO} is reached, whichever is higher. Ice accretion is assumed to start at ~~liftoff~~ the end of the take-off distance in the take-off maximum icing conditions of Part I, paragraph (c) of this Appendix.

…

(d) …

(2) The ice accretion starts at ~~lift-off~~ the end of the take-off distance;

…

Create a new Appendix O as follows:

Appendix O

Supercooled Large Drop icing conditions

Appendix O consists of two parts. Part I defines Appendix O as a description of supercooled large drop (SLD) icing conditions in which the drop median volume diameter (MVD) is less than or greater than 40 µm, the maximum mean effective drop diameter (MED) of Appendix C continuous maximum (stratiform clouds) icing conditions. For Appendix O, SLD icing conditions consist of freezing drizzle and freezing rain occurring in and/or below stratiform clouds. Part II defines ice accretions used to show compliance with CS-25 specifications.

Part I—Meteorology

Appendix O 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.

(a) Freezing Drizzle (Conditions with spectra maximum drop diameters from 100 µm to 500 µm):

(1) Pressure altitude range: 0 to 6 706 m (22 000 feet) MSL.

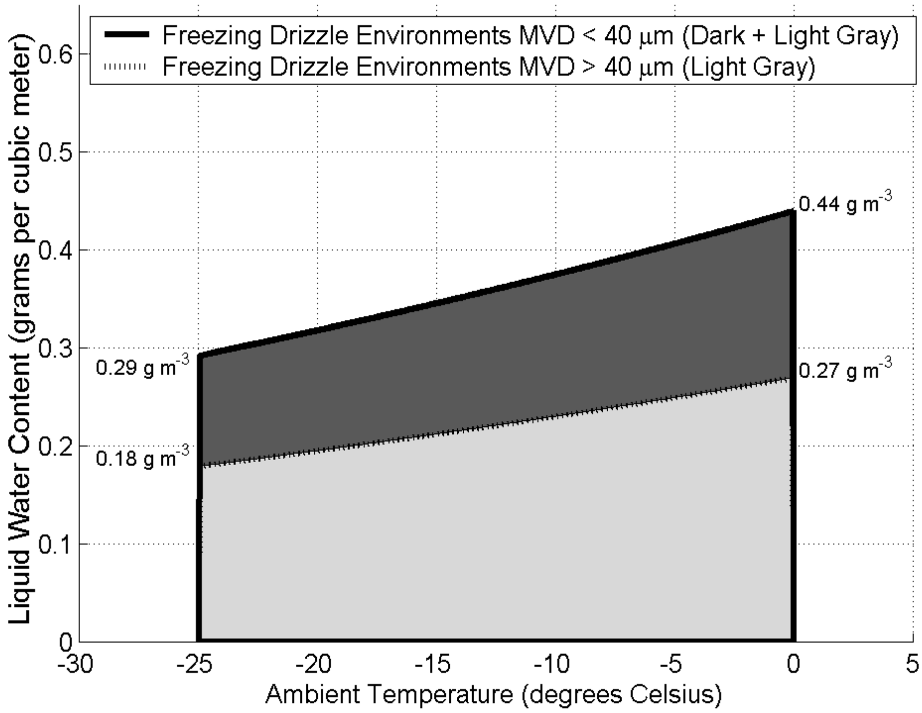
(2) Maximum vertical extent: 3 656 m (12 000 feet).

(3) Horizontal extent: standard distance of 32.2 km (17.4 nautical miles).

(4) Total liquid water content:

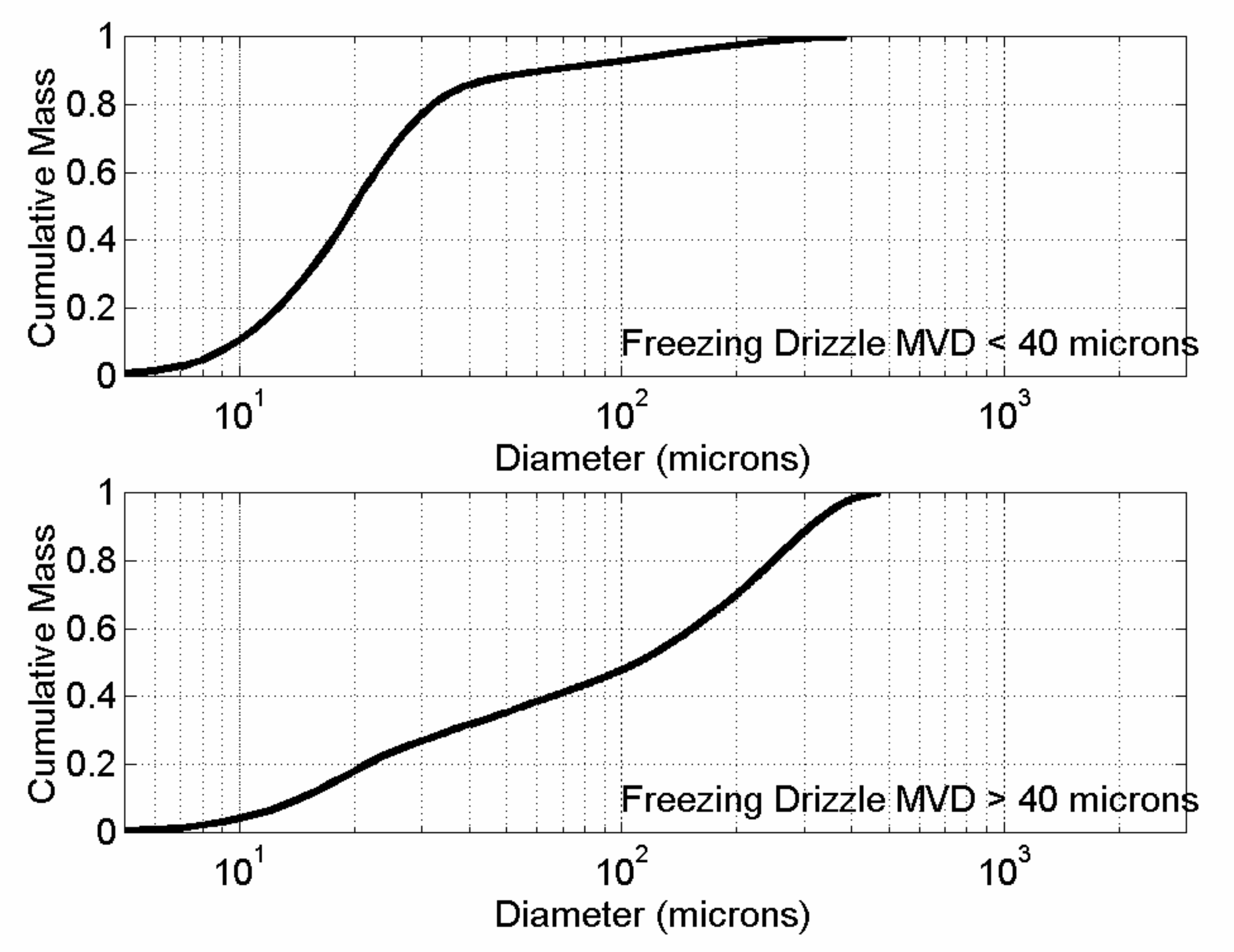
Note: Liquid water content (LWC) in grams per cubic meter (g/m^3) based on horizontal extent standard distance of 32.2 km (17.4 nautical miles).

Figure 1 –Appendix O, Freezing Drizzle, Liquid Water Content



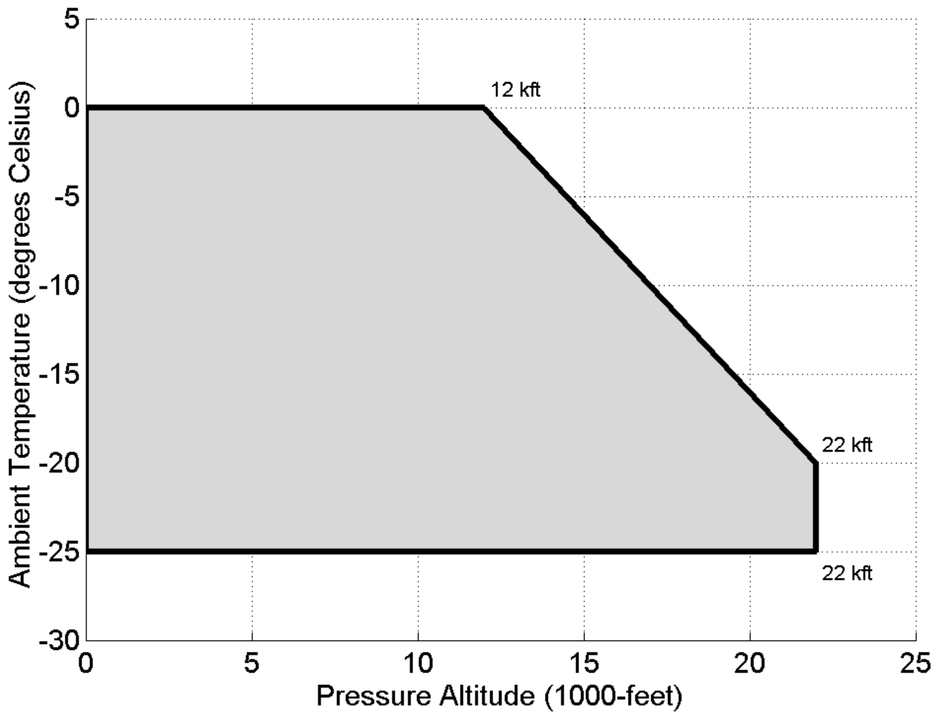
(5) Drop diameter distribution:

Figure 2 – Appendix O, Freezing Drizzle, Drop Diameter Distribution



(6) Altitude and temperature envelope:

Figure 3 – Appendix O, Freezing Drizzle, Altitude and Temperature



(b) Freezing Rain (Conditions with spectra maximum drop diameters greater than 500 µm):

(1) Pressure altitude range: 0 to 3656 m (12000 ft) MSL.

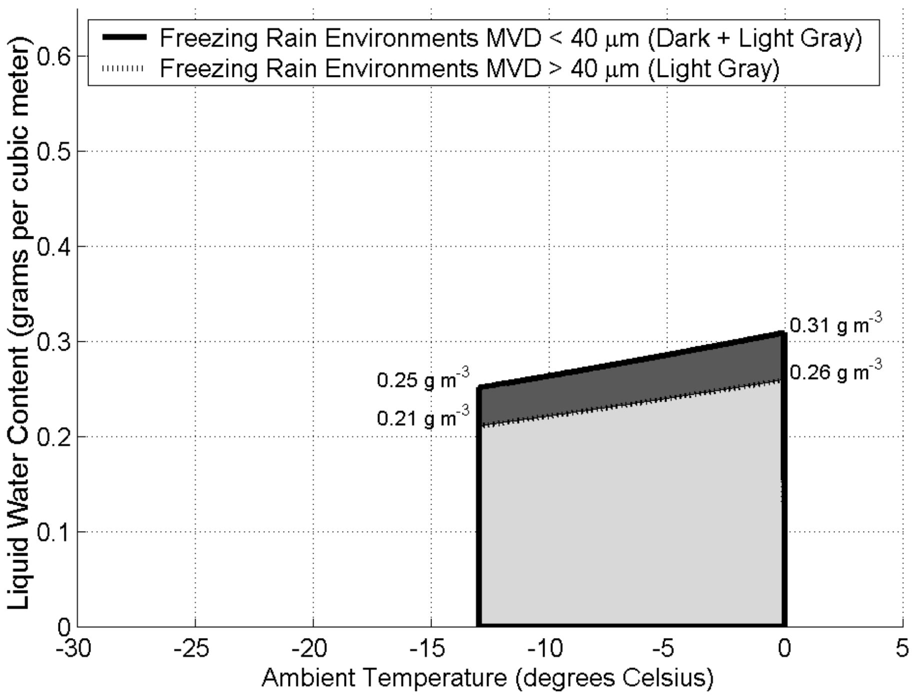
(2) Maximum vertical extent: 2134 m (7000 ft).

(3) Horizontal extent: standard distance of 32.2 km (17.4 nautical miles).

(4) Total liquid water content:

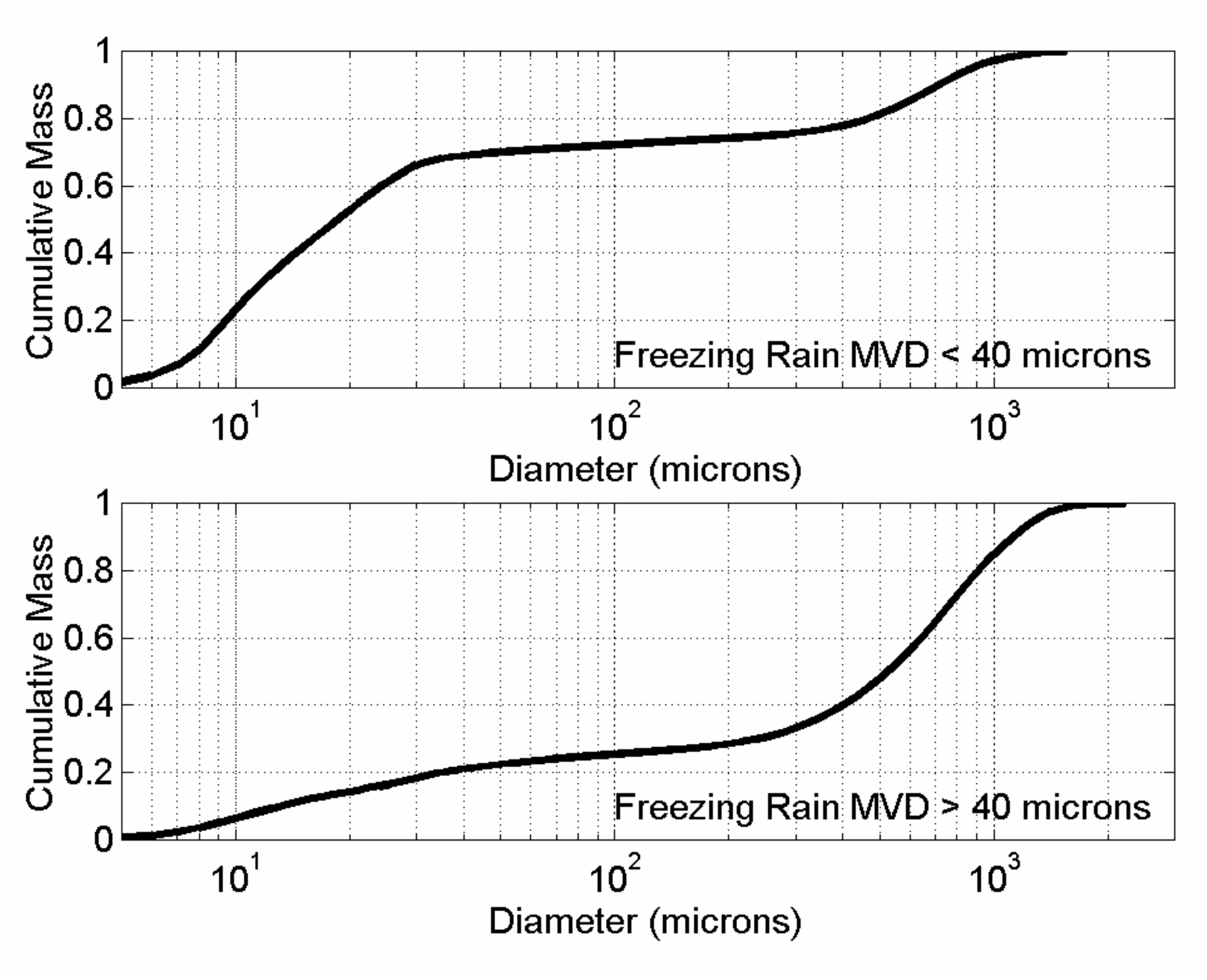
Note: LWC in grams per cubic meter (g/m^3) based on horizontal extent standard distance of 32.2 km (17.4 nautical miles).

Figure 4 – Appendix O, Freezing Rain, Liquid Water Content



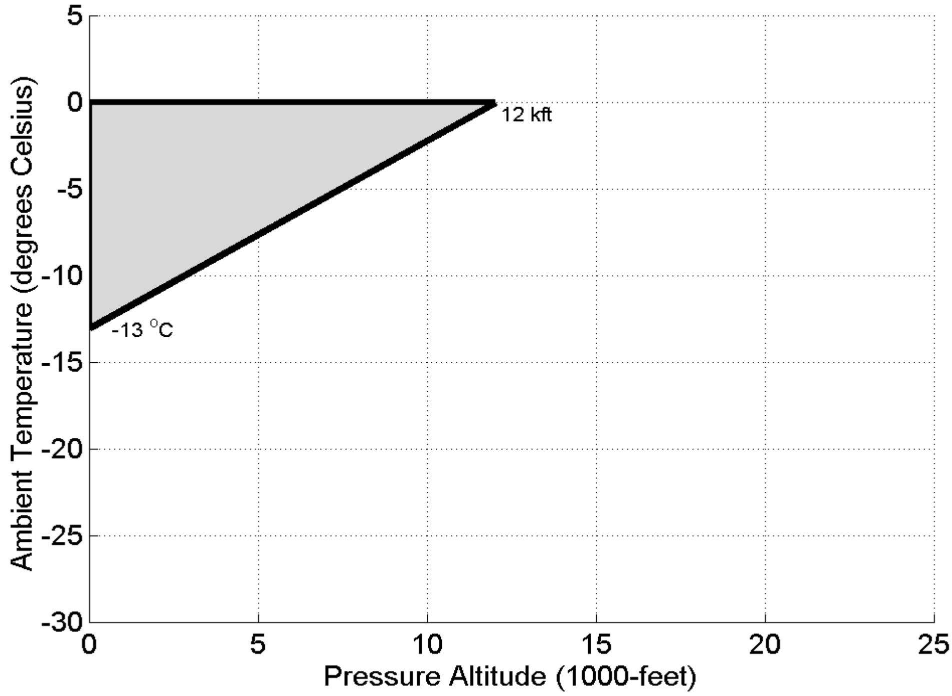
(5) Drop diameter distribution:

Figure 5 – Appendix O, Freezing Rain, Drop Diameter Distribution



(6) Altitude and temperature envelope:

Figure 6 – Appendix O, Freezing Rain, Altitude and Temperature



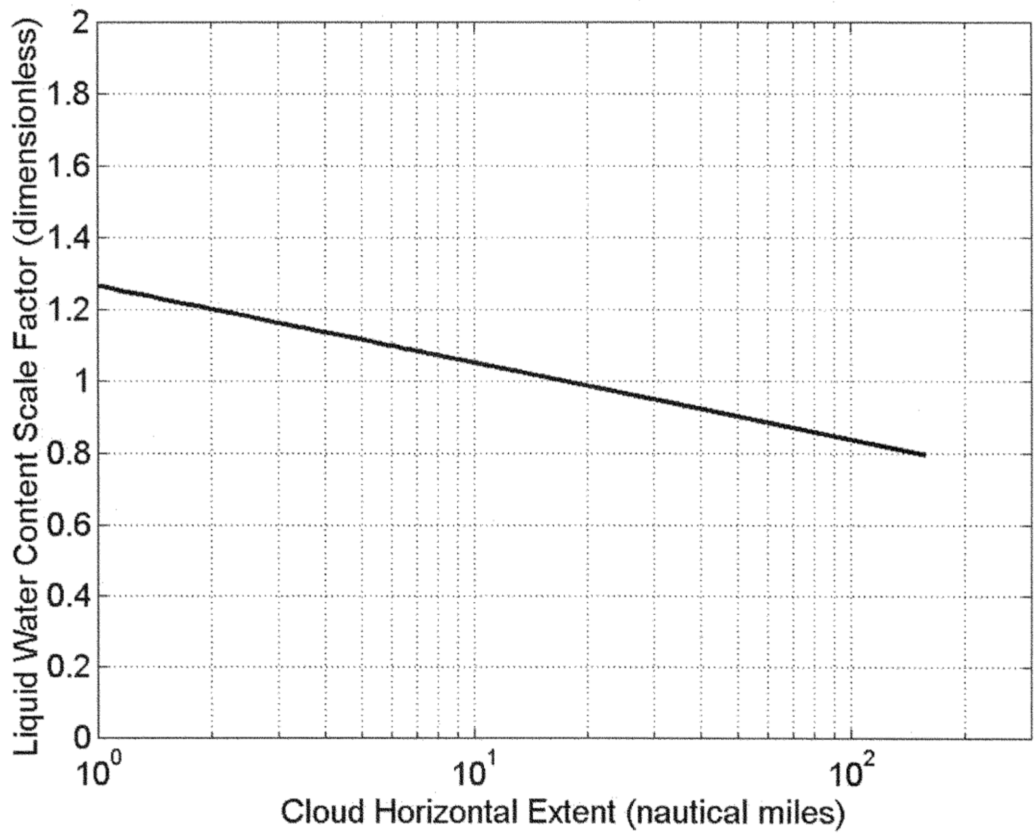
(c) Horizontal extent

The liquid water content for freezing drizzle and freezing rain conditions for horizontal extents other than the standard 32.2 km (17.4 nautical miles) can be determined by the value of the liquid water content determined from Figure 1 or Figure 4, multiplied by the factor provided in Figure 7, which is defined by the following equation:

$S = 1.266 - 0.213 \log_{10}(H)$

Where S = Liquid Water Content Scale Factor (dimensionless) and H = horizontal extent in nautical miles

Figure 7 – Appendix O, Horizontal Extent, Freezing Drizzle and Freezing Rain



Part II—Airframe ice accretions

(a) General.

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

(1) For an aeroplane certified in accordance with CS 25.1420(a)(1), the ice accretions for each flight phase are defined in part II, paragraph (b) of this appendix.

(2) For an aeroplane certified in accordance with CS 25.1420(a)(2), the most critical ice accretion for each flight phase defined in part II, paragraphs (b) and (c) of this appendix, must be used. For the ice accretions defined in part II, paragraph (c) of this appendix, only the portion of part I of this appendix in which the aeroplane is capable of operating safely must be considered.

(3) For an aeroplane certified in accordance with CS 25.1420(a)(3), the ice accretions for each flight phase are defined in part II, paragraph (c) of this appendix.

(b) Ice accretions for aeroplanes certified in accordance with CS 25.1420(a)(1) or (a)(2).

(1) <u>En-route ice</u> is the en-route ice as defined by part II, paragraph (c)(3), of this appendix, for an aeroplane certified in accordance with CS 25.1420(a)(2), or defined by part II, paragraph (a)(3), of Appendix C, for an aeroplane certified in accordance with CS 25.1420(a)(1), plus:

(i) Pre-detection ice as defined by part II paragraph (b)(5) of this appendix; and

(ii) The ice accumulated during the transit of one cloud with a horizontal extent of 32.2 km (17.4 nautical miles) in the most critical of the icing conditions defined in part I of this appendix and one cloud with a horizontal extent of 32.2 km (17.4 nautical miles) in the continuous maximum icing conditions defined in Appendix C.

(2) <u>Holding ice</u> is the holding ice defined by part II, paragraph (c)(4), of this appendix, for an aeroplane certified in accordance with CS 25.1420(a)(2), or defined by part II, paragraph (a)(4) of Appendix C, for an aeroplane certified in accordance with CS 25.1420(a)(1), plus:

(i) Pre-detection ice as defined by part II, paragraph (b)(5) of this appendix; and

(ii) The ice accumulated during the transit of one cloud with a 32.2 km (17.4 nautical miles) horizontal extent in the most critical of the icing conditions defined in part I of this appendix and one cloud with a horizontal extent of 32.2 km (17.4 nautical miles) in the continuous maximum icing conditions defined in Appendix C.

(iii) Except the total exposure to holding ice conditions does not need to exceed 45 minutes

(3) <u>Approach ice</u> is the more critical of the holding ice defined by part II, paragraph (b)(2) of this appendix, or the ice calculated in the applicable paragraph (b)(3)(i) or (ii) of part II of this appendix:

(i) For an aeroplane certified in accordance with CS 25.1420(a)(2), the ice accumulated during descent from the maximum vertical extent of the icing conditions defined in part I of this appendix to 610 m (2 000 feet) above the landing surface in the cruise configuration, plus transition to the approach configuration, plus:

(A) Pre-detection ice, as defined by part II, paragraph (b)(5) of this appendix; and

(B) The ice accumulated during the transit at 610 m (2 000 feet) above the landing surface of one cloud with a horizontal extent of 32.2 km (17.4 nautical miles) in the most critical of the icing conditions defined in part I of this appendix and one cloud with a horizontal extent of 32.2 km (17.4 nautical miles) in the continuous maximum icing conditions defined in Appendix C.

(ii) For an aeroplane certified in accordance with CS 25.1420(a)(1), the ice accumulated during descent from the maximum vertical extent of the maximum continuous icing conditions defined in part I of Appendix C to 610 m (2 000 feet) above the landing surface in the cruise configuration, plus transition to the approach configuration, plus:

(A) Pre-detection ice, as defined by part II, paragraph (b)(5) of this appendix; and

(B) The ice accumulated during the transit at 610 m (2 000 feet) above the landing surface of one cloud with a horizontal extent of 32.2 km (17.4 nautical miles) in the most critical of the icing conditions defined in part I of this appendix and one cloud with a horizontal extent of 32.2 km (17.4 nautical miles) in the continuous maximum icing conditions defined in Appendix C.

(4) Landing ice is the more critical of the holding ice as defined by part II, paragraph (b)(2) of this appendix, or the ice calculated in the applicable paragraph (b)(4)(i) or (ii) of part II of this appendix:

(i) For an aeroplane certified in accordance with CS 25.1420(a)(2), the ice accretion defined by part II, paragraph (c)(5)(i) of this appendix, plus a descent from 610 m (2 000 feet) above the landing surface to a height of 61 m (200 feet) above the landing surface with a transition to the landing configuration in the icing conditions defined in part I of this appendix, plus:

(A) Pre-detection ice, as defined in part II, paragraph (b)(5) of this appendix; and

(B) The ice accumulated during an exit manoeuvre, beginning with the minimum climb gradient required by CS 25.119, from a height of 61 m (200 feet) above the landing surface through one cloud with a horizontal extent of 32.2 km (17.4 nautical miles) in the most critical of the icing conditions defined in part I of this appendix and one cloud with a horizontal extent of 32.2 km (17.4 nautical miles) in the continuous maximum icing conditions defined in Appendix C.

(ii) For an aeroplane certified in accordance with CS 25.1420(a)(1), the ice accumulated in the maximum continuous icing conditions defined in Appendix C, during a descent from the maximum vertical extent of the icing conditions defined in Appendix C, to 610 m (2 000 feet) above the landing surface in the cruise configuration, plus transition to the approach configuration and flying for 15 minutes at 610 m (2 000 feet) above the landing surface, plus a descent from 610 m

(2 000 feet) above the landing surface to a height of 61 m (200 feet) above the landing surface with a transition to the landing configuration, plus:

(A) Pre-detection ice, as described by part II, paragraph (b)(5) of this appendix; and

(B) The ice accumulated during an exit manoeuvre, beginning with the minimum climb gradient required by CS 25.119, from a height of 61 m (200 feet) above the landing surface through one cloud with a horizontal extent of 32.2 km (17.4 nautical miles) in the most critical of the icing conditions defined in part I of this appendix and one cloud with a horizontal extent of 32.2 km (17.4 nautical miles) in the continuous maximum icing conditions defined in Appendix C.

(5) Pre-detection ice is the ice accretion before detection of Appendix O conditions that require exiting per CS 25.1420(a)(1) and (a)(2). It is the pre-existing ice accretion that may exist from operating in icing conditions in which the aeroplane is approved to operate prior to encountering the icing conditions requiring an exit, plus the ice accumulated during the time needed to detect the icing conditions, followed by two minutes of further ice accumulation to take into account the time for the flight crew to take action to exit the icing conditions, including coordination with air traffic control.

(i) For an aeroplane certified in accordance with CS 25.1420(a)(1), the pre-existing ice accretion must be based on the icing conditions defined in Appendix C.

(ii) For an aeroplane certified in accordance with CS 25.1420(a)(2), the pre-existing ice accretion must be based on the more critical of the icing conditions defined in Appendix C, or the icing conditions defined in part I of this appendix in which the aeroplane is capable of safely operating.

(c) Ice accretions for aeroplanes certified in accordance with CS 25.1420(a)(2) or CS 25.1420(a)(3).

For an aeroplane certified in accordance with CS 25.1420(a)(2), only the portion of the icing conditions of part I of this appendix in which the aeroplane is capable of operating safely must be considered.

(1) Take-off ice is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, occurring between the end of the take-off distance and 122 m (400 feet) above the take-off surface, assuming accretion starts at the end of the take-off distance in the take-off maximum icing conditions defined in part I of this appendix.

(2) Final take-off ice is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, between 122 m (400 feet) and either 457 m (1 500 feet) above the take-off surface, or the height at which the transition from the take-off to the en-route configuration is completed and V_{FTO} is reached, whichever is higher. Ice accretion is assumed to start at lift-off the end of the take-off distance in the icing conditions defined in part I of this appendix.

(3) En-route ice is the most critical ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, during the en-route flight phase in the icing conditions defined in part I of this appendix.

(4) Holding ice is the most critical ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, resulting from 45 minutes of flight within a cloud with a 32.2 km (17.4 nautical miles) horizontal extent in the icing conditions defined in part I of this appendix, during the holding phase of flight.

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

(i) Ice accumulated in the icing conditions defined in part I of this appendix during a descent from the maximum vertical extent of the icing conditions defined in part I of this appendix, to 610 m (2 000 feet) above the landing surface in the cruise configuration, plus transition to the approach configuration and flying for 15 minutes at 610 m (2 000 feet) above the landing surface; or

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

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

(i) Ice accretion defined by part II, paragraph (c)(5)(i), of this appendix, plus ice accumulated in the icing conditions defined in part I of this appendix during a descent from 610 m (2 000 feet) above the landing surface to a height of 61 m (200 feet) above the landing surface with a transition to the landing configuration, followed by a go-around at the minimum climb gradient required by CS 25.119, from a height of 61 m (200 feet) above the landing surface to 610 m (2 000 feet) above the landing surface, flying for 15 minutes at 610 m (2 000 feet) above the landing surface in the approach configuration, and a descent to the landing surface (touchdown) in the landing configuration; or

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

(7) For both unprotected and protected parts, the ice accretion for the take-off phase must be determined for the icing conditions defined in part I of this appendix, using the following assumptions:

(i) The aerofoils, control surfaces, and, if applicable, propellers are free from frost, snow, or ice at the start of take-off;

(ii) The ice accretion begins at lift-off;

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

(iv) Failure of the critical engine occurs at V_{EF}; and

(v) Crew activation of the ice protection system is in accordance with a normal operating procedure provided in the Aeroplane Flight Manual, except that after beginning the take-off roll, it must be assumed that the crew takes no action to activate the ice protection system until the aeroplane is at least 122 m (400 feet) above the take-off surface.

(d) The ice accretion before the ice protection system has been activated and is performing its intended function is the critical ice accretion formed on the unprotected and normally protected surfaces before activation and effective operation of the ice protection system in the icing conditions defined in part I of this appendix. This ice accretion only applies in showing compliance to CS 25.143(j) and 25.207(h).

(e) In order to reduce the number of ice accretions to be considered when demonstrating compliance with the requirements of CS 25.21(g), any of the ice accretions defined in this appendix may be used for any other flight phase if it is shown to be at least as critical as the specific ice accretion defined for that flight phase. Configuration differences and their effects on ice accretions must be taken into account.

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

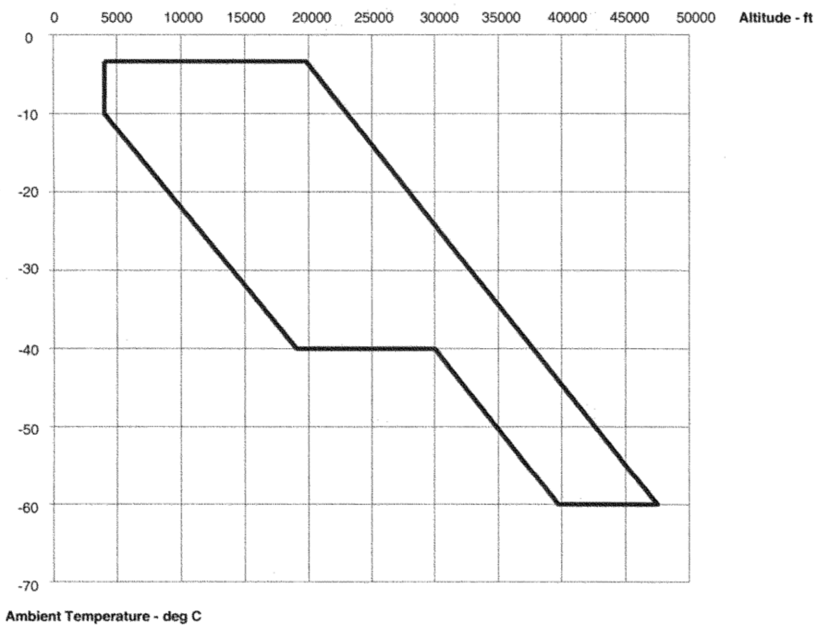
Create a new Appendix P as follows:

Appendix P

Mixed phase and ice crystal icing envelope (Deep convective clouds)

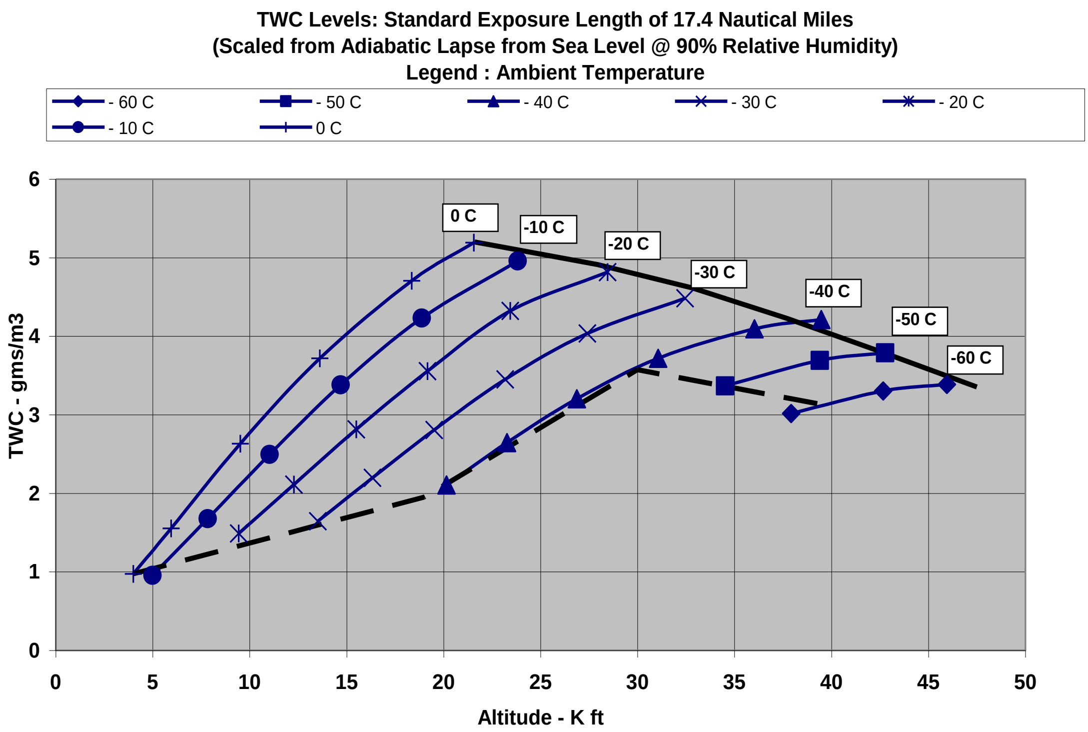
The ice crystal icing envelope is depicted in Figure 1 below.

Figure 1 – Convective cloud ice crystal envelope



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 32.2 km (17.4 nautical miles). Figure 2 displays TWC for this distance over a range of ambient temperature within the boundaries of the ice crystal envelope specified in Figure 1.

Figure 2 – Total Water Content



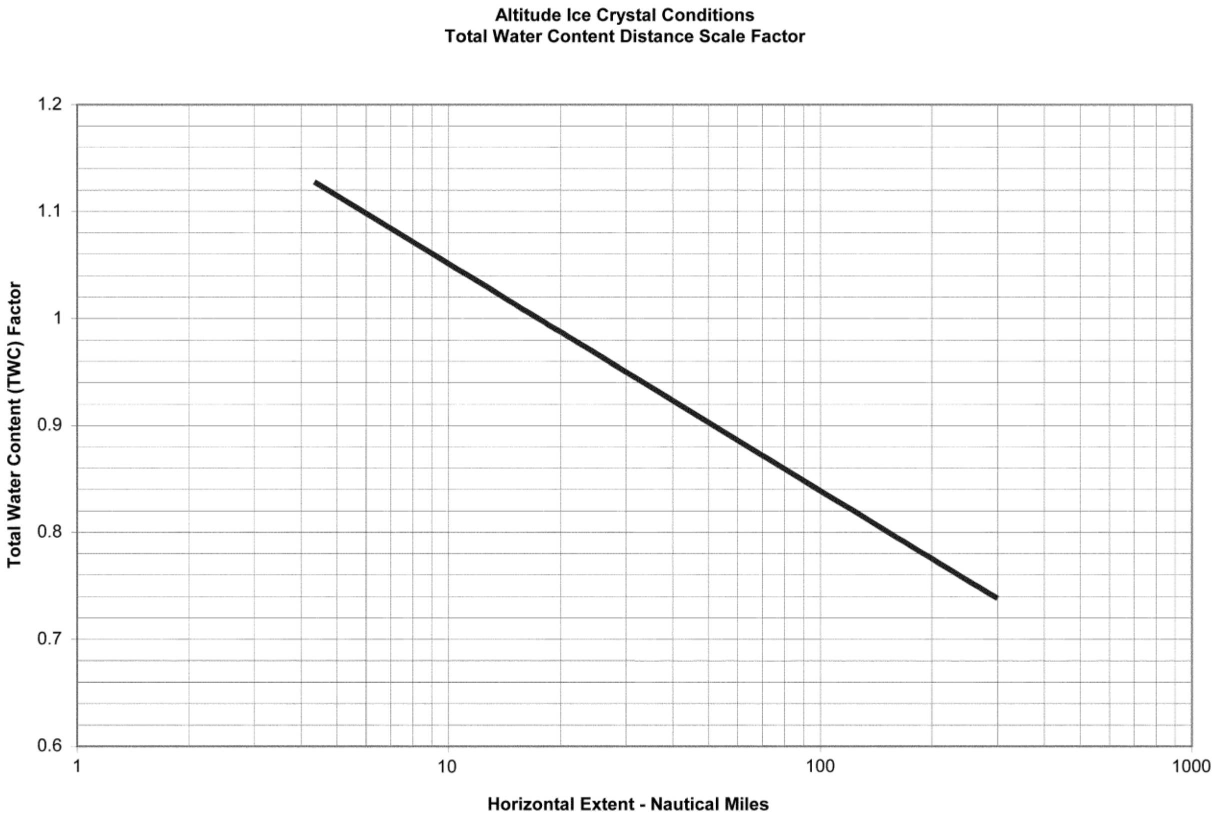
Ice crystal size median mass dimension (MMD) range is 50–200 microns (equivalent spherical size) based upon measurements near convective storm cores. The TWC can be treated as completely glaciated (ice crystal) except as noted in the Table 1.

Table 1 – Supercooled Liquid Portion of TWC

Temperature range – deg C	Horizontal cloud length	LWC – g/m^3
0 to -20	≤92.6 km (50 nautical miles)	≤1.0
0 to -20	Indefinite	≤0.5
< -20		0

The TWC levels displayed in Figure 2 represent TWC values for a standard exposure distance (horizontal cloud length) of 32.2 km (17.4 nautical miles) that must be adjusted with length of icing exposure.

Figure 3 - Exposure Length Influence on TWC



BOOK 2

AMC — SUBPART B

Amend AMC 25.21(g) as follows:

AMC 25.21(g)

Performance and Handling Characteristics in Icing Conditions ~~Contained in Appendix C, of CS-25~~

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A3.2 Wing

A3.3 Empennage

A3.4 Aerodynamic Balancing of Flight Control Surfaces

A3.5 Ice Protection/Detection System

A4 Appendix 4 - Examples of Aeroplane Flight Manual Limitations and Operating Procedures for Operations in Supercooled Large Drop Icing Conditions

A5 Appendix 5 - Related Acceptable Means of Compliance (AMC) and FAA Advisory Circulars (AC)

A6 Appendix 6 - Acronyms and definitions

1 *Purpose*.

1.1 This AMC describes an acceptable means for showing compliance with the requirements related to performance and handling characteristics of Large Aeroplanes as affected by flight in ~~the~~ icing conditions ~~that are defined in Appendix C to CS-25~~. The means of compliance described in this AMC is intended to provide guidance to supplement the engineering and operational judgement that should form the basis of any compliance findings relative to handling characteristics and performance in Appendix C and Appendix O icing conditions.

1.2 The guidance information is presented in sections 4 to 6 and three appendices.

1.3 Section 4 explains the various performance and handling requirements in relation to the flight conditions that are relevant for determining the shape and texture of ice accretions for the aeroplane in the atmospheric icing conditions of CS-25, Appendix C and Appendix O.

1.4 Section 5 describes acceptable methods and procedures that an applicant may use to show that an aeroplane meets these requirements. Depending on the design features of a specific aeroplane as discussed in Appendix 3 of this AMC, its similarity to other types or models, and the service history of those types or models, some judgement will often be necessary for determining that any particular method or procedure is adequate for showing compliance with a particular requirement.

1.5 Section 6 provides an acceptable flight test programme where flight testing is selected by the applicant and agreed by the ~~Authority~~ Agency as being the primary means of compliance.

1.6 The three appendices provide additional reference material associated with ice accretion, artificial ice shapes, and aeroplane design features.

2 *Related Requirements.* The following paragraphs of CS-25 are related to the guidance in this AMC:

- CS 25.21 (Proof of compliance)
- CS 25.103 (Stall speed)
- CS 25.105 (Take-off)
- CS 25.107 (Take-off speeds)
- CS 25.111 (Take-off path)
- CS 25.119 (Landing climb)
- CS 25.121 (Climb: One-engine-inoperative)
- CS 25.123 (En-route flight paths)

- CS 25.125 (Landing)
- CS 25.143 (Controllability and Manoeuvrability - General)
- CS 25.207 (Stall warning)
- CS 25.237 (Wind velocities)
- CS 25.253 (High-speed characteristics)
- CS 25.1309 (Equipment, systems, and installations)
- CS 25.1419 (Ice protection)
- CS 25.1420 (Supercooled large drop icing conditions)
- CS 25.1581 (Aeroplane Flight Manual)
- CS 25, Appendix C
- CS 25, Appendix O

3 *Reserved.*

4 *Requirements and Guidance.*

4.1 *General.* This section provides guidance for showing compliance with Subpart B requirements for flight in the icing conditions of Appendix C and Appendix O to CS-25.

4.1.1 Operating rules for commercial operation of large aeroplanes (e.g. ~~JAR~~EU-OPS 1.345) require that the aeroplane is free of any significant ice contamination at the beginning of the take-off roll due to application of appropriate ice removal and ice protection procedures during flight preparation on the ground.

4.1.2 ~~Appendix C to CS-25 defines the ice accretions to be used in showing compliance with CS 25.21(g). Appendix 1 of this AMC provides details on ice accretions, including accounting for delay in the operation of the ice protection system and consideration of ice detection systems.~~ For certification for flight in the icing conditions described in Appendix C of CS-25, CS 25.21(g)(1) requires that an aeroplane meet certain performance and handling qualities requirements while operating in the icing environment defined in Appendix C. In addition, CS 25.1420 requires applicants to consider icing conditions beyond those covered by Appendix C. The additional icing conditions that must be considered are the supercooled large drop icing conditions defined in Appendix O. CS 25.21(g)(2) and (3) respectively provide the performance and handling qualities requirements to be met by applicants not seeking certification in the icing conditions of Appendix O and by applicants seeking certification in any portion of the icing conditions of Appendix O. Appendix 1 of this AMC provides detailed guidance for determining ice accretions in both Appendix C and Appendix O icing conditions that can be used for showing compliance.

CS 25.1420 requires applicants to choose to do one of the following:

(a) Not seek approval for flight in the supercooled large drop atmospheric icing conditions defined in Appendix O.

(b) Seek approval for flight in only a portion of Appendix O icing conditions.

(c) Seek approval for flight throughout the entire Appendix O atmospheric icing envelope.

4.1.3 Because an aeroplane may encounter supercooled large drop icing conditions at any time while flying in icing conditions, certain safety requirements must be met for the supercooled large drop icing conditions of Appendix O, even if the aeroplane will not be certified for flight in the complete range of Appendix O atmospheric icing conditions. CS 25.21(g)(2) requires the stall speed (CS 25.103), landing climb (CS 25.119), and landing (CS 25.125) requirements to be met in supercooled large drop atmospheric icing conditions beyond those the aeroplane will be certified for. Compliance with these requirements plus the requirements for flight in Appendix C icing conditions are intended to provide adequate performance capability for a safe exit from all icing conditions after an encounter with supercooled large drop atmospheric icing conditions beyond those the aeroplane is certified for.

4.1.4 If the aeroplane is not to be certified for flight in all of the supercooled large drop icing conditions of Appendix O, there must be a means of indicating when the aeroplane has encountered icing conditions beyond those it is certified for. See AMC 25.1420 for guidance on acceptable means of detecting and indicating when the aeroplane has encountered icing conditions beyond those it is certified for. The applicant should provide procedures in the aeroplane flight manual to enable a safe exit from all icing conditions after an encounter with icing conditions beyond those the aeroplane is certified for.

4.1.5 To certify an aeroplane for operations in Appendix O icing conditions only for certain flight phase(s), the applicant should define the flight phase(s) for which approval is sought in a way that will allow a flight crew to easily determine whether the aeroplane is operating inside or outside its certified icing envelope. The critical ice accretion or accretions used to show compliance with the applicable requirements should cover the range of aeroplane configurations, operating speeds, angles-of-attack, and engine thrust or power settings that may be encountered during that phase of flight (not just at the conditions specified in the CS-25 subpart B requirements). For the ice accretion scenarios defined in paragraph A1.4.3(c) of Appendix 1 to this AMC, the applicable flight phases are take-off (including the ground roll, take-off, and final take-off segments), en route, holding, and approach/landing (including both the approach and landing segments).

4.1.6 Ice accretions used to show compliance with the applicable CS-25 subpart B regulations should be consistent with the extent of the desired certification for flight in icing conditions. Appendices C and O define the ice accretions, as a function of flight phase, that must be considered for certification for flight in those icing conditions. Any of the applicable ice accretions (or a composite accretion representing a combination of accretions) may be used to show compliance with a particular subpart B requirement if it is either the ice accretion identified in the requirement or one shown to be more conservative than that. In addition, the ice accretion with the most adverse effect on handling characteristics may be used for compliance with the aeroplane performance requirements if each difference in performance is conservatively taken into account. Ice accretion(s) used to show compliance should take into account the speeds, configurations (including configuration changes), angles of attack, power or thrust settings, etc. for the flight phases and icing conditions they are intended to cover. For example, if the applicant desires certification for flight in the supercooled large drop icing conditions of Appendix O in addition to those of Appendix C, compliance with the applicable subpart B requirements may be shown using the most critical of the Appendix C and Appendix O ice accretions.

4.1.~~3~~7 Certification experience has shown that it is not necessary to consider ice accumulation on the propeller, induction system or engine components of an inoperative engine for handling qualities substantiation. Similarly, the mass of the ice need not normally be considered.

4.1.~~4~~8 Flight in icing conditions includes operation of the aeroplane after leaving the icing conditions, but with ice accretion remaining on the critical surfaces of the aeroplane.

4.1.9 Ice-contaminated tailplane stall (ICTS) refers to a phenomenon identified as a causal factor in several aeroplane incidents and accidents. It results from airflow separation on the lower surface of the tailplane because ice is present. ICTS can occur if the angle-of-attack of the horizontal tailplane exceeds its stall angle-of-attack. Even very small quantities of ice on the tailplane leading edge can significantly reduce the angle-of-attack at which the tailplane stalls. An increase in tailplane angle-of-attack, which may lead to a tailplane stall, can result from changes in aeroplane configuration (for example, extending flaps, which increases the downwash angle at the tail or the pitch trim required) or flight conditions (a high approach speed, gusts, or manoeuvring, for example). An ICTS is characterized by reduction or loss of pitch control or pitch stability while in, or soon after leaving, icing conditions. A flight test procedure for determining susceptibility to ICTS is presented in paragraph 6.9.4, *Low g Manoeuvres and Sideslips*, of this AMC.

(a) For aeroplanes with unpowered longitudinal control systems, the pressure differential between the upper and lower surfaces of the stalled tailplane may result in a high elevator hinge moment, forcing the elevator trailing edge down. This elevator hinge moment reversal can be of sufficient magnitude to cause the longitudinal control (for example, the control column) to suddenly move forward with a force beyond the capability of the flight crew to overcome. On some aeroplanes, ICTS has been caused by a lateral flow component coming off the vertical stabilizer, as may occur in sideslip conditions or because of a wind gust with a lateral component.

(b) Aerodynamic effects of reduced tailplane lift should be considered for all aeroplanes, including those with powered controls. Aeroplanes susceptible to this phenomenon are those having a near zero or negative tailplane stall margin with tailplane ice contamination.

4.1.10 There have been aeroplane controllability incidents in icing conditions as a result of ice on unprotected leading edges of extended trailing edge flaps or flap vanes. The primary safety concern illustrated by these incidents is the potential for controllability problems due to the accretion of ice on trailing edge flap or flap vane leading edges while extending flaps in icing conditions. The flight tests specified in Table 4 of this AMC, in which handling characteristics are tested at each flap position while ice is being accreted in natural icing conditions, are intended to investigate this safety concern. Unless controllability concerns arise from these tests, it is not necessary to conduct flight tests with artificial ice shapes on the extended trailing edge flap or flap vanes or to include extended trailing edge flap or flap vane ice accretions when evaluating aeroplane performance with flaps extended.

4.1.11 Supercooled large drop icing conditions, or runback ice in any icing condition, can cause a ridge of ice to form aft of the protected area on the upper surface of the wing. This can lead to separated airflow over the aileron. Ice-induced airflow separation upstream of the aileron can have a significant effect on aileron hinge moment. Depending on the extent of the separated flow and the design of the flight control system, ice accretion upstream of the aileron may lead to aileron hinge moment reversal, reduced aileron effectiveness, and aileron control reversal. Although aeroplanes with de-icing boots and unpowered aileron controls are most susceptible to this problem, all aeroplanes should be evaluated for roll control capability in icing conditions.

Acceptable flight test procedures for checking roll control capability are presented in paragraphs 6.9.3, 6.15, and 6.17.2.e of this AMC and consist of bank-to-bank roll manoeuvres, steady heading sideslips, and rolling manoeuvres at stall warning speed.

4.1.12 Appendix 5 contains related Acceptable Means of Compliance and FAA Advisory Circulars. Appendix 6 contains acronyms and definitions used in this AMC.

4.2 *Proof of Compliance (CS 25.21(g)).*

4.2.1 Demonstration of compliance with certification requirements for flight in icing conditions may be accomplished by any of the means discussed in paragraph 5.1 of this AMC.

4.2.2 Certification experience has shown that aeroplanes of conventional design do not require additional detailed substantiation of compliance with the requirements of the following paragraphs of CS-25 for flight in icing conditions or with ice accretions:

25.23, Load distribution limits

25.25, Weight limits

25.27, Centre of gravity limits

25.29, Empty weight and corresponding centre of gravity

25.31, Removable ballast

25.231, Longitudinal stability and control

25.233, Directional stability and control

25.235, Taxiing condition

25.253(a) and (b), High-speed characteristics, and

25.255, Out-of-trim characteristics

4.2.3 Where normal operation of the ice protection system results in changing the stall warning system and/or stall identification system activation settings, it is acceptable to establish a procedure to return to the non icing settings when it can be demonstrated that the critical wing surfaces are free of ice accretion.

4.3 *Propeller Speed and Pitch Limits (CS 25.33).* Certification experience has shown that it may be necessary to impose additional propeller speed limits for operations in icing conditions.

4.4 *Performance - General (CS 25.101).*

4.4.1 The propulsive power or thrust available for each flight condition must be appropriate to the aeroplane operating limitations and normal procedures for flight in icing conditions. In general, it is acceptable to determine the propulsive power or thrust available by suitable analysis, substantiated when required by appropriate flight tests (e.g. when determining the power or thrust available after 8 seconds for CS 25.119). The following aspects should be considered:

a. Operation of induction system ice protection.

b. Operation of propeller ice protection.

c. Operation of engine ice protection.

d. Operation of airframe ice protection system.

4.4.2 The following should be considered when determining the change in performance due to flight in icing conditions:

a. Thrust loss due to ice accretion on propulsion system components with normal operation of the ice protection system, including engine induction system and/or engine components, and propeller spinner and blades.

b. The incremental airframe drag due to ice accretion with normal operation of the ice protection system.

c. Changes in operating speeds due to flight in icing conditions.

4.4.3 Certification experience has shown that any increment in drag (or decrement in thrust) due to the effects of ice accumulation on the landing gear, propeller, induction system and engine components may be determined by a suitable analysis or by flight test.

4.4.4 Apart from the use of appropriate speed adjustments to account for operation in icing conditions, any changes in the procedures established for take-off, balked landing, and missed approaches should be agreed with the ~~Authority~~ Agency.

4.4.5 Performance associated with flight in icing conditions is applicable after exiting icing conditions until the aeroplane critical surfaces are free of ice accretion and the ice protection systems are selected “Off.”

4.4.6 Certification experience has also shown that runback ice may be critical for propellers, and propeller analysis do not always account for it. Therefore, runback ice on the propeller should be addressed~~,~~. Research has shown that ice accretions on propellers, and resulting thrust decrement, may be larger in Appendix O (supercooled large drop) icing conditions than in Appendix C icing conditions for some designs. This ~~which~~ may be accomplished through ~~necessitate~~ ~~airplane~~ aeroplane performance checks in natural icing conditions, icing tanker tests, icing wind tunnel tests, aerodynamic analysis, or the use of an assumed (conservative) loss in propeller efficiency. Testing should include a range of outside air temperatures, including warmer (near freezing) temperatures that could result in runback icing.

4.5 *Stall speed (CS 25.103)*. Certification experience has shown that for aeroplanes of conventional design it is not necessary to make a separate determination of the effects of Mach number on stall speeds for the aeroplane with ice accretions.

4.6 *Failure Conditions (CS 25.1309)*.

4.6.1 The failure modes of the ice protection system and the resulting effects on aeroplane handling and performance should be analysed in accordance with CS 25.1309. In determining the probability of a failure condition, it should be assumed that the probability of entering icing conditions defined in CS-25 Appendix C is one. As explained in AMC 25.1420, on an annual basis, the average probability of encountering the icing conditions defined in Appendix O may be assumed to be 1×10^{-2} per flight hour. This probability should not be reduced on a phase-of-flight basis. The "Failure Ice" configuration is defined in Appendix 1, paragraph A1.3.

4.6.2 For probable failure conditions that are not annunciated to the flight crew, the guidance in this AMC for a normal condition is applicable with the "Failure Ice" configuration.

4.6.3 For probable failure conditions that are annunciated to the flight crew, with an associated procedure that does not require the aeroplane to exit icing conditions, the guidance in this AMC for a normal condition is applicable with the "Failure Ice" configuration.

4.6.4 For probable failure conditions that are annunciated to the flight crew, with an associated operating procedure that requires the aeroplane to leave the icing conditions as soon as ~~practicable~~possible, it should be shown that the aeroplane's resulting performance and handling characteristics with the failure ice accretion are commensurate with the hazard level as determined by a system safety analysis in accordance with CS 25.1309. The operating procedures and related speeds may restrict the aeroplane's operating envelope, but the size of the restricted envelope should be consistent with the safety analysis.

4.6.5 For failure conditions that are ~~improbable~~ extremely remote but not extremely improbable, the analysis and substantiation of continued safe flight and landing, in accordance with CS 25.1309, should take into consideration whether annunciation of the failure is provided and the associated operating procedures and speeds to be used following the failure condition.

4.7 *Flight-related Systems*. In general, systems aspects are covered by the applicable systems and equipment requirements in other subparts of CS-25, and associated guidance material. However, certification experience has shown that other flight related systems aspects should be considered when determining compliance with the flight requirements of subpart B. For example, the following aspects may be relevant:

a. The ice protection systems may not anti-ice or de-ice properly at all power or thrust settings. This may result in a minimum power or thrust setting for operation in icing conditions which affects descent and/or approach capability. The effect of power or thrust setting should also be considered in determining the applicable ice accretions. For example, a thermal bleed air system may be running wet resulting in the potential for runback ice.

b. Ice blockage of control surface gaps and/or freezing of seals causing increased control forces, control restrictions or blockage.

c. Airspeed, altitude and/or angle of attack sensing errors due to ice accretion forward of the sensors (e.g. radome ice). Dynamic pressure ("q") operated feel systems using separate sensors also may be affected.

d. Ice blockage of unprotected inlets and vents that may affect the propulsive thrust available, aerodynamic drag, powerplant control, or flight control.

e. Operation of stall warning and stall identification reset features for flight in icing conditions, including the effects of failure to operate.

f. Operation of icing condition sensors, ice accretion sensors, and automatic or manual activation of ice protection systems.

g. Flight guidance and ~~A~~automatic flight control systems operation. ~~Stall characteristics with critical ice accretions may be affected in stalls following autopilot disconnect or stall approaches with the autopilot engaged. (e.g. because of the trim setting at autopilot disconnect).~~ See AMC No. 1 and 2 to 25.1329 for guidance on compliance with CS 25.1329 for flight in icing conditions, including stall and manoeuvrability evaluations with the aeroplane under flight guidance system control.

h. Installed thrust. This includes operation of ice protection systems when establishing acceptable power or thrust setting procedures, control, stability, lapse rates, rotor speed margins, temperature margins, Automatic Take-off Thrust Control System (ATTCS) operation, and power or thrust lever angle functions.

4.8 *Aeroplane Flight Manual (CS 25.1581)*.

4.8.1 *Limitations.*

4.8.1.1 Where limitations are required to ensure safe operation in icing conditions, these limitations should be stated in the AFM.

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

4.8.1.3 For aeroplanes without leading edge high-lift devices, unless an acceptable means exists to ensure that the protected surfaces of the wing leading edges are free of ice contamination immediately prior to take-off, the wing ice protection system should be operative and efficient before take-off (at least during the final taxi phase) whenever the outside air temperature is below 6 C (42 F) and any of the following applies:

- Visible moisture is present in the air or on the wing,
- The difference between the dew point temperature and the outside air temperature is less than 3 C (5 °F), or
- Standing water, slush, ice, or snow is present on taxiways or runways.

An acceptable means to ensure that the wing leading edges are free of ice contamination immediately prior to take-off would be the application of anti-icing fluid with adequate hold over time and compliant with SAE AMS 1428, Types II, III, or IV.

Note: The aircraft must be de-iced in compliance with applicable operational rules.

4.8.1.4 To comply with CS 25.1583(e), *Kinds of operation*, the AFM Limitations section should clearly identify the extent of each approval to operate in icing conditions, including the extent of any approval to operate in the supercooled large drop atmospheric icing conditions defined in CS-25 Appendix O.

4.8.1.5 For aeroplanes not certified to operate throughout the atmospheric icing envelope of CS-25 Appendix O for every flight phase, the Limitations section of the AFM should also identify the means for detecting when the certified icing conditions have been exceeded and state that intentional flight, including take-off and landing, into these conditions is prohibited. A requirement to exit all icing conditions must be included if icing conditions for which the aeroplane is not certified are encountered.

4.8.2 *Operating Procedures.*

4.8.2.1 AFM operating procedures for flight in icing conditions should include normal operation of the aeroplane including operation of the ice protection system and operation of the aeroplane following ice protection system failures. Any changes in procedures for other aeroplane system failures that affect the capability of the aeroplane to operate in icing conditions should be included.

4.8.2.2 Normal operating procedures provided in the AFM should reflect the procedures used to certify the aeroplane for flight in icing conditions. This includes configurations, speeds, ice protection system operation, power plant and systems operation, for take-off, climb, cruise, descent, holding, go-around, and landing. For aeroplanes not certified for flight in all of the supercooled large drop atmospheric icing conditions defined in Appendix O to CS-25, procedures should be provided for safely exiting all icing conditions if the aeroplane encounters Appendix O icing conditions that exceed the icing conditions the aeroplane is certified for.

4.8.2.3 For aeroplanes without leading edge high-lift devices, the AFM normal operating procedures section should contain a statement similar to the following:

> "WARNING
>
> Minute amounts of ice or other contamination on the leading edges or wing upper surfaces can result in a stall without warning, leading to loss of control on take-off."

4.8.2.4~~3~~ Abnormal operating procedures should include the procedures to be followed in the event of annunciated ice protection system failures and suspected unannunciated failures. Any changes to other abnormal procedures contained in the AFM, due to flight in icing conditions, should also be included.

4.8.3 *Performance Information.* Performance information, derived in accordance with subpart B of CS-25, must be provided in the AFM for all relevant phases of flight.

4.8.4 Examples of AFM limitations and operating procedures are contained in Appendix 4 of this AMC.

5 *Acceptable Means of Compliance - General.*

5.1 *General.*

5.1.1 This section describes acceptable methods and procedures that an applicant may use to show that an aeroplane meets the performance and handling requirements of subpart B in the atmospheric conditions of Appendix C and Appendix O to CS-25.

5.1.2 Compliance with CS 25.21(g) should be shown by one or more of the methods listed in this section.

5.1.3 The compliance process should address all phases of flight, including take-off, climb, cruise, holding, descent, landing, and go-around as appropriate to the aeroplane type, considering its typical operating regime and the extent of its certification approval for operation in the atmospheric icing conditions of Appendix O to CS-25.

5.1.4 The design features included in Appendix 3 of this AMC should be considered when determining the extent of the substantiation programme.

5.1.5 Appropriate means for showing compliance include the actions and items listed in Table 1 below. These are explained in more detail in the following sections of this AMC.

TABLE 1: Means for Showing Compliance

Flight Testing	Flight testing in dry air using artificial ice shapes or with ice shapes created in natural icing conditions.
Wind Tunnel Testing and Analysis	An analysis of results from wind tunnel tests with artificial or actual ice shapes.
Engineering Simulator Testing and Analysis	An analysis of results from engineering simulator tests.
Engineering Analysis	An analysis which may include the results from ~~executing an agreed computer code~~ any of the other means of compliance as well as the use of engineering judgment.
Ancestor Aeroplane Analysis	An analysis of results from a closely related ancestor aeroplane.

5.1.6 Various factors that affect ice accretion on the airframe with an operative ice protection system and with ice protection system failures are discussed in Appendix 1 of this AMC.

5.1.7 An acceptable methodology to obtain agreement on the artificial ice shapes is given in Appendix 2 of this AMC. That appendix also provides the different types of artificial ice shapes to be considered.

5.2 *Flight Testing.*

5.2.1 *General*.

5.2.1.1 The extent of the flight test programme should consider the results obtained with the non-contaminated aeroplane and the design features of the aeroplane as discussed in Appendix 3 of this AMC.

5.2.1.2 It is not necessary to repeat an extensive performance and flight characteristics test programme on an aeroplane with ice accretion. A suitable programme that is sufficient to demonstrate compliance with the requirements can be established from experience with aeroplanes of similar size, and from review of the ice protection system design, control system design, wing design, horizontal and vertical stabiliser design, performance characteristics, and handling characteristics of the non-contaminated aeroplane. In particular, it is not necessary to investigate all weight and centre of gravity combinations when results from the non-contaminated aeroplane clearly indicate the most critical combination to be tested. It is not necessary to investigate the flight characteristics of the aeroplane at high altitude (i.e. above the ~~upper limit~~ highest altitudes specified in Appendix C and Appendix O to CS-25). An acceptable flight test programme is provided in section 6 of this AMC.

5.2.1.3 Certification experience has shown that tests are usually necessary to evaluate the consequences of ice protection system failures on handling characteristics and performance and to demonstrate continued safe flight and landing.

5.2.2 *Flight Testing Using Approved Artificial Ice Shapes*.

5.2.2.1 The performance and handling tests may be based on flight testing in dry air using artificial ice shapes that have been agreed with the ~~Authority~~ Agency.

5.2.2.2 Additional limited flight tests are discussed in paragraph 5.2.3, below.

5.2.3 *Flight Testing In Natural Icing Conditions.*

5.2.3.1 Where flight testing with ice accretion obtained in natural atmospheric icing conditions is the primary means of compliance, the conditions should be measured and recorded. The tests should ensure good coverage of CS-25 Appendix C and Appendix O conditions (consistent with the extent of the certification approval sought for operation in Appendix O icing conditions) and, in particular, the critical conditions. The conditions for accreting ice (including the icing atmosphere, configuration, speed and duration of exposure) should be agreed with the ~~Authority~~ Agency.

5.2.3.2 Where flight testing with artificial ice shapes is the primary means of compliance, additional limited flight tests should be conducted with ice accretion obtained in natural icing conditions. The objective of these tests is to corroborate the handling characteristics and performance results obtained in flight testing with artificial ice shapes. As such, it is not necessary to measure the atmospheric characteristics (i.e. liquid water content (LWC) and median volume~~tric~~ diameter (MVD)) of the flight test icing conditions. For some derivative aeroplanes with similar aerodynamic characteristics as the ancestor, it may not be necessary to carry out additional flight test in natural icing conditions if such tests have been already performed with the ancestor. Depending on the extent of the Appendix O icing conditions that certification is being sought for, and the means used for showing compliance with the performance and handling characteristics requirements, it may also not be necessary to conduct flight tests in the natural icing conditions of Appendix O. See AMC 25.1420 for guidance on when it is necessary to conduct flight tests in the natural atmospheric icing conditions of Appendix O.

5.3 *Wind Tunnel Testing and Analysis.* Analysis of the results of dry air wind tunnel testing of models with artificial ice shapes, as defined in Part II of Appendix C and Appendix O to CS-25, may be used to substantiate the performance and handling characteristics.

5.4 *Engineering Simulator Testing and Analysis.* The results of an engineering simulator analysis of an aeroplane that includes the effects of the ice accretions as defined in Part II of Appendix C and Appendix O to CS-25 may be used to substantiate the handling characteristics. The data used to model the effects of ice accretions for the engineering simulator may be based on results of dry air wind tunnel tests, flight tests, computational analysis, and engineering judgement.

5.5 *Engineering Analysis.* An engineering analysis that includes the effects of the ice accretions as defined in Part II of Appendix C and Appendix O to CS-25 may be used to substantiate the performance and handling characteristics. The effects of the ice shapes used in this analysis may be determined by an analysis of the results of dry air wind tunnel tests, flight tests, computational analysis, engineering simulator analysis, and engineering judgement.

5.6 *Ancestor Aeroplane Analysis.*

5.6.1 To help substantiate acceptable performance and handling characteristics, the applicant may use an analysis of ~~A~~an ancestor aeroplane ~~analysis~~ that includes the effect of the ice accretions as defined in Part II of Appendix C and Appendix O to CS-25 ~~may be used to substantiate the~~

~~performance and handling characteristics~~. This analysis should consider the similarity of the configuration, operating envelope, performance and handling characteristics, and ice protection system of the ancestor aeroplane to the one being certified.

5.6.2 The analysis may include flight test data, dry air wind tunnel test data, icing tunnel test data, engineering simulator analysis, service history, and engineering judgement.

6 *Acceptable Means of Compliance - Flight Test Programme.*

6.1 *General.*

6.1.1 This section provides an acceptable flight test programme where flight testing is selected by the applicant and agreed by the ~~Authority~~ Agency as being the primary means for showing compliance.

6.1.2 Where an alternate means of compliance is proposed for a specific paragraph in this section, it should enable compliance to be shown with at least the same degree of confidence as flight test would provide (see CS 25.21(a)(1)).

6.1.3 Ice accretions for each flight phase are defined in Part II of Appendix C and Part II of Appendix O to CS-25. Additional guidance for determining the applicable ice accretions is provided in Appendix 1 to this AMC.

6.1.~~3~~4 This test programme is based on the assumption that the applicant will choose to use the holding ~~I~~ice accretion for the majority of the testing assuming that it is the most conservative ice accretion. In general, the applicant may choose to use an ice accretion that is either conservative or is the specific ice accretion that is appropriate to the particular phase of flight. In accordance with part II(~~a~~b) of ~~a~~Appendix C and part II(e) of Appendix O to CS-25, if the holding ice accretion is not as conservative as the ice accretion appropriate to the flight phase, then the ice accretion appropriate to the flight phase (or a more conservative ice accretion) must be used.

6.1.5 For the approach and landing configurations, in accordance with the guidance provided in paragraph 4.1.10 of this AMC, the flight tests in natural icing conditions specified in Table 4 of this AMC are usually sufficient to evaluate whether ice accretions on trailing edge flaps adversely affect aeroplane performance or handling qualities. If these tests show that aeroplane performance or handling qualities are adversely affected, additional tests may be necessary to show compliance with the aeroplane performance and handling qualities requirements.

6.2 *Stall Speed (CS 25.103).*

6.2.1 The stall speed for intermediate high lift configurations can normally be obtained by interpolation. However if a stall identification system (e.g. stick pusher) ~~firing~~activation point is set as a function of the high lift configuration and/or the ~~firing~~activation point is reset for icing conditions, or if significant configuration changes occur with extension of trailing edge flaps (such as wing leading edge high-lift device position movement), additional tests may be necessary.

6.2.2 *Acceptable Test Programme*. The following represents an acceptable test programme subject to the provisions outlined above:

a. Forward centre of gravity position appropriate to the configuration.

b. Normal stall test altitude.

c. In the configurations listed below, trim the aeroplane at an initial speed of 1.13 to 1.30 V_{SR}. Decrease speed at a rate not to exceed 0.5 m/sec² (1 knot per second) until an acceptable stall identification is obtained.

i. High lift devices retracted configuration, "Final Take-off Ice."

ii. High lift devices retracted configuration, "En-route Ice."

iii. Holding configuration, "Holding Ice."

iv. Lowest lift take-off configuration, "Holding Ice."

v. Highest lift take-off configuration, "Take-off Ice."

vi. Highest lift landing configuration, "Holding Ice."

6.3 *Accelerate-stop Distance (CS 25.109).* The effect of any increase in V_1 due to take-off in icing conditions may be determined by a suitable analysis.

6.4 *Take-off Path (CS 25.111).* If V_{SR} in the configuration defined by CS 25.121(b) with the "Take-off Ice" accretion defined in Appendix C and Appendix O to CS-25 exceeds V_{SR} for the same configuration without ice accretions by more than the greater of 5.6 km/h (3 knots) or 3%, the take-off demonstrations should be repeated to substantiate the speed schedule and distances for take-off in icing conditions. The effect of the take-off speed increase, thrust loss, and drag increase on the take-off path may be determined by a suitable analysis.

6.5 *Landing Climb: All-engines-operating (CS 25.119). Acceptable Test Programme*. The following represents an acceptable test programme:

a. The "Holding Ice" accretion should be used.

b. Forward centre of gravity position appropriate to the configuration.

c. Highest lift landing configuration, landing climb speed no greater than V_{REF}.

d. Stabilise at the specified speed and conduct 2 climbs or drag polar checks as agreed with the ~~Authority~~ Agency.

6.6 *Climb: One-engine-inoperative (CS 25.121). Acceptable Test Programme*. The following represents an acceptable test programme:

a. Forward centre of gravity position appropriate to the configuration.

b. In the configurations listed below, stabilise the aeroplane at the specified speed with one engine inoperative (or simulated inoperative if all effects can be taken into account) and conduct 2 climbs in each configuration or drag polar checks substantiated for the asymmetric drag increment as agreed with the ~~Authority~~ Agency.

i. High lift devices retracted configuration, final take-off climb speed, "Final Take-off Ice."

ii. Lowest lift take-off configuration, landing gear retracted, V_2 climb speed, "Take-off Ice."

iii. Approach configuration appropriate to the highest lift landing configuration, landing gear retracted, approach climb speed, "Holding Ice."

6.7 *En-route Flight Path (CS 25.123). Acceptable Test Programme*. The following represents an acceptable test programme:

a. The "En-route Ice" accretion should be used.

b. Forward centre of gravity position appropriate to the configuration.

c. En-route configuration and climb speed.

d. Stabilise at the specified speed with one engine inoperative (or simulated inoperative if all effects can be taken into account) and conduct 2 climbs or drag polar checks substantiated for the asymmetric drag increment as agreed with the ~~Authority~~ Agency.

6.8 *Landing (CS 25.125).* The effect of landing speed increase on the landing distance may be determined by a suitable analysis.

6.9 *Controllability and Manoeuvrability - General (CS 25.143 and 25.177).*

6.9.1 A qualitative and quantitative evaluation is usually necessary to evaluate the aeroplane's controllability and manoeuvrability. In the case of marginal compliance, or the force limits or stick force per g limits of CS 25.143 being approached, additional substantiation may be necessary to establish compliance. In general, it is not necessary to consider separately the ice accretion appropriate to take-off and en-route because the "Holding Ice" is usually the most critical.

6.9.2 *General Controllability and Manoeuvrability*. The following represents an acceptable test programme for general controllability and manoeuvrability, subject to the provisions outlined above:

a. The "Holding Ice" accretion should be used.

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. In the configurations listed in Table 2, trim at the specified speeds and conduct the following manoeuvres:

i. 30° banked turns left and right with rapid reversals;

ii. Pull up to 1.5g (except that this may be limited to 1.3g at V_{REF}), and pushover to 0.5g (except that the pushover is not required at V_{MO} and V_{FE}); and

iii. Deploy and retract deceleration devices.

TABLE 2: Trim Speeds

Configuration	*Trim Speed*
High lift devices retracted configuration:	• 1.3 V_{SR}, and • V_{MO} or 463 km/h (250 knots) IAS , whichever is less
Lowest lift takeoff configuration:	• 1.3 V_{SR}, and • V_{FE} or 463 km/h (250 knots) IAS, whichever is less
Highest lift landing configuration:	• V_{REF}, and

	• V_{FE} or 463 km/h (250 knots) IAS, whichever is less.

V_{SR} – Reference Stall Speed

V_{MO} – Maximum operating limit speed

IAS – Indicated air speed

V_{FE} – Maximum flap extended speed

V_{REF} – Reference landing speed

d. Lowest lift take-off configuration: At the greater of 1.13 V_{SR} or V_{2MIN}, with the critical engine inoperative (or simulated inoperative if all effects can be taken into account), conduct 30° banked turns left and right with normal turn reversals and, in wings-level flight, a 9.3 km/h (5 knot) speed decrease and increase.

e. Conduct an approach and go-around with all engines operating using the recommended procedure.

f. Conduct an approach and go-around with the critical engine inoperative (or simulated inoperative if all effects can be taken into account) using the recommended procedure.

g. Conduct an approach and landing using the recommended procedure. In addition satisfactory controllability should be demonstrated during a landing at V_{REF} minus 9.3 km/h (5 knots). These tests should be done at heavy weight and forward centre of gravity.

h. Conduct an approach and landing with the critical engine inoperative (or simulated inoperative if all effects can be taken into account) using the recommended procedure.

6.9.3 *Evaluation of Lateral Control Characteristics*. Aileron hinge moment reversal and other lateral control anomalies have been implicated in icing accidents and incidents. The following manoeuvre, along with the evaluation of lateral controllability during a deceleration to the stall warning speed covered in paragraph 6.17.2(e) of this AMC and the evaluation of static lateral-directional stability covered in paragraph 6.15 of this AMC, is intended to evaluate any adverse effects arising from both stall of the outer portion of the wing and control force characteristics.

For each of the test conditions specified in subparagraphs (a) and (b) below, perform the manoeuvres described in subparagraphs 1 through 6 below.

(a) Holding configuration, holding ice accretion, maximum landing weight, forward centre-of-gravity position, minimum holding speed (highest expected holding angle-of-attack); and

(b) Landing configuration, most critical of holding, approach, and landing ice accretions, medium to light weight, forward centre-of-gravity position, V_{REF} (highest expected landing approach angle-of-attack).

1 Establish a 30-degree banked level turn in one direction.

2 Using a step input of approximately 1/3 full lateral control deflection, roll the aeroplane in the other direction.

3 Maintain the control input as the aeroplane passes through a wings level attitude.

4 At approximately 20 degrees of bank in the other direction, apply a step input in the opposite direction to approximately 1/3 full lateral control deflection.

5 Release the control input as the aeroplane passes through a wings level attitude.

6 Repeat this test procedure with 2/3 and up to full lateral control deflection unless the roll rate or structural loading is judged excessive. It should be possible to readily arrest and reverse the roll rate using only lateral control input, and the lateral control force should not reverse with increasing control deflection.

6.9.4 *Low g Manoeuvres and Sideslips.* The following represents an example of an acceptable test program for showing compliance with controllability requirements in low g manoeuvres and in sideslips to evaluate susceptibility to ice-contaminated tailplane stall.

6.9.4.1 CS25.143(i)(2) states: "It must be shown that a push force is required throughout a pushover manoeuvre down to zero g or the lowest load factor obtainable if limited by elevator power or other design characteristic of the flight control system. It must be possible to promptly recover from the manoeuvre without exceeding a pull control force of 222 N. (50 lbf) ~~pull control force~~;".

6.9.4.2 Any changes in force that the pilot must apply to the pitch control to maintain speed with increasing sideslip angle must be steadily increasing with no force reversals, unless the change in control force is gradual and easily controllable by the pilot without using exceptional piloting skill, alertness, or strength. Discontinuities in the control force characteristic, unless so small as to be unnoticeable, would not be considered to meet the requirement that the force be steadily increasing. A gradual change in control force is a change that is not abrupt and does not have a steep gradient that can be easily managed by a pilot of average skill, alertness, and strength. Control forces in excess of those permitted by CS25.143(c) would be considered excessive.

(See paragraph 6.15.1 of this AMC for lateral-directional aspects).

6.9.4.3 The test manoeuvres described in paragraphs 6.9.4.1 and 6.9.4.2, above, should be conducted using the following configurations and procedures:

a. The "Holding Ice" accretion should be used. For aeroplanes with unpowered elevators, these tests should also be performed with "Sandpaper Ice."

b. Medium to light weight, the most critical of aft or forward centre of gravity position, symmetric fuel loading.

c. In the configurations listed below, with the aeroplane in trim, or as nearly as possible in trim, at the specified trim speed, perform a continuous manoeuvre (without changing trim) to reach zero g normal load factor or, if limited by elevator control authority, the lowest load factor obtainable at the target speed.

i. Highest lift landing configuration at idle power or thrust, and the more critical of:

- Trim speed 1.23 V_{SR}, target speed not <u>more</u> than 1.23 V_{SR}, or

- Trim speed V_{FE}, target speed not <u>less</u> than V_{FE} - 37 km/h (20 knots)

ii. Highest lift landing configuration at go-around power or thrust, and the more critical of:

- Trim speed 1.23 V_{SR}, target speed not <u>more</u> than 1.23 V_{SR}, or

- Trim speed V_{FE}, target speed not <u>less</u> than V_{FE} - 37 km/h (20 knots)

d.~~.~~ Conduct steady heading sideslips to full rudder authority, 801 N. (180 lbf) rudder force or full lateral control authority (whichever comes first), with highest lift landing configuration, trim speed 1.23 V_{SR}, and power or thrust for -3° flight path angle.

6.9.5 *Controllability prior to Activation and Normal Operation of the Ice Protection System*. The following represents an acceptable test programme for compliance with controllability requirements with the ice accretion prior to activation and normal operation of the ice protection system.

~~6.9.5.1 Where the ice protection system is activated as described in paragraph A1.2.3.4.a of Appendix 1 of this AMC, paragraphs 6.9.1, 6.9.2 and 6.9.4 of this AMC are applicable with the ice accretion prior to normal system operation.~~

~~6.9.5.2 Where the ice protection system is activated as described in paragraphs A1.2.3.4.b,c,d or e of Appendix 1 of this AMC, it is acceptable to demonstrate adequate controllability with the ice accretion prior to normal system operation, as follows:~~

~~a.~~ In the configurations, speeds, and power settings listed below, with the ice accretion specified in the requirement, trim the aeroplane at the specified speed. Conduct pull up to 1.5g and pushover to 0.5g without longitudinal control force reversal.

i. High lift devices retracted configuration (or holding configuration if different), holding speed, power or thrust for level flight.

ii. Landing configuration, V_{REF} for non-icing conditions, power or thrust for landing approach (limit pull up to stall warning).

6.10 *Longitudinal Control (CS 25.145).*

6.10.1 No specific quantitative evaluations are required for demonstrating compliance with CS 25.145(b) and (c). Qualitative evaluations should be combined with the other testing. The results from the non-contaminated aeroplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, these cases should be repeated with ice.

6.10.2 *Acceptable Test Programme*. The following represents an acceptable test programme for compliance with CS 25.145(a):

a. The "Holding ice" accretion should be used.

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. In the configurations listed below, trim the aeroplane at 1.3 V_{SR}. Reduce speed using elevator control to stall warning plus one second and demonstrate prompt recovery to the trim speed using elevator control.

i. High lift devices retracted configuration, maximum continuous power or thrust.

ii. Maximum lift landing configuration, maximum continuous power or thrust.

6.11 *Directional and Lateral Control (CS 25.147).* Qualitative evaluations should be combined with the other testing. The results from the non-contaminated aeroplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, these cases should be repeated with ice.

6.12 Trim (CS 25.161).

6.12.1 Qualitative evaluations should be combined with the other testing. The results from the non-contaminated aeroplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, these cases should be repeated with ice. In addition a specific check should be made to demonstrate compliance with CS 25.161(c)(2).

6.12.2 The following represents a representative test program for compliance with 25.161(c)(2).

a. The “Holding ice” accretion should be used.

b. Most critical landing weight, forward centre of gravity position, symmetric fuel loading.

c. In the configurations below, trim the aircraft at the specified speed.

i. Maximum lift landing configuration, landing gear extended, and the most critical of:

- Speed 1.3VSR1 with Idle power or thrust; or,

- Speed VREF with power or thrust corresponding to a 3 deg glidepath'

6.13 *Stability - General (CS 25.171).* Qualitative evaluations should be combined with the other testing. Any tendency to change speed when trimmed or requirement for frequent trim inputs should be specifically investigated.

6.14 *Demonstration of Static Longitudinal Stability (CS 25.175).*

6.14.1 Each of the following cases should be tested. In general, it is not necessary to test the cruise configuration at low speed (CS 25.175(b)(2)) or the cruise configuration with landing gear extended (CS 25.175(b)(3)); nor is it necessary to test at high altitude. The maximum speed for substantiation of stability characteristics in icing conditions (as prescribed by CS 25.253(c)) is the lower of 556 km/h (300 knots) CAS, V_{FC}, or a speed at which it is demonstrated that the airframe will be free of ice accretion due to the effects of increased dynamic pressure.

6.14.2 *Acceptable Test Programme*. The following represents an acceptable test programme for demonstration of static longitudinal stability:

a. The "Holding Ice" accretion should be used.

b. High landing weight, aft centre of gravity position, symmetric fuel loading.

c. In the configurations listed below, trim the aeroplane at the specified speed. The power or thrust should be set and stability demonstrated over the speed ranges as stated in CS 25.175(a) through (d), as applicable.

i. Climb: With high lift devices retracted, trim at the speed for best rate-of-climb, except that the speed need not be less than 1.3 VSR.

ii. Cruise: With high lift devices retracted, trim at V_{MO} or 463 km/h (250 knots) CAS, whichever is lower.

iii. Approach: With the high lift devices in the approach position appropriate to the highest lift landing configuration, trim at 1.3 V_{SR}.

iv. Landing: With the highest lift landing configuration, trim at $1.3V_{SR}$.

6.15 *Static Directional and Lateral Stability (CS 25.177).*

6.15.1 Compliance should be demonstrated using steady heading sideslips to show compliance with directional and lateral stability. The maximum sideslip angles obtained should be recorded and may be used to substantiate a crosswind value for landing (see paragraph 6.19 of this AMC).

6.15.2 *Acceptable Test Programme*. The following represents an acceptable test programme for static directional and lateral stability:

a. The "Holding Ice" accretion should be used.

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. In the configurations listed below, trim the aeroplane at the specified speed and conduct steady heading sideslips to full rudder authority, 801 N. (180 lbf) rudder pedal force, or full lateral control authority, whichever comes first.

i. High lift devices retracted configuration: Trim at best rate-of-climb speed, but need not be less than $1.3 V_{SR}$.

ii. Lowest lift take-off configuration: Trim at the all-engines-operating initial climb speed.

iii. Highest lift landing configuration: Trim at V_{REF}.

6.16 *Dynamic Stability (CS 25.181).* Provided that there are no marginal compliance aspects with the non-contaminated aeroplane, it is not necessary to demonstrate dynamic stability in specific tests. Qualitative evaluations should be combined with the other testing. Any tendency to sustain oscillations in turbulence or difficulty in achieving precise attitude control should be investigated.

6.17 *Stall Demonstration (CS 25.201).*

6.17.1 Sufficient stall testing should be conducted to demonstrate that the stall characteristics comply with the requirements. In general, it is not necessary to conduct a stall programme which encompasses all weights, centre of gravity positions (including lateral asymmetry), altitudes, high lift configurations, deceleration device configurations, straight and turning flight stalls, power off and power on stalls. Based on a review of the stall characteristics of the non-contaminated aeroplane, a reduced test matrix can be established. However, additional testing may be necessary if:

- the stall characteristics with ice accretion show a significant difference from the non-contaminated aeroplane,
- testing indicates marginal compliance, or
- a stall identification system (e.g. stick pusher) is required to be reset for icing conditions.

6.17.2 *Acceptable Test Programme*. Turning flight stalls at decelerations greater than 1 knot/sec are not required. Slow decelerations (much slower than 1 knot/sec) may be critical on aeroplanes with anticipation logic in their stall protection system or on aeroplanes with low directional stability, where large sideslip angles could develop. The following represents an acceptable test programme subject to the provisions outlined above.

a. The "Holding Ice" accretion should be used.

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. Normal stall test altitude.

d. In the configurations listed below, trim the aeroplane at the same initial stall speed factor used for stall speed determination. For power-on stalls, use the power setting as defined in CS 25.201(a)(2) but with ice accretions on the aeroplane. Decrease speed at a rate not to exceed 1 knot/sec to stall identification and recover using the same test technique as for the non-contaminated aeroplane.

i. High lift devices retracted configuration: Straight/Power Off, Straight/Power On, Turning/Power Off, Turning/Power On.

ii. Lowest lift take-off configuration: Straight/Power On, Turning/Power Off.

iii. Highest lift take-off configuration: Straight/Power Off, Turning/Power On.

iv. Highest lift landing configuration: Straight/Power Off, Straight/Power On, Turning/Power Off, Turning/Power On.

e. For the configurations listed in paragraph 6.17.2(d)i and iv, and any other configuration if deemed more critical, in 1 knot/second deceleration rates down to stall warning with wings level and power off, roll the ~~airplane~~ aeroplane left and right up to 10 degrees of bank using the lateral control.

6.18 *Stall Warning (CS 25.207).*

6.18.1 Stall warning should be assessed in conjunction with stall speed testing and stall demonstration testing (CS 25.103, CS 25.201 and paragraphs 6.2 and 6.17 of this AMC, respectively) and in tests with faster entry rates.

6.18.2 *Normal Ice Protection System Operation*. The following represents an acceptable test programme for stall warning in slow down turns of at least 1.5g and at entry rates of at least 1 m/sec^2 (2 knot/sec):

a. The "Holding Ice" accretion should be used.

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. Normal stall test altitude.

d. In the configurations listed below, trim the aeroplane at 1.3V_{SR} with the power or thrust necessary to maintain straight level flight. Maintain the trim power or thrust during the test demonstrations. Increase speed as necessary prior to establishing at least 1.5g and a deceleration of at least 1 m/sec^2 (2 knot/sec). Decrease speed until 1 sec after stall warning and recover using the same test technique as for the non-contaminated aeroplane.

i. High lift devices retracted configuration;

ii. Lowest lift take-off configuration; and

iii. Highest lift landing configuration.

6.18.3 *Ice Accretion Prior to Activation and Normal System Operation*. The following represent acceptable means for evaluating stall warning margin with the ice accretion prior to activation and normal operation of the ice protection system.

~~6.18.3.1 Where the ice protection system is activated as described in paragraph A1.2.3.4.a, of~~

~~Appendix 1 of this AMC, paragraphs 6.18.1 and 6.18.2 of this AMC are applicable with the ice accretion prior to normal system operation.~~

~~6.18.3.2 Where the ice protection system is activated as described in paragraphs A1.2.3.4.b,c,d or e of Appendix 1 of this AMC, it is acceptable to demonstrate adequate stall warning with the ice accretion prior to normal system operation, as follows:~~

a. In the configurations listed below, with the ice accretion specified in the requirement, trim the aeroplane at 1.3 V_{SR}.

i. High lift devices retracted configuration: Straight/Power Off.

ii. Landing configuration: Straight/Power Off.

b. At decelerations of up to 0.5 m/sec^2 (1 knot per second), reduce the speed to stall warning plus 1 second, and demonstrate that stalling can be prevented using the same test technique as for the non-contaminated aeroplane, without encountering any adverse characteristics (e.g., a rapid roll-off). As required by CS 25.207(h)(~~2~~3)(ii), where stall warning is provided by a different means than for the aeroplane without ice accretion, the stall characteristics must be satisfactory and the delay must be at least 3 seconds.

6.19 *Wind Velocities (CS 25.237).*

6.19.1 Crosswind landings with "Landing Ice" should be evaluated on an opportunity basis.

6.19.2 The results of the steady heading sideslip tests with “Landing Ice” may be used to establish the safe cross wind component. If the flight test data show that the maximum sideslip angle demonstrated is similar to that demonstrated with the non-contaminated aeroplane, and the flight characteristics (e.g. control forces and deflections) are similar, then the non-contaminated aeroplane crosswind component is considered valid.

6.19.3 If the results of the comparison discussed in paragraph 6.19.2, above, are not clearly similar, and in the absence of a more rational analysis, a conservative analysis based on the results of the steady heading sideslip tests may be used to establish the safe crosswind component. The crosswind value may be estimated from:

$$V_{CW} = V_{REF} * \sin(\text{sideslip angle}) / 1.5$$

Where:

V_{CW} is the crosswind component,

V_{REF} is the landing reference speed appropriate to a minimum landing weight, and *sideslip angle* is that demonstrated at V_{REF} (see paragraph 6.15 of this AMC).

6.20 *Vibration and Buffeting (CS 25.251).*

6.20.1 Qualitative evaluations should be combined with the other testing, including speeds up to the maximum speed obtained in the longitudinal stability tests (see paragraph 6.14 of this AMC).

6.20.2 It is also necessary to demonstrate that the aeroplane is free from harmful vibration due to residual ice accumulation. This may be done in conjunction with the natural icing tests.

6.20.3 An aeroplane with pneumatic de-icing boots should be evaluated to V_{DF}/M_{DF} with the de-icing boots operating and not operating. It is not necessary to do this demonstration with ice accretion.

6.21 *Natural Icing Conditions.*

6.21.1 *General.*

6.21.1.1 Whether the flight testing has been performed with artificial ice shapes or in natural icing conditions, additional limited flight testing described in this section should be conducted in natural icing conditions specified in Appendix C to CS-25 and, if necessary, in the icing conditions described in Appendix O to CS-25. (AMC 25.1420 provides guidance on when it is necessary to perform flight testing in the atmospheric icing conditions of Appendix O.) Where flight testing with artificial ice shapes is the primary means for showing compliance, the objective of the tests described in this section is to corroborate the handling characteristics and performance results obtained in flight testing with artificial ice shapes.

6.21.1.2 It is acceptable for some ice to be shed during the testing due to air loads or wing flexure, etc. However, an attempt should be made to accomplish the test manoeuvres as soon as possible after exiting the icing cloud to minimise the atmospheric influences on ice shedding.

6.21.1.3 During any of the manoeuvres specified in paragraph 6.21.2, below, the behaviour of the aeroplane should be consistent with that obtained with artificial ice shapes. There should be no unusual control responses or uncommanded aeroplane motions. Additionally, during the level turns and bank-to-bank rolls, there should be no buffeting or stall warning.

6.21.2 *Ice Accretion/Manoeuvres*.

6.21.2.1 *Holding scenario.*

a. The manoeuvres specified in Table 3, below, should be carried out with the following ice accretions representative of normal operation of the ice protection system:

i. *On unprotected Parts*: A thickness of 75 mm (3 inches) on those parts of the aerofoil where the collection efficiency is highest should be the objective. (A thickness of 50 mm (2 inches) is normally a minimum value, unless a lesser value is agreed by the ~~Authority~~ Agency.)

ii. *On protected parts*: The ice accretion thickness should be that resulting from normal operation of the ice protection system.

b. For aeroplanes with control surfaces that may be susceptible to jamming due to ice accretion (e.g. elevator horns exposed to the air flow), the holding speed that is critical with respect to this ice accretion should be used.

TABLE 3: Holding Scenario - Manoeuvres

Configuration	*~~c.g.~~Centre of Gravity Position*	*Trim speed*	*Manoeuvre*
Flaps up, gear up	Optional (aft range)	Holding, except 1.3 V_{SR} for the stall manoeuvre	• Level, 40° banked turn, • Bank-to-bank rapid roll, 30° - 30°, • Speedbrake extension, retraction, • Full straight stall (1 knot/second deceleration rate, wings level, power off).
Flaps in intermediate positions, gear up	Optional (aft range)	1.3 V_{SR}	Deceleration to the speed reached 3 seconds after activation of stall warning in a 1 knot/second deceleration.
Landing flaps, gear down	Optional (aft range)	V_{REF}	• Level, 40° banked turn, • Bank-to-bank rapid roll, 30° - 30°, • Speedbrake extension, retraction (if approved), • Full straight stall (1 knot/second deceleration rate, wings level, power off).

6.21.2.2 *Approach/Landing Scenario.* The manoeuvres specified in Table 4, below, should be carried out with successive accretions in different configurations on unprotected surfaces. Each test condition should be accomplished with the ice accretion that exists at that point. The final ice accretion (Test Condition 3) represents the sum of the amounts that would accrete during a normal descent from holding to landing in icing conditions.

TABLE 4: Approach/Landing Scenario - Manoeuvres

Test Condition	*Ice accretion thickness (*)*	*Configuration*	*~~c.g.~~Centre of Gravity Position*	*Trim speed*	*Manoeuvre*
_	First 13 mm (0.5 in.)	Flaps up, gear up	Optional (aft range)	Holding	No specific test

1	Additional 6.3 mm (0.25 in.) (19 mm (0.75 in.) total)	First intermediate flaps, gear up	Optional (aft range)	Holding	• Level 40° banked turn, • Bank-to-bank rapid roll, 30°- 30°, • Speed brake extension and retraction (if approved), • Deceleration to stall warning.
2	Additional 6.3 mm (0.25 in.) (25 mm (1.00 in.) total)	Further intermediate flaps, gear up (as applicable)	Optional (aft range)	1.3 V_{SR}	• Bank-to-bank rapid roll, 30° - 30°, • Speed brake extension and retraction (if approved), • Deceleration to stall warning.
3	Additional 6.3 mm (0.25 in.) (31 mm (1.25 in.) total)	Landing flaps, gear down	Optional (aft range)	V_{REF}	• Bank-to-bank rapid roll, 30° - 30°, • Speed brake extension and retraction (if approved), • Bank to 40°, • Full straight stall.

(*) The indicated thickness is that obtained on the parts of the unprotected aerofoil with the highest collection efficiency.

6.21.3 For aeroplanes with unpowered elevator controls, in the absence of an agreed substantiation of the criticality of the artificial ice shape used to demonstrate compliance with the controllability requirement, the pushover test of paragraph 6.9.~~3~~4 should be repeated with a thin accretion of natural ice on the unprotected surfaces.

6.21.4 Existing propeller speed limits or, if required, revised propeller speed limits for flight in icing, should be verified by flight tests in natural icing conditions.

6.22 *Failure Conditions (CS 25.1309).*

6.22.1 For failure conditions which are annunciated to the flight crew, credit may be taken for the established operating procedures following the failure.

6.22.2 *Acceptable Test Programme*. In addition to a general qualitative evaluation, the following test programme (modified as necessary to reflect the specific operating procedures) should be carried out for the most critical probable failure condition where the associated procedure requires the aeroplane to exit the icing condition:

a. The ice accretion is defined as a combination of the following:

i. On the unprotected surfaces - the “Holding ice” accretion described in paragraph A1.2.1 of this AMC;

ii. On the normally protected surfaces that are no longer protected - the “Failure ice” accretion described in paragraph A1.3.2 of this AMC; and

iii. On the normally protected surfaces that are still functioning following the segmental failure of a cyclical de-ice system – the ice accretion that will form during the rest time of the de-ice system following the critical failure condition.

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. In the configurations listed below, trim the aeroplane at the specified speed. Conduct 30° banked turns left and right with normal reversals. Conduct pull up to 1.5g and pushover to 0.5g.

i. High lift devices retracted configuration (or holding configuration if different): Holding speed, power or thrust for level flight. In addition, deploy and retract deceleration devices.

ii. Approach configuration: Approach speed, power or thrust for level flight.

iii. Landing configuration: Landing speed, power or thrust for landing approach (limit pull up to 1.3g). In addition, conduct steady heading sideslips to angle of sideslip appropriate to type and landing procedure.

d. In the configurations listed below, trim the aeroplane at estimated 1.3 V_{SR}. Decrease speed to stall warning plus 1 second, and demonstrate prompt recovery using the same test technique as for the non-contaminated aeroplane. Natural stall warning is acceptable for the failure case.

i. High lift devices retracted configuration: Straight/Power Off.

ii. Landing configuration: Straight/Power Off.

e. Conduct an approach and go-around with all engines operating using the recommended procedure.

f. Conduct an approach and landing with all engines operating (unless the one-engine-inoperative condition results in a more critical probable failure condition) using the recommended procedure.

6.22.3 For improbable failure conditions, flight test may be required to demonstrate that the effect on safety of flight (as measured by degradation in flight characteristics) is commensurate with the failure probability or to verify the results of ~~analyses~~analysis and/or wind tunnel tests. The extent of any required flight test should be similar to that described in paragraph 6.22.2, above, or as agreed with the ~~Authority~~ Agency for the specific failure condition.

Appendix 1 - Airframe Ice Accretion

A1.1 *General.*

~~The most critical ice accretion in terms of handling characteristics and/or performance for each flight phase should be determined. The parameters to be considered include:~~

- ~~the flight conditions (e.g. aeroplane configuration, speed, angle of attack, altitude) and~~
- ~~the icing conditions of Appendix C to CS-25 (e.g. temperature, liquid water content, mean effective drop diameter).~~

a. In accordance with CS 25.1419, each aeroplane certified for flight in icing conditions must be capable of safely operating in the continuous maximum and intermittent maximum icing conditions of Appendix C. Therefore, at a minimum, certification for flight in icing conditions must include consideration of ice accretions that can occur in Appendix C icing conditions.

b. In accordance with CS 25.1420(a)(1), each aeroplane certified for flight in icing conditions must, at a minimum, be capable of safely operating:

i. In the atmospheric icing conditions of Appendix C to CS-25, and

ii. After encountering the atmospheric icing conditions of Appendix O, and subsequently while exiting all icing conditions.

Therefore, at a minimum, certification for flight in icing conditions must consider ice accretions that can occur during flight in Appendix C icing conditions and during detection and exiting of Appendix O icing conditions.

c. In accordance with CS 25.1420(a)(2), an aeroplane may also be certified for operation in a portion of the atmospheric icing conditions of Appendix O to CS-25. In that case, the aeroplane must also be capable of operating safely after encountering, and while exiting, atmospheric icing conditions in the portion of Appendix O for which operation is not approved. Ice accretions used for certification must consider:

i. Operations in Appendix C icing conditions,

ii. Operations in the Appendix O icing conditions for which approval is sought, and

iii. Detection and exiting of the Appendix O icing conditions beyond those for which approval is sought.

d. In accordance with CS 25.1420(a)(3), in addition to being certified for flight in Appendix C conditions, an aeroplane may be certified for operation throughout the atmospheric icing conditions of Appendix O to CS-25. Certification for flight throughout the atmospheric icing conditions of Appendix O must consider ice accretions resulting from:

i. Operations in Appendix C icing conditions, and

ii. Operations in Appendix O icing conditions.

e. The CS-25 subpart B aeroplane performance and handling characteristics requirements identify the specific ice accretions that apply in showing compliance. In accordance with Appendix C, part II(b) and Appendix O, part II(e), to reduce the number of ice accretions used for demonstrating compliance, the applicant may use any of the applicable ice accretions (or a composite accretion representing a combination of accretions) to show compliance with a particular subpart B requirement if that accretion is either the ice accretion identified in the requirement or is shown to be more conservative than the ice accretion identified in the requirement. In addition, the ice accretion with the most adverse effect on handling characteristics may be used for compliance with the aeroplane performance requirements if any difference in performance is conservatively taken into account. Ice accretion(s) used to show compliance should take into account the speeds, configurations (including configuration changes), angles of attack, power or thrust settings, etc. for the flight phases and icing conditions they are intended to cover.

f. The applicant should determine the most critical ice accretion in terms of handling characteristics and performance for each flight phase. Parameters to be considered include:

- flight conditions (for example, aeroplane configuration, speed, angle-of-attack, altitude) and
- atmospheric icing conditions for which certification is desired (for example, temperature, liquid water content (LWC), mean effective drop diameter (MED), drop median volume diameter (MVD)).

g. For each phase of flight, the shape, chordwise and spanwise, and the roughness of the shapes, considered in selection of a critical ice shape should accurately reflect the full range of atmospheric icing conditions for which certification is desired in terms of MED, LWC, MVD, and temperature during the respective phase of flight. Justification and selection of the most critical ice shape for each phase of flight should be agreed to by the Agency.

h. See Appendix R of FAA Advisory Circular AC 20-73A, Aircraft Ice Protection, for additional detailed information about determining the applicable critical ice accretion (shape and roughness).

A1.2 *Operative Ice Protection System.*

A1.2.1 ***All flight phases except take-off.***

A1.2.1.1 For unprotected parts, the ice accretion to be considered should be determined in accordance with ~~CS 25.1419~~ Appendices C and O to CS-25.

A1.2.1.2 Unprotected parts consist of the unprotected aerofoil leading edges and all unprotected airframe parts on which ice may accrete. The effect of ice accretion on protuberances such as antennae or flap hinge fairings need not normally be investigated. However aeroplanes that are characterised by unusual unprotected airframe protuberances, e.g. fixed landing gear, large engine pylons, or exposed control surface horns or winglets, etc., may experience significant additional effects, which should therefore be taken into consideration.

A1.2.1.3 For holding ice, the applicant should determine the effect of a 45-minute hold in continuous maximum icing conditions. The analysis should assume that the aeroplane remains in a rectangular “race track” pattern, with all turns being made within the icing cloud. Therefore, no horizontal extent correction should be used for this analysis. For some previous aeroplane certification programs, the maximum pinnacle height was limited to 75 mm (3 inches). This method of compliance may continue to be accepted for follow-on products if service experience has been satisfactory, and the designs are similar enough to conclude that the previous experience is applicable. The applicant should substantiate the critical mean effective drop diameter, liquid water content, and temperature that result in the formation of an ice accretion that is critical to the aeroplane’s performance and handling qualities. The shape and texture of the ice are important and should be agreed with the ~~Authority~~ Agency.

A1.2.1.4 For protected parts, the ice protection systems are normally assumed to be operative.

However, the applicant should consider the effect of ice accretion on the protected surfaces that result from:

a. The rest time of a de-icing cycle. Performance may be established on the basis of a representative intercycle ice accretion for normal operation of the de-icing system (consideration should also be given to the effects of any residual ice accretion that is not shed.) The average drag increment determined over the de-icing cycle may be used for performance calculations.

b. Runback ice which occurs on or downstream of the protected surface.

c. Ice accretion prior to activation and normal operation of the ice protection system (see paragraph A1.2.3, below).

A1.2.2 Take-off phase.

A1.2.2.1 For both unprotected and protected parts, the ice accretion identified in Appendix C and Appendix O to CS-25 for the take-off phase may be determined by calculation, assuming ~~that the Takeoff Maximum icing conditions defined in Appendix C exist, and~~ the following:

- aerofoils, control surfaces and, if applicable, propellers are free from frost, snow, or ice at the start of the take-off;
- the ice accretion starts at ~~lift-off~~ the end of the take-off distance;
- the critical ratio of thrust/power-to-weight;
- failure of the critical engine occurs at V_{EF}; and
- flight crew activation of the ice protection system in accordance with an AFM procedure, except that after commencement of the take-off roll no flight crew action to activate the ice protection system should be assumed to occur until the aeroplane is 122 m (400 ft) above the take-off surface.

A1.2.2.2 The ice accretions identified in Appendix C and Appendix O to CS-25 for the take-off phase are:

- "Take-off ice": The most critical ice accretion between ~~lift-off~~ the end of the take-off distance and 122 m (400 ft) above the take-off surface, assuming accretion starts at ~~lift-off~~ the end of the take-off distance in the icing environment.
- "Final Take-off ice": The most critical ice accretion between 122 m (400 ft) and the height at which the transition to the en route configuration and speed is completed, or 457 m (1 500 ft) above the take-off surface, whichever is higher, assuming accretion starts at ~~lift-off~~ the end of the take-off distance in the icing environment.

A1.2.3 *Ice accretion prior to activation and normal system operation.*

A1.2.3.1 ~~Ice protection systems are normally operated as anti-icing systems (i.e. designed to prevent ice accretion on the protected surface) or de-icing systems (i.e. designed to remove ice from the protected surface). In some cases, systems may be operated as anti-icing or de-icing systems depending on the phase of flight. Operation of ice protection systems can also include a resetting of stall warning and/or stall identification system (e.g. stick pusher) activation thresholds.~~

When considering ice accretion before the ice protection system has been activated and is performing its intended function, the means of activating the ice protection system and the system response time should be taken into account. System response time is defined as the time interval between activation of the system and its effective operation (for example, for a thermal ice protection system used for de-icing, the time to heat the surface and perform its de-icing function).

If activation of the ice protection system depends on flight crew recognition of icing conditions or response to a cockpit annunciation, appropriate delays in identifying the icing conditions and activating the ice protection system should be taken into account. For the icing conditions of Appendix C, the aeroplane should be assumed to be in continuous maximum icing conditions during the time between entering the icing conditions and effective operation of the ice protection system.

A1.2.3.2 ~~The aeroplane Flight Manual contains the operating limitations and operating procedures established by the applicant. Since ice protection systems are normally only operated when icing conditions are encountered or when airframe ice is detected, means of flight crew determination of icing conditions and/or airframe ice should be considered in determining the ice accretion prior to normal system operation. This includes the ice accretion appropriate to the specified means of identification of icing conditions and an additional ice accretion, represented by a time in the Continuous Maximum icing conditions of Appendix C. This additional ice accretion is to account for flight crew delay in either identifying the conditions and activating the ice protection systems (see paragraphs A1.2.3.3(a), (b) and (c) below), or activating the ice protection system following indication from an ice detection system (see paragraph A1.2.3.3 (d) below). In addition the system response time should be considered. System response time is defined as the time interval between activation of the ice protection system and the performance of its intended function (e.g. for a thermal ice protection system, the time to heat the surface and remove the ice).~~

For an aeroplane certified in accordance with CS 25.1420 (a)(2) or (a)(3), the requirements of CS 25.1419 (e), (f), (g), and (h) must be met for the icing conditions defined in Appendix O in which the aeroplane is certified to operate.

CS 25.1419(e) requires one of the following three methods for detecting icing and activating the airframe ice protection system:

(a) A primary ice detection system that automatically activates or that alerts the flight crew to activate the airframe ice protection system; or

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

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

~~A1.2.3.3 An ice detection system may be installed that will provide information either to the flight crew or directly to the ice protection system regarding in-flight icing conditions or ice accretions. There are basically two classes of ice detection systems:~~

~~A. A primary ice detection system, when used in conjunction with approved AFM procedures, can be relied upon as the sole means of detecting ice accretion or icing conditions. The ice protection system may be automatically activated by the primary ice detection system, or it may be manually activated by the flight crew following an annunciation from the primary ice detection system.~~

~~B. advisory ice detection system provides an advisory annunciation of the presence of ice accretion or icing conditions, but is not relied on as the sole, or primary, means of detection. The flight crew is responsible for monitoring the icing conditions using a primary method as directed in the AFM. The~~

~~advisory ice detection system provides information to advise the cockpit crew of the presence of ice accretion or icing conditions, but it can only be used in conjunction with other primary methods to determine the need for operating the ice protection system.~~

A1.2.3.4~~3~~ The following ~~examples indicate~~ guidance should be used to determine the ice accretion ~~to be considered~~ on the unprotected and ~~normally~~ protected aerodynamic surfaces before activation and normal system operation of the ice protection system.~~:~~

~~a. If activation of normal operation of any ice protection system is dependent on visual recognition of a specified ice accretion on a reference surface (e.g. ice accretion probe, wing leading edge), the ice accretion should not be less than that corresponding to the ice accretion on the reference surface taking into account probable flight crew delays in recognition of the specified ice accretion and operation of the system, determined as follows:~~

~~i. the specified accretion, plus~~

~~ii. the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part I(a), plus~~

~~iii. the ice accretion during the system response time.~~

~~b. If activation of normal operation of any ice protection system is dependent on visual recognition of the first indication of ice accretion on a reference surface (e.g. ice accretion probe), the ice accretion should not be less than that corresponding to the ice accretion on the reference surface taking into account probable flight crew delays in recognition of the ice accreted and operation of the system, determined as follows:~~

~~i. the ice accretion corresponding to first indication on the reference surface, plus~~

~~ii. the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part I(a), plus~~

~~iii. the ice accretion during the system response time.~~

~~c. If activation of normal operation of any ice protection system is dependent upon pilot identification of icing conditions (as defined by an appropriate static or total air temperature and visible moisture conditions), the ice accretion should not be less than that corresponding to the ice accreted during probable crew delays in recognition of icing conditions and operation of the system, determined as follows:~~

~~i. the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part I(a), plus~~

~~ii. the ice accretion during the system response time.~~

~~d. If activation of normal operation of any ice protection system is dependent on pilot action following an annunciation from a primary ice detection system, the ice accretion should not be less than that corresponding to the ice accreted prior to annunciation from the ice detection system, plus that accreted due to probable flight crew delays in activating the ice protection system and operation of the system, determined as follows:~~

~~i. the ice accretion corresponding to the time between entry into the icing conditions and indication from the ice detection system, plus~~

~~ii. the ice accretion equivalent to ten seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part I(a), plus~~

~~iii. the ice accretion during the system response time.~~

~~e. If activation of normal operation of any ice protection system is automatic following an annunciation from a primary ice detection system, the ice accretion should not be less than that corresponding to the ice accreted prior to annunciation from the ice protection system and operation of the system, determined as follows:~~

~~i. the ice accretion on the protected surfaces corresponding to the time between entry into the icing conditions and activation of the system, plus~~

~~ii. the ice accretion during the system response time.~~

~~f. If the aeroplane is equipped with an advisory ice detection system that supplements the means of detection referenced in paragraphs (a) through (c) above, the ice accretions should continue to be determined as specified in paragraph (a), (b), or (c) above, as appropriate for the primary means of detecting icing conditions specified in the AFM procedures.~~

a. If the ice protection system activates automatically after annunciation from a primary ice detection system, the assumed ice accretion should take into account the time it takes for automatic activation of the ice protection system and the time it takes for the system to perform its intended function. The assumed ice accretion can be determined as follows:

i. The ice accretion on the protected surfaces corresponding to the time between entry into the icing conditions and activation of the system, plus

ii. The ice accretion during the system response time.

b. If ice protection system activation depends on pilot action following annunciation from a primary ice detection system, the assumed ice accretion should take into account flight crew delays in activating the ice protection system and the time it takes for the system to perform its intended function. The assumed ice accretion can be determined as follows:

i. The ice accretion corresponding to the time between entry into the icing conditions and annunciation from the primary ice detection system, plus

ii. The ice accretion corresponding to 10 additional seconds of operation in icing conditions, plus

iii. The ice accretion during the system response time.

c. If ice protection system activation depends on the flight crew visually recognizing the first indication of ice accretion on a reference surface (for example, an ice accretion probe) combined with an advisory ice detection system, the assumed ice accretion should take into account flight crew delays in detecting the accreted ice and in activating the ice protection system, and the time it takes for the system to perform its intended function. This may be determined as follows:

i. The ice accretion that would be easily recognizable by the flight crew under all foreseeable conditions (for example, at night in clouds) as it corresponds to the first indication of ice accretion on the reference surface, plus

ii. the ice accretion equivalent to 30 seconds of operation in icing conditions, plus

iii. the ice accreted during the system response time.

d. If ice protection system activation depends on pilot identification of icing conditions (as defined by an appropriate static or total air temperature in combination with visible moisture conditions) with or without an advisory ice detector, the assumed ice accretion should take into account flight crew delays in recognizing the presence of icing conditions and flight crew delays in activating the ice protection system, and the time it takes for the system to perform its intended function. This may be determined as follows:

i. the ice accretion equivalent to 30 seconds of operation in icing conditions, plus

ii. the ice accretion during the system response time.

A1.3 *Ice Protection System Failure Cases.*

A1.3.1 *Unprotected parts.* The same accretion as in paragraph A1.2.1 is applicable.

A1.3.2 *Protected parts following system failure*. "Failure Ice" is defined as follows:

A1.3.2.1 In the case where the failure condition is not annunciated, the ice accretion on normally protected parts where the ice protection system has failed should be the same as the accretion specified for unprotected parts.

A1.3.2.2 In the case where the failure condition is annunciated and the associated procedure does not require the aeroplane to exit icing conditions, the ice accretion on normally protected parts where the ice protection system has failed should be the same as the accretion specified for unprotected parts.

A1.3.2.3 In the case where the failure condition is annunciated and the associated procedure requires the aeroplane to exit icing conditions as soon as possible, the ice accretion on normally protected parts where the ice protection has failed, should be taken as one-half of the accretion specified for unprotected parts unless another value is agreed by the ~~Authority~~ Agency.

A1.4 Additional guidance for Appendix O ice accretions.

A1.4.1 *Ice Accretion in Appendix O Conditions Before those Conditions Have Been Detected by the Flight crew.*

This ice accretion, defined as pre-detection ice in Appendix O, part II(b)(5), refers to the ice accretion existing at the time the flight crew become aware that they are in Appendix O icing conditions and have taken action to begin exiting from all icing conditions.

a. Both direct entry into Appendix O icing conditions and entry into Appendix O icing conditions from flight in Appendix C icing conditions should be considered.

b. The time that the applicant should assume it will take to detect Appendix O icing conditions exceeding those for which the aeroplane is certified should be based on the means of detection. AMC 25.1419 and AMC 25.1420 provide guidance for certifying the detection means. In general, the Agency expects that the time to detect exceedance icing conditions may be significantly longer for a detection means relying on the flight crew seeing and recognizing a visual icing cue than it is for an ice detection system that provides an attention-getting alert to the flight crew.

c. Visual detection requires time for accumulation on the reference surface(s) of enough ice to be reliably identified by either pilot in all atmospheric and lighting conditions. Time between pilot scans of reference surface(s) should be considered.

i. The amount of ice needed for reliable identification is a function of the distinguishing characteristics of the ice (for example, size, shape, contrast compared to the surface feature that it is adhered to), the distance from the pilots (for example, windshield vs. engine vs. wingtip), and the relative viewing angle (location with respect to the pilots' primary fields of view).

ii. Pilot scan time of the reference surface(s) will be influenced by many factors. Such factors include phase of flight, workload, frequency of occurrence of Appendix O conditions, pilot awareness of the possibility of supercooled large drop conditions, and ease of seeing the reference surface(s). The infrequency of Appendix O conditions (approximately 1 in 100 to 1 in 1 000, on average in all worldwide icing encounters) and the high workload associated with some phases of flight in instrument conditions (for example, approach and landing) justify using a conservative estimate for the time between pilot scans.

iii. In the absence of specific studies or tests validating visual detection times, the following times should be used for visual detection of exceedance icing conditions following accumulation of enough ice to be reliably identified by either pilot in all atmospheric and lighting conditions:

1. For a visual reference located on or immediately outside a cockpit window (for example, ice accretions on side windows, windshield wipers, or icing probe near the windows) – 3 minutes.

2. For a visual reference located on a wing, wing mounted engine, or wing tip – 5 minutes.

A1.4.2 *Ice Accretions for Encounters with Appendix O Conditions Beyond those in Which the Aeroplane is Certified to Operate.*

a. Use the ice accretions in Table 1, below, to evaluate compliance with the applicable CS-25 subpart B requirements for operating safely after encountering Appendix O atmospheric icing conditions for which the aeroplane is not approved, and then safely exiting all icing conditions.

b. The ice accretions of Table 1 apply when the aeroplane is not certified for flight in any portion of Appendix O atmospheric icing conditions, when the aeroplane is certified for flight in only a portion of Appendix O conditions, and for any flight phase for which the aeroplane is not certified for flight throughout the Appendix O icing envelope.

c. Table 1 shows the scenarios to be used for determining ice accretions for certification testing of encounters with Appendix O conditions beyond those in which the aeroplane is certified to operate (for detecting and exiting those conditions):

Table 1

Flight Phase/Condition -	Appendix O Detect-and-Exit Ice Accretion
Ground Roll	No accretion
Take-off	No accretion[1]
Final Take-off	No accretion[1]
En Route	En Route Detect-and-Exit Ice Combination of: (1) either Appendix C en route ice or Appendix O en route ice for which approval is sought, whichever is applicable, (2) pre-detection ice, (3) accretion from one standard cloud horizontal extent (32.2 km (17.4 nautical miles)) in Appendix O conditions for which the aeroplane is not approved, and (4) accretion from one standard cloud horizontal extent (32.2 km (17.4 nautical miles)) in Appendix C continuous maximum icing conditions.
Holding	Holding Detect-and-Exit Ice Combination of: (1) either Appendix C holding ice or Appendix O holding ice for which approval is sought, whichever is applicable, (2) pre-detection ice, (3) accretion from one standard cloud horizontal extent (32.2 km (17.4 nautical miles)) in Appendix O conditions for which the aeroplane is not approved, and (4) accretion from one standard cloud horizontal extent (32.2 km (17.4 nautical miles)) in Appendix C continuous maximum icing conditions. The total time in icing conditions need not exceed 45 minutes.
Approach	Approach Detect-and-Exit Ice The more critical of holding detect-and-exit ice or the combination of: (1) ice accreted during a descent in the cruise configuration from the maximum vertical extent of the Appendix C continuous maximum icing conditions or the Appendix O icing environment for which approval is sought, whichever is applicable, to 610 m (2 000 feet) above the landing surface, where transition to the approach configuration is made, (2) pre-detection ice, and (3) ice accreted at 610 m (2 000 feet) above the landing surface while transiting one standard cloud horizontal extent (32.2 km (17.4 nautical

Flight Phase/Condition -	**Appendix O Detect-and-Exit Ice Accretion**
	miles)) in Appendix O conditions for which the aeroplane is not approved and one standard cloud horizontal extent (32.2 km (17.4 nautical miles)) in Appendix C continuous maximum icing conditions.
Landing	Landing Detect-and-Exit Ice The more critical of holding detect-and-exit ice or the combination of: (1) either Appendix C or Appendix O approach and landing ice for which approval is sought, whichever is applicable, (2) pre-detection ice, and (3) ice accreted during an exit maneuver beginning with the minimum climb gradient specified in CS 25.119 from a height of 61 m (200 feet) above the landing surface and transiting through one standard cloud horizontal extent (32.2 km (17.4 nautical miles)) in Appendix O conditions for which the aeroplane is not approved, and one standard cloud horizontal extent (32.2 km (17.4 nautical miles)) in Appendix C continuous maximum icing conditions. For the purposes of defining the landing detect-and-exit ice shape, the Appendix C approach and landing ice is defined as the ice accreted during: • a descent in the cruise configuration from the maximum vertical extent of the Appendix C continuous maximum icing environment to 610 m (2 000 feet) above the landing surface, • a transition to the approach configuration and manoeuvring for 15 minutes at 610 m (2 000 feet) above the landing surface, and • a descent from 610 m (2 000 feet) to 61 m (200 feet) above the landing surface with a transition to the landing configuration.
Ice Accretion Before the Ice Protection System Has Been Activated and is Performing its Intended Function	Ice accreted on protected and unprotected surfaces during the time it takes for icing conditions (either Appendix C or Appendix O) to be detected, the ice protection system to be activated, and the ice protection system to become fully effective in performing its intended function.
Ice Accretion in Appendix O Conditions Before Those Conditions Have Been Detected by the Flight crew and Actions Taken, in Accordance With the AFM, to Either Exit All Icing Conditions	Ice accreted on protected and unprotected surfaces during: • the time it takes to detect and identify Appendix O conditions (based on the method of detection) beyond those in which the aeroplane is certified to operate, and • the time it takes the flight crew to refer to and act on procedures, including coordinating with Air Traffic Control, to exit all icing conditions. • a minimum time period of two minutes should be used as the time

Flight Phase/Condition -	Appendix O Detect-and-Exit Ice Accretion
or Continue Flight in Appendix O Icing Conditions	needed for the flight crew to refer to and act on the procedures to exit all icing conditions after the Appendix O icing conditions are recognised.
Failures of the Ice Protection System	No accretion[2]

Notes:

[1] Intentional flight, including Take-off, is not permitted into Appendix O conditions beyond those in which the aeroplane is certified to operate.

[2] It is not necessary to consider an unintentional encounter with Appendix O icing conditions beyond those in which the aeroplane is certified to operate while operating with a failed ice protection system.

A1.4.3 *Ice Accretions for Encounters with Appendix O Atmospheric Icing Conditions in Which the Aeroplane is Certified to Operate.*

a. The applicant should use the ice accretions in Table 2 to evaluate compliance with the applicable CS-25 subpart B requirements for operating safely in the Appendix O atmospheric icing conditions for which approval is sought.

b. The decision about which ice accretions to use should include consideration of combinations of Appendix C and Appendix O icing conditions within the scenarios defined in paragraph A1.4.3(c) of this appendix. For example, flight in Appendix O conditions may result in ice accumulating, and potentially forming a ridge, behind a protected surface. Once this accretion site has been established, flight in Appendix C icing conditions for the remaining portion of the applicable flight phase scenario may result in a more critical additional accretion than would occur for continued flight in Appendix O icing conditions.

c. Table 2 shows the scenarios the applicant should use for determining ice accretions for certification for flight in the icing conditions of Appendix O to CS-25.

Table 2

Flight Phase/Condition	**Appendix O Ice Accretion**
Ground Roll	No accretion
Take-off	Take-off Ice Ice accretion occurring between the end of the take-off distance and 122 m (400 feet) above the take-off surface assuming ice accretion starts at the end of the take-off distance.
Final Take-off	Final Take-off Ice Ice accretion occurring between a height of 122 m (400 ft) above the take-off surface and the height at which the transition to the en-route configuration and speed is completed, or 457 m (1 500 feet) above the take-off surface, whichever is higher, assuming ice accretion starts at the end of the take-off distance.
En Route	En Route Ice Ice accreted during the en route phase of flight.
Holding	Holding Ice Ice accreted during a 45-minute hold with no reduction for horizontal cloud extent (that is, the hold is conducted entirely within the 32.2 km (17.4 nautical mile) standard cloud extent).
Approach	Approach Ice More critical ice accretion of: (1) Ice accreted during a descent in the cruise configuration from the maximum vertical extent of the Appendix O icing environment to 610 m (2 000 feet) above the landing surface, followed by: • transition to the approach configuration and • manoeuvring for 15 minutes at 610 m (2 000 feet) above the landing surface; or (2) Holding ice (if the aeroplane is certified for holding in Appendix O conditions).

Landing	Landing Ice More critical ice accretion of: (1) Approach ice plus ice accreted during descent from 610 m (2 000 feet) above the landing surface to 61 m (200 feet) above the landing surface with: • a transition to the landing configuration, followed by • a go-around manoeuvre beginning with the minimum climb gradient specified in CS 25.119 from 61 m (200 feet) to 610 m (2 000 feet) above the landing surface, and • holding for 15 minutes at 610 m (2 000 feet) above the landing surface in the approach configuration, and • a descent to the landing surface in the landing configuration, or (2) Holding ice (if the aeroplane is certified for holding in Appendix O conditions).
Ice Accretion Before the Ice Protection System has been Activated and is Performing its Intended Function	Ice accreted during the time it takes for the flight crew to recognise icing conditions and activate the ice protection system, plus the time for the ice protection system to perform its intended function.
Ice Accretion in Appendix O Conditions Before those Conditions have been Detected by the Flight crew and Actions Taken, in Accordance With the AFM, to Either Exit All Icing Conditions or Continue Flight in Appendix O Icing Conditions	Ice accreted during the time it takes for the flight crew to detect Appendix O conditions and refer to and initiate associated procedures, and any time it takes for systems to perform their intended functions (if applicable). Pre-detection ice need not be considered if there are no specific crew actions or systems changes associated with flight in Appendix O conditions.
Failures of the Ice Protection System	Same criteria as for Appendix C (see paragraph **A1.3** of this appendix), but in Appendix O conditions.

Appendix 2 - Artificial Ice Shapes

A2.1 *General.*

A2.1.1 The artificial ice shapes used for flight testing should be those which have the most adverse effects on handling characteristics. If analytical data show that other reasonably expected ice shapes could be generated which could produce higher performance decrements, then the ice shape having the most adverse effect on handling characteristics may be used for performance tests provided that any difference in performance can be conservatively taken into account.

A2.1.2 The artificial shapes should be representative of natural icing conditions in terms of location, general shape, thickness and texture. Following determination of the form and surface texture of the ice shape under paragraph A2.2, a surface roughness for the shape should be agreed with the ~~Authority~~ Agency as being representative of natural ice accretion.

A2.1.3 "Sandpaper Ice" is addressed in paragraph A2.3.

A2.2 *Shape and Texture of Artificial Ice*.

A2.2.1 The shape and texture of the artificial ice should be established and substantiated by agreed methods. Common practices include:

- use of computer codes,
- flight in measured natural icing conditions,
- icing wind tunnel tests, and
- flight in a controlled simulated icing cloud (e.g. from an icing tanker).

A2.2.2 In absence of another agreed definition of texture the following may be used:

- roughness height: 3 mm
- particle density: 8 to $10/cm^2$

A2.3 *"Sandpaper Ice."*

A2.3.1 "Sandpaper Ice" is the most critical thin, rough layer of ice. Any representation of "Sandpaper Ice" (e.g. carborundum paper no. 40) should be agreed by the ~~Authority~~ Agency.

A2.3.2 Because sandpaper ice must be considered in the basic icing certification within the Appendix C environmental icing envelope, it does not need to be considered for certification of flight in Appendix O icing conditions.

A2.3.~~2~~3 The spanwise and chordwise coverage should be consistent with the areas of ice accretion determined for the conditions of CS-25, Appendix C except that, for the zero g pushover manoeuvre of paragraph 6.9.~~3~~4 of this AMC, the "Sandpaper Ice" may be restricted to the horizontal stabiliser if this can be shown to be conservative.

Appendix 3 - Design Features

A3.1 *Aeroplane Configuration and Ancestry*. An important design feature of an overall aeroplane configuration that can affect performance, controllability and manoeuvrability is its size. In addition, the safety record of the aeroplane's closely-related ancestors may be taken into consideration.

A3.1.1 *Size.* The size of an aeroplane determines the sensitivity of its flight characteristics to ice thickness and roughness. The relative effect of a given ice height (or ice roughness height) decreases as aeroplane size increases.

A3.1.2 *Ancestors.* If a closely related ancestor aeroplane was certified for flight in icing conditions, its safety record may be used to evaluate its general arrangement and systems integration.

A3.2 *Wing*. Design features of a wing that can affect performance, controllability, and manoeuvrability include aerofoil type, leading edge devices and stall protection devices.

A3.2.1 *Aerofoil.* ~~Aerofoils with significant natural laminar flow when non-contaminated may show large changes in lift and drag with ice. Conventional aerofoils operating at high Reynolds numbers make the transition to turbulent flow near the leading edge when non-contaminated, thus reducing the adverse effects of the ice.~~ Aerodynamic effects of ice accretions result mainly from the effects of the ice accretion on the behaviour of the aerofoil's boundary layer. The boundary layer is the layer of air close to the surface of the aerofoil that is moving across the aerofoil at a velocity lower than the freestream velocity, that is, the velocity of the aerofoil. Ice accretions that occur in areas favourable to keeping the boundary layer attached to the aircraft surface will result in effects that are less aerodynamically adverse than ice accretions that occur in areas less favourable to attached boundary layer conditions. Ice shapes that build up in areas of local airflow deceleration (positively increasing surface pressure), or result in conditions unfavourable to keeping attached flow conditions, as the airflow negotiates the ice surface, will result in the most adverse effects.

A3.2.2 *Leading Edge Device.* The presence of a leading edge device (such as a slat) reduces the percentage decrease in C_{LMAX} due to ice by increasing the overall level of C_L. Gapping the slat may improve the situation further. Leading edge devices can also reduce the loss in angle of attack at stall due to ice.

A3.2.3 *Stall Protection Device.* An aeroplane with an automatic slat-gapping device may generate a greater C_{LMAX} with ice than the certified C_{LMAX} with the slat sealed and a non-contaminated leading edge. This may provide effective protection against degradation in stall performance or characteristics.

A3.2.4 *Lateral Control.* The effectiveness of the lateral control system in icing conditions can be evaluated by comparison with closely related ancestor aeroplanes.

A3.3 *Empennage*. The effects of size and aerofoil type also apply to the horizontal and vertical tails. Other design features include tailplane sizing philosophy, aerofoil design, trimmable stabiliser, and control surface actuation. Since tails are usually not equipped with leading edge devices, the effects of ice on tail aerodynamics are similar to those on a wing with no leading edge devices. However, these effects usually result in changes to aeroplane handling and/or control characteristics rather than degraded performance.

A3.3.1 *Tail Sizing.* The effect on aeroplane handling characteristics depends on the tailplane design philosophy. The tailplane may be designed and sized to provide full functionality in icing conditions without ice protection, or it may be designed with a de-icing or anti-icing system.

A3.3.2 *Horizontal Stabiliser Design.* Cambered aerofoils and trimmable stabilisers may reduce the susceptibility and consequences of elevator hinge moment reversal due to ice-induced tailplane stall.

A3.3.3 *Control Surface Actuation.* Hydraulically powered irreversible elevator controls are not affected by ice-induced aerodynamic hinge moment reversal.

A3.3.4 *Control Surface Size.* For mechanical elevator controls, the size of the surface significantly affects the control force due to an ice-induced aerodynamic hinge moment reversal. Small surfaces are less susceptible to control difficulties for given hinge moment coefficients.

A3.3.5 *Vertical Stabiliser Design.* The effectiveness of the vertical stabiliser in icing conditions can be evaluated by comparison with closely-related ancestor aeroplanes.

A3.4 *Aerodynamic Balancing of Flight Control Surfaces.* The aerodynamic balance of unpowered or boosted reversible flight control surfaces is an important design feature to consider. The design should be carefully evaluated to account for the effects of ice accretion on flight control system hinge moment characteristics. Closely balanced controls may be vulnerable to overbalance in icing. The effect of ice in front of the control surface, or on the surface, may upset the balance of hinge moments leading to either increased positive force gradients or negative force gradients.

A3.4.1 This feature is particularly important with respect to lateral flight control systems when large aileron hinge moments are balanced by equally large hinge moments on the opposite aileron. Any asymmetric disturbance in flow which affects this critical balance can lead to a sudden uncommanded deflection of the control. This auto deflection, in extreme cases, may be to the control stops.

A3.5 *Ice Protection/Detection System*. The ice protection/detection system design philosophy may include design features that reduce the ice accretion on the wing and/or tailplane.

A3.5.1 *Wing Ice Protection/Detection.* A~~n~~ primary ice detection system that automatically activates a wing de-icing or anti-icing system may ensure that there is no significant ice accretion on wings that are susceptible to performance losses with small amounts of ice.

A3.5.1.1 If the ~~entire~~ wing leading edge is not entirely protected, the part that is protected may be selected to provide good handling characteristics at stall, with an acceptable performance degradation.

A3.5.2 *Tail Ice Protection/Detection.* A~~n~~ primary ice detection system may automatically activate a tailplane de-icing or anti-icing system on aeroplanes that do not have visible cues for system operation.

A3.5.2.1 An ice protection system on the unshielded aerodynamic balances of aeroplanes with unpowered reversible controls can reduce the risk of ice-induced aerodynamic hinge moment reversal.

Appendix 4 - Examples of Aeroplane Flight Manual Limitations and Operating Procedures for Operations in Supercooled Large Drop Icing Conditions

A4.1 *Aeroplane approved for flight in Appendix C icing conditions but not approved for flight in Appendix O icing conditions.*

a. *AFM Limitations*.

Intentional flight, including take-off and landing, into supercooled large drop (SLD) icing conditions, which includes freezing drizzle or freezing rain, is prohibited. If freezing drizzle or freezing rain conditions are encountered, or if [insert cue description here], immediately request priority handling from air traffic control to facilitate a route or altitude change to exit all icing conditions. Stay clear of all icing conditions for the remainder of the flight, including landing, unless it can be determined that ice accretions no longer remain on the airframe.

b. *AFM Operating Procedures (Normal Procedures Section).*

Freezing drizzle and freezing rain conditions are severe icing conditions for this aeroplane. Intentional flight, including take-off and landing, into freezing drizzle or freezing rain conditions is prohibited. A flight delay or diversion to an alternate airport is required if these conditions exist at the departure or destination airports.

[insert cue description here] is one indication of severe icing for this aeroplane. If severe icing is encountered, immediately request priority handling from air traffic control to facilitate a route or altitude change to exit all icing conditions. Stay clear of all icing conditions for the remainder of the flight, including landing, unless it can be determined that ice accretions no longer remain on the airframe.

c. *Flight Crew Operating Manual Operating Procedures.*

Warning: Hazardous icing effects may result from environmental conditions outside of those for which this aeroplane is certified. Flight into unapproved icing conditions may result in ice build-up on protected surfaces exceeding the capability of the ice protection system, or in ice forming aft of the protected surfaces. This ice might not be shed when using the ice protection systems, and may seriously degrade performance and controllability of the aeroplane.

Operations in icing conditions were evaluated as part of the certification process for this aeroplane. Freezing drizzle and freezing rain conditions were not evaluated and are considered severe icing conditions for this aeroplane.

Intentional flight, including take-off and landing, into freezing drizzle or freezing rain conditions is prohibited. A flight delay or diversion to an alternate airport is required if these conditions exist at the departure or destination airports. [insert cue description here] is an indication of severe icing conditions that exceed those for which this aeroplane is certified. If severe icing is encountered, immediately request priority handling from air traffic control to facilitate a route or altitude change to exit all icing conditions. Stay clear of all icing conditions for the remainder of the flight, including landing, unless it can be determined that ice accretions no longer remain on the airframe.

A4.2. *Aeroplane approved for flight in Appendix C icing conditions and freezing drizzle conditions of Appendix O but not approved for flight in freezing rain conditions of Appendix O.*

a. *AFM Limitations.*

Intentional flight, including take-off and landing, into freezing rain conditions is prohibited. If freezing rain conditions are encountered, or if [insert cue description here], immediately request priority handling from air traffic control to facilitate a route or altitude change to exit all icing conditions. Stay clear of all icing conditions for the remainder of the flight, including landing, unless it can be determined that ice accretions no longer remain on the airframe.

b. *AFM Operating Procedures (Normal Procedures Section).*

Freezing rain conditions are severe icing conditions for this aeroplane. Intentional flight, including take-off and landing, into freezing rain conditions is prohibited. A flight delay or diversion to an alternate airport is required if these conditions exist at the departure or destination airports.

[insert cue description here] is one indication of severe icing for this aeroplane. If severe icing is encountered, immediately request priority handling from air traffic control to facilitate a route or altitude change to exit all icing conditions. Stay clear of all icing conditions for the remainder of the flight, including landing, unless it can be determined that ice accretions no longer remain on the airframe.

c. *Flight Crew Operating Manual Operating Procedures.*

Warning: Hazardous icing effects may result from environmental conditions outside of those for which this aeroplane is certified. Flight into unapproved icing conditions may result in ice build-up on protected surfaces exceeding the capability of the ice protection system, or may result in ice forming aft of the protected surfaces. This ice might not be shed when using the ice protection systems, and may seriously degrade the performance and controllability of the aeroplane.

Operations in icing conditions, including freezing drizzle, were evaluated as part of the certification process for this aeroplane. Freezing rain conditions were not evaluated and are considered severe icing conditions for this aeroplane.

Intentional flight, including take-off and landing, into freezing rain conditions is prohibited. A flight delay or diversion to an alternate airport is required if these conditions exist at the departure or destination airports. [insert cue description here] is an indication of severe icing conditions that exceed those for which this aeroplane is certified. If severe icing is encountered, immediately request priority handling from air traffic control to facilitate a route or altitude change to exit all icing conditions. Stay clear of all icing conditions for the remainder of the flight, including landing, unless it can be determined that ice accretions no longer remain on the airframe.

A4.3 *Aeroplane approved for flight in Appendix C and Appendix O icing conditions except for en route and holding flight phases in Appendix O icing conditions.*

a. *AFM Limitations.*

Intentional holding or en route flight into freezing drizzle or freezing rain conditions is prohibited. If freezing drizzle or freezing rain conditions are encountered during a hold (in any aeroplane configuration) or in the en route phase of flight (climb, cruise, or descent with high lift devices and gear retracted), or if [insert cue description here], immediately request priority handling from air traffic control to facilitate a route or altitude change to exit all icing conditions. Stay clear of all icing conditions for the remainder of the flight, including landing, unless it can be determined that ice accretions no longer remain on the airframe.

b. *AFM Operating Procedures (Normal Procedures Section).*

Freezing drizzle and freezing rain conditions encountered during a hold (in any aeroplane configuration) or in the en route phase of flight (climb, cruise, or descent with high lift devices and gear retracted) are severe icing conditions for this aeroplane. Intentional holding or en route flight into freezing drizzle or freezing rain conditions is prohibited.

[insert cue description here] is one indication of severe icing for this aeroplane. If severe icing is encountered, immediately request priority handling from air traffic control to facilitate a route or altitude change to exit all icing conditions. Stay clear of all icing conditions for the remainder of the flight, including landing, unless it can be determined that ice accretions no longer remain on the airframe.

c. *Flight Crew Operating Manual Operating Procedures.*

Warning: Hazardous icing effects may result from environmental conditions outside of those for which this aeroplane is certified. Flight into unapproved icing conditions may result in ice build-up on protected surfaces exceeding the capability of the ice protection system, or in ice forming aft of the protected surfaces. This ice might not be shed when using the ice protection systems, and may seriously degrade the performance and controllability of the aeroplane.

Operations in icing conditions were evaluated as part of the certification process for this aeroplane. En route (climb, cruise, and descent with high lift devices and gear retracted) and holding flight (in any aeroplane configuration) in freezing drizzle and freezing rain conditions were not evaluated and are considered severe icing conditions for this aeroplane.

Intentional holding or en route flight into freezing drizzle or freezing rain conditions is prohibited. [insert cue description here] is an indication of severe icing conditions that exceed those for which the aeroplane is certified. If severe icing is encountered, immediately request priority handling from air traffic control to facilitate a route or altitude change to exit all icing conditions. Stay clear of all icing conditions for the remainder of the flight, including landing, unless it can be determined that ice accretions no longer remain on the airframe.

A4.4 *Aeroplane approved for flight in Appendix C icing conditions and a portion of Appendix O icing conditions.*

a. *AFM Limitations*.

Intentional flight, including take-off and landing, into [insert pilot usable description here] conditions is prohibited. If [insert pilot usable description here] conditions are encountered, or if [insert cue description here], immediately request priority handling from air traffic control to facilitate a route or altitude change to exit all icing conditions. Stay clear of all icing conditions for the remainder of the flight, including landing, unless it can be determined that ice accretions no longer remain on the airframe.

b. *AFM Operating Procedures (Normal Procedures Section).*

[insert pilot usable description here] are severe icing conditions for this aeroplane. Intentional flight, including take-off and landing, into [insert pilot usable description here] conditions is prohibited. A flight delay or diversion to an alternate airport is required if these conditions exist at the departure or destination airports.

[insert cue description here] is one indication of severe icing for this aeroplane. If severe icing is encountered, immediately request priority handling from air traffic control to facilitate a route or altitude change to exit all icing conditions. Stay clear of all icing conditions for the remainder of the flight, including landing, unless it can be determined that ice accretions no longer remain on the airframe.

c. *Flight Crew Operating Manual Operating Procedures*.

Warning: Hazardous icing effects may result from environmental conditions outside of those for which this aeroplane is certified. Flight into unapproved icing conditions may result in ice build-up on protected surfaces exceeding the capability of the ice protection system, or may result in ice forming aft of the protected surfaces. This ice may not be shed when using the ice protection systems, and may seriously degrade the performance and controllability of the aeroplane.

Operations in icing conditions were evaluated as part of the certification process for this aeroplane. [insert pilot usable description here] were not evaluated and are considered severe icing conditions for this aeroplane.

Intentional flight, including take-off and landing, into [insert pilot usable description here] is prohibited. A flight delay or diversion to an alternate airport is required if these conditions exist at the departure or destination airports. [insert cue description here] is an indication of severe icing conditions that exceed those for which this aeroplane is certified. If severe icing is encountered, immediately request priority handling from air traffic control to facilitate a route or altitude change to exit all icing conditions. Remain clear of all icing conditions for the remainder of the flight, including landing, unless it can be determined that ice accretions no longer remain on the airframe.

Appendix 5 - Related Acceptable Means of Compliance (AMC) and FAA Advisory Circulars (AC)

Acceptable Means of Compliance

The following AMCs are related to the guidance contained in this AMC:

AMC 25.1309, System Design and Analysis

AMC N°. 1 to CS 25.1329, Flight Guidance System

AMC N°. 2 to CS 25.1329, Flight testing of Flight Guidance Systems

AMC 25.1419, Ice Protection

AMC 25.1420, Supercooled large drop icing conditions

Advisory Circulars

The following FAA ACs are related to the guidance contained in this AMC.

AC 20-73A, Aircraft Ice Protection

Appendix 6 – Acronyms and definitions

AC	Advisory Circular
AFM	Aeroplane Flight Manual
ATTCS	Automatic Takeoff Thrust Control System
FAA	Federal Aviation Administration
ICTS	Ice-Contaminated Tailplane Stall.
LWC	Liquid Water Content
MED	Mean Effective Diameter
MVD	Median Volume Diameter
C_L	Lift Coefficient
C_{LMAX}	Maximum Lift Coefficient
Trim	A flight condition in which the aerodynamic moment acting about the axis of interest is zero. In the absence of an external disturbance no control input is needed to maintain the flight condition.

AMC – SUBPART D

Amend AMC 25.629 as follows:

AMC 25.629

Aeroelastic stability requirements

1. *General.*

The general requirement for demonstrating freedom from aeroelastic instability is contained in CS 25.629, which also sets forth specific requirements for the investigation of these aeroelastic phenomena for various aeroplane configurations and flight conditions. Additionally, there are other conditions defined by the CS-25 paragraphs listed below to be investigated for aeroelastic stability to assure safe flight. Many of the conditions contained in this AMC pertain only to the current ~~version~~ amendment of CS-25. Type design changes to aeroplanes certified to an earlier CS-25 ~~change~~ amendment must meet the certification basis established for the modified aeroplane.

Related CS-25 paragraphs:

CS 25.251 - Vibration and buffeting

CS 25.305 - Strength and deformation

CS 25.335 - Design airspeeds

CS 25.343 - Design fuel and oil loads

CS 25.571 - Damage-tolerance and fatigue evaluation of structure

CS 25.629 - Aeroelastic stability requirements

CS 25.631 - Bird strike damage

CS 25.671 - General (Control systems)

CS 25.672 - Stability augmentation and automatic and power operated systems

CS 25.1309 - Equipment, systems and installations

CS 25.1329 - Flight Guidance system

CS 25.1419 - Ice protection

CS 25.1420 – Supercooled large drop icing conditions

2. *Aeroelastic Stability Envelope*

2.1. For nominal conditions without failures, malfunctions, or adverse conditions, freedom from aeroelastic instability is required to be shown for all combinations of airspeed and altitude encompassed by the design dive speed (V_D) and design dive Mach number (M_D) versus altitude envelope enlarged at all points by an increase of 15 percent in equivalent airspeed at both constant Mach number and constant altitude. Figure 1A represents a typical design envelope expanded to the required aeroelastic stability envelope. Note that some required Mach number and airspeed combinations correspond to altitudes below standard sea level.

2.2. The aeroelastic stability envelope may be limited to a maximum Mach number of 1.0 when M_D is less than 1.0 and there is no large and rapid reduction in damping as M_D is approached.

2.3. Some configurations and conditions that are required to be investigated by CS 25.629 and other CS-25 regulations consist of failures, malfunctions or adverse conditions. Aeroelastic stability investigations of these conditions need to be carried out only within the design airspeed versus altitude envelope defined by:

(i) the V_D/M_D envelope determined by CS 25.335(b); or,

(ii) an altitude-airspeed envelope defined by a 15 percent increase in equivalent airspeed above V_C at constant altitude, from sea level up to the altitude of the intersection of 1.15 V_C with the extension of the constant cruise Mach number line, M_C, then a linear variation in equivalent airspeed to M_C + 0.05 at the altitude of the lowest V_C/M_C intersection; then at higher altitudes, up to the maximum flight altitude, the boundary defined by a 0.05 Mach increase in M_C at constant altitude.

…

3. *<u>Configurations and Conditions</u>.* The following paragraphs provide a summary of the configurations and conditions to be investigated in demonstrating compliance with CS-25. Specific design configurations may warrant additional considerations not discussed in this AMC.

3.1. *<u>Nominal Configurations and Conditions</u>.* Nominal configurations and conditions of the aeroplane are those that are likely to exist in normal operation. Freedom from aeroelastic instability should be shown throughout the expanded clearance envelope described in paragraph 2.1 above for:

3.1.1. The range of fuel and payload combinations, including zero fuel in the wing, for which certification is requested.

3.1.2. Configurations with ~~any likely~~ ice mass accumulations on unprotected surfaces for aeroplanes approved for operation in icing conditions. See paragraph 5.1.4.5 below.

3.1.3. All normal combinations of autopilot, yaw damper, or other automatic flight control systems.

3.1.4. All possible engine settings and combinations of settings from idle power to maximum available thrust including the conditions of one engine stopped and windmilling, in order to address the influence of gyroscopic loads and thrust on aeroelastic stability.

3.2. *<u>Failures, Malfunctions. and Adverse Conditions</u>.* The following conditions should be investigated for aeroelastic instability within the fail-safe envelope defined in paragraph 2.3 above.

3.2.1. Any critical fuel loading conditions, not shown to be extremely improbable, which may result from mismanagement of fuel.

3.2.2. Any single failure in any flutter control system.

3.2.3. For aeroplanes not approved for operation in icing conditions, ~~any likely~~ ice accumulation expected as a result of an inadvertent encounter. For aeroplanes approved for operation in icing conditions, ~~any likely~~ ice accumulation expected as the result of any single failure in the de-icing system, or any combination of failures not shown to be extremely improbable. See paragraph 5.1.4.5 below.

3.2.4. Failure of any single element of the structure supporting any engine, independently mounted propeller shaft, large auxiliary power unit, or large externally mounted aerodynamic body (such as an external fuel tank).

3.2.5. For aeroplanes with engines that have propellers or large rotating devices capable of significant dynamic forces, any single failure of the engine structure that would reduce the rigidity of the rotational axis.

3.2.6. The absence of aerodynamic or gyroscopic forces resulting from the most adverse combination of feathered propellers or other rotating devices capable of significant dynamic forces. In addition, the effect of a single feathered propeller or rotating device ~~must~~ should be coupled with the failures of paragraphs 3.2.4 and 3.2.5 above.

…

5.1.4.2. *Mass Balance.*

(a) The magnitude and spanwise location of control surface balance weights may be evaluated by analysis and/or wind tunnel flutter model tests. If the control surface torsional degrees of freedom are not included in the analysis, then adequate separation ~~must~~ needs to be maintained between the frequency of the control surface first torsion mode and the flutter mode.

(b) Control surface unbalance tolerances should be specified to provide for repair and painting. The accumulation of water, ice, and/or dirt in or near the trailing edge of a control surface should be avoided. Free play between the balance weight, the support arm, and the control surface ~~must~~ should not be allowed. Control surface mass properties (weight and static unbalance) should be confirmed by measurement before ground vibration testing.

(c) The balance weights and their supporting structure should be substantiated for the extreme load factors expected throughout the design flight envelope. If the absence of a rational investigation, the following limit accelerations, applied through the balance weight centre of gravity should be used.

- 100g normal to the plane of the surface
- 30g parallel to the hinge line
- 30g in the plane of the surface and perpendicular to the hinge line

…

5.1.4.5. *Ice Accumulation.* Aeroelastic stability analyse~~i~~s should use the mass distributions derived from ~~any likely~~ ice accumulation up to and including those that can accrete in the applicable icing conditions in Appendices C and O to CS-25. This includes any accretions that could develop on control surfaces. ~~The ice accumulation determination can take account of the ability to detect the ice and the time required to leave the icing condition.~~ The analyse~~i~~s need not consider the aerodynamic effects of ice shapes. For aeroplanes approved for operation in icing conditions, all of the CS-25 Appendix C icing conditions and the Appendix O icing conditions for which certification is sought are applicable. For aeroplanes not approved for operation in icing conditions, all of the Appendix C and O icing conditions are applicable since the inadvertent encounter discussed in paragraph 3.2.3 of this AMC can occur in any icing condition. For all aeroplanes, the ice accumulation determination should take into account the ability to detect the ice and, if appropriate, the time required to leave the icing condition.

…

5.2.5.3. Flight flutter testing requires excitation sufficient to excite the modes shown by analysis to be the most likely to couple for flutter. Excitation methods may include control surface motions or internal moving mass or external aerodynamic exciters or flight turbulence. The method of excitation ~~must~~ should be appropriate for the modal response frequency being investigated. The effect of the excitation system itself on the aeroplane flutter characteristics should be determined prior to flight testing.

…

Amend AMC 25.773 as follows:

AMC 25.773

Pilot compartment view

The FAA Advisory Circular AC 25.773-1 : Pilot Compartment View Design Considerations (January 8, 1993), may be used to support the demonstration ~~is accepted by the EASA as providing acceptable means~~ of compliance with CS 25.773.

Create a new AMC 25.773(b)(1)(ii) as follows:

AMC 25.773(b)(1)(ii)
Pilot compartment view in icing conditions

CS 25.773(b)(1)(ii) requires that the aeroplane have a means of maintaining a clear portion of windshield in the icing conditions defined in Appendix C and in certain Appendix O icing conditions (corresponding to the CS 25.1420 certification option selected).

The effectiveness of all cockpit windows and windshield ice and precipitation protective systems should be established within relevant icing environment. Sufficient tests, including flight test in natural or simulated Appendix C icing conditions, should be performed to validate the performance prediction done by analysis.

When thermal ice protection systems are used (e.g. electrical heating system), a thermal analysis should be conducted to substantiate the selected nominal heated capacity. Past certification experience has shown that a nominal heating capacity of 70 W/dm^2 provide adequate protection in icing conditions; such value, if selected, should anyway be substantiated by the thermal analysis. The applicant should conduct dry air flight tests to verify the thermal analysis. Measurements of both the inner and outer surface temperature of the protected windshield area may be needed to verify the thermal analysis. The thermal analysis should show that the windshield surface temperature is sufficient to maintain anti-icing capability without causing structural damage to the windshield.

When anti-icing fluid systems are used, tests shall be performed to demonstrate that the fluid does not become opaque at low temperatures. The AFM should include information advising the flight crew how long it will take to deplete the amount of fluid remaining in the reservoir.

An evaluation of visibility, including distortion effects through the protected area, should be made for both day and night operations. In addition, the size and location of the protected area should be reviewed to confirm that it provides adequate visibility for the flight crew, especially during the approach and landing phases of flight.

Create a new AMC 25.773(b)(4) as follows:

AMC 25.773(b)(4)
Pilot compartment non openable windows

Total loss of external visibility is considered catastrophic. A sufficient field of view must exist to allow the pilot to safely operate the aeroplane during all operations, including taxi.

This field of view must remain clear in all operating conditions. Precipitation conditions such as outside ice, heavy rain, severe hail, as well as encounter with birds and insects must be considered.

This AMC material applies to conventional, multiple pane window systems, i.e. those which are composed of a main windshield and separate side panels assembled with structural posts. In the event a one piece ‘uni-body wraparound’ windshield is proposed, the applicant must meet the intent of the applicable rules, even though there are no separate side windows.

1. Ice and heavy rain

Unless system failures leading to loss of a sufficient field of view for safe operation are shown to be extremely improbable, the following provides acceptable means to show compliance with CS 25.773(b)(4):

- Each main windshield should be equipped with an independent protection system. The systems should be designed so that no malfunction or failure of one system will adversely affect the other.
- For each forward side window it should be shown that any ice accumulations (Appendix C icing conditions and any applicable Appendix O icing conditions) will not degrade visibility, or the applicant should provide individual window ice protection system capability.
- The icing accretion limits should be determined by analysis and verified by test. The extent of icing of side windows should be verified during natural or simulated icing flight tests with window ice protection systems unpowered. A limited number of test points, sufficient to validate the analysis, are required within Appendix C or Appendix O.

2. Hail, birds and insects

It should be shown by flight tests that exceptional pilot skill is not required to land the aeroplane using the normal aeroplane instruments and the view provided through the main or side windows having the degree of impairment to vision resulting from the encounter of severe hail, birds or insects. Appropriate test data should substantiate the estimated damage or contamination to the main or forward side windows during such an encounter.

It is unlikely that hail damage can be avoided. Rather than avoidance, the approach to ensure vision assuming hail strike has been to use damage assessment criteria contained in the ASTM International "Standard Test Method for Hail Impact Resistance of Aerospace Transparent Enclosures," ANSI/ASTM F 320-10 or equivalent. For the test set up to determine hail damage or windshield resistance to hail, reference can be made to ANSI/ASTM F 320-10, and "Global Climatic Data for Developing Military Products " MIL HDBK 310 (dated 23 June 1997).

For each impacted window, ANSI/ASTM 320-10 is used to characterize a damage pattern on a limited area of the window. For test purpose, the simulated damage patterns should be applied to the full impacted window surfaces in order to simulate in a conservative manner the visibility degradation through the windows.

The applicant should propose and substantiate the aircraft conditions when hail strike occurs. In the absence of such substantiation, the conservative assumptions will be to consider the maximum aircraft nominal speed combined with the hailstone falling speed.

When the damages are such that there is no remaining visibility through the windshield after hail encounter, or when the ice protection system is no longer operating after the hail encounter, a typical test configuration would be to block visibility out of the forward main windows for the pilot flying, and use simulated damage (if any) and ice accretions (if applicable) on the side window(s).

When conducting flight tests, adequate forward vision should be maintained for a safety pilot while providing appropriate forward view degradation for the test pilot.

Means of compliance to address birds and insects should be proposed by the applicant. The Agency is not aware of any in-service occurrence involving a total loss of visibility through the windshield after birds or insects encounter.

Create a new AMC 25.773(c) as follows:

AMC 25.773(c)

Internal windshield and window fogging

In absence of pilot compartment openable windows, if the failures of the means to prevent fogging cannot be shown to be extremely improbable, the applicant should show that a sufficient field of view is maintained to allow the pilot to safely operate the aeroplane during all operations, including taxi. This should be accomplished by the following:

- The extent of fogging should be established and verified during flight tests with the means to prevent fogging inoperative,
- If it is proposed that the flight crew must take action to remove inside fogging, the effectiveness of the associated operational procedure should be demonstrated by flight test.

AMC – SUBPART E

Amend AMC 25.929(a) as follows:

AMC 25.929(a)
Propeller De-icing

~~Where the propeller has been fitted to the engine in complying with the tests of AMC E 780, compliance with CS 25.929(a) will be assured.~~

1. Analysis.

The applicant should perform an analysis that:

(1) substantiates ice protection coverage in relation to chord length and span.

(2) substantiates the ice protection system power density.

(3) consider the effect of intercycle ice accretions and potential for propeller efficiency degradation for all flight phases.

(4) assess the different propeller Ice Protection System failure modes which are not extremely improbable and leading to the:

(i) highest propeller performance level degradation, and

(ii) highest propeller vibration levels taking also into account possible ice shedding.

(5) assess the impact of ice released by the propeller on the vibration levels, the adjacent components (if any) and the aircraft structure, both for normal operation and in the different propeller de-icing system failure modes.

Similarity to prior designs with successful service histories in icing may be used to show compliance. A demonstration of similarity requires an evaluation of both system and installation differences. The applicant should show specific similarities in the areas of physical, functional, thermodynamic, pneumatic, and aerodynamic characteristics as well as in environmental exposure. The analysis should show that propeller installation, operation, and effect on the aeroplane's performance and handling are equivalent to that of the same or similar propeller in the previously approved configuration. Differences should be evaluated for their effect on IPS functionality and on safe flight in icing. If there is uncertainty about the effects of the differences, the applicant should conduct additional tests and/or analysis as necessary and appropriate to resolve the open issues.

2. Compliance Tests.

2.1 Surface temperature measurements should be made and monitored in dry air flight testing. These measurements are useful for correlating analytically predicted dry air temperatures with actual temperatures, and as a general indicator that the system is functioning and that each de-icer is heating. It is suggested that system current, brush block voltage (i.e., between each input brush and the ground brush) and system duty cycles be monitored to ensure that adequate power is applied to the de-icers.

2.2 System operation should be checked throughout the full rotation speed range. and propeller cyclic pitch range expected during flight in icing. Additionally, if the propeller Ice Protection System is regulated based on different outside parameters such as temperature, then system operation should also be checked against those parameters. All significant vibrations should be investigated.

2.3 The analysis assessing the effect of intercycle ice accretions and potential for propeller efficiency degradation should be adequately validated by tests.

2.4 The Ice Protection System failure modes determined in 1.4 above should be adequately validated by tests.

2.5 The applicant should consider the maximum temperatures a composite propeller blade may be subjected to when de-icers are energized. It may be useful to monitor de-icer bond-side temperatures. When performing this evaluation, the most critical conditions should be investigated (e.g., aeroplane on the ground; propellers not rotating) on a hot day with the system inadvertently energized.

2.6 Shedding procedures and post failure procedures mentioned in the AFM should be demonstrated by test.

3. Runback Ice.

Water not evaporated by thermal ice protection systems and unfrozen water in near-freezing conditions (or in conditions when the freezing fraction is less than one) may run aft and form runback ice. This runback ice can then accumulate additional mass from direct impingement. Computer codes may be unable to estimate the characteristics of the runback water or resultant ice shapes (rivulets or thin layers), but some codes may be able to estimate the mass of the runback ice. Thus runback ice should be determined experimentally, or the mass determined by computer codes with assumptions about runback extent and thickness similar to those used successfully with prior models. The runback ice should be determined both for normal operation and for propeller Ice Protection System failure modes when not operating in the predefined cycles.

The applicant should consider potential hazards resulting from the loss of propeller performance, the increased vibration level and the runback ice shedding.

Replace the existing AMC 25.1093(b) by the following:

AMC 25.1093(b)

Powerplant Icing

Compliance with CS 25.1093(b) is required even if certification for flight in icing conditions is not sought. Applicants must, therefore, propose acceptable means of compliance which may include flight tests in natural icing conditions.

The results of tests and analysis used for compliance with CS-E 780 may be used to support compliance with CS 25.1093(b). This requires close coordination between the engine manufacturer and the aeroplane manufacturer to make sure that CS-E 780 tests cover all potential ice sources.

If an applicant can show that the ice protection and the ice ingestion capability of a powerplant is equivalent to a previously certified powerplant installation which has demonstrated a safe in-service experience, then certification may be shown by similarity to previous designs. Other airframe ice shedding sources should also be reviewed if necessary.

(a) Compliance with CS 25.1093(b)(1)

Compliance with CS 25.1093(b)(1) can be shown by analysis, laboratory testing, ground testing, dry air flight testing, similarity, and/or natural icing flight testing as necessary.

As a general rule, engine air intake systems, including auxiliary components (e.g. scoops, oil coolers, struts, fairings…), should be shown to operate continuously in icing conditions without regard to time, as in a hold condition. An exception would be for low engine power/thrust conditions where a sustained level flight is not possible. Even then, a conservative approach must be used when a series of multiple horizontal and vertical cloud extent factors are assumed. Applicants are reminded that the cloud horizontal extent factor is not intended to be used to limit the severity of exposure to icing conditions where it is reasonable to assume that the aircraft will be required to operate in that condition. The applicant will show by analysis, and verify by test, that the engine air intake Ice Protection System (IPS) provides adequate protection under all flight operations.

If there is a minimum power/thrust required for descent to ensure satisfactory operation in icing conditions, the increase to that minimum power/thrust in icing conditions should be automatic when the IPS is switched on. The engine may revert back to normal flight idle for short term operation, such as on final approach to landing; in such a case, this reversion to normal flight idle should be assessed in term of engine ice ingestion, and any required operational time limitation or pilot action should be included in the AFM.

1. Analysis & Test Point Selection.

Applicants will adequately analyse the engine air intake IPS performance and address potential ingestion hazards to the engine from any predicted ice build-up on the engine air intake, including any runback or lip ice.

In establishing compliance with the requirements of CS 25.1093(b)(1), reference should be made to AMC 25.1419 paragraph (a) for the assessment of the CS-25 Appendix C icing environment. In particular for the following aspects:

- Analytical Simulation Methods;
- Analysis of areas and components to be protected;
- Impingement Limit Analysis;
- Ice Shedding Analysis;
- Thermal Analysis and Runback Ice; and
- Similarity Analysis.

In establishing compliance with the requirements of CS 25.1093(b)(1), reference should be made to AMC 25.1420 paragraph (d) for the assessment of the Appendix O icing environment in particular for the following aspects:

- Analysis of areas and components to be protected;
- Failure analysis, and
- Similarity analysis.

In addition, the following specific analysis should be conducted:

1.1 Critical Points Analysis (CPA)

A Critical Points Analysis (CPA) is one analytical approach to identify the most critical operational icing conditions to show that an engine air intake system, including auxiliary components (e.g. scoops, oil-coolers, struts, fairings…), complies with CS 25.1093(b)(1).

For Appendix C icing conditions, in lieu of a detailed CPA, the conditions specified in paragraph 2.1, "Icing wind tunnel tests", are acceptable and can be used for testing without further justification.

The CPA provides a means to predict critical conditions to be assessed and allows for a selection of conditions which will ensure that the ice protection system will be adequate throughout the combined aircraft operation/icing envelope.

The CPA should include ice accretion calculations that account for freezing fraction and aerodynamic effects of the ice as it moves into the air intake, forward aircraft airspeed effects, engine configuration effects and altitude effects such as bypass ratio effects. It should also include prolonged flight operation in icing (for example, in-flight hold pattern), or repeated icing encounters.

The CPA should consider:

1. the aircraft/engine operating envelope. This should consider climb, cruise, hold and flight idle descent conditions in the icing envelopes.

2. the environmental icing envelopes defined in CS-25 Appendices C, O and P. The Intermittent Maximum Icing Conditions of Appendix C envelope extension down to −40°C should also be considered.

3. thermal behavior of the ice protection system in icing conditions. For each icing condition a heat balance can be made to assess the material temperature and runback water/ice accretion in icing conditions. This balance considers the heat available from the de-icing/anti-icing system and the heat lost to the impinging liquid water and external convection. The result determines the need to undertake an icing test at that point.

Applicants should determine the critical ice accretion conditions and compare each of them individually with the amount of ice the engine has satisfactorily demonstrated to ingest during engine certification (CS-E 780). Applicants may assume that 1/3 of the ice on the air intake perimeter is ingested as one piece. This assumption is consistent with the historical approach taken by the engine manufacturers.

The critical ice accretion including runback ice (if any) may be different for each flight phases. If this is the case, the engine manufacturer should provide the relevant information. A particular attention should be made to:

- ice accretion occurring during the holding phase, which may be ingested during descent at Idle power/thrust (potentially critical for engine performance and handling characteristics) or
- ice accretion occurring during the descent at Idle power/thrust (with potentially reduced ice protection availability), which may be ingested during a Go Around at Take-Off power/thrust (potentially critical for mechanical damage).

Airspeed and scoop factor should be part of this assessment.

Applicants should demonstrate that the full flight envelope and the full range of atmospheric icing conditions specified in Appendices C, O and P to CS-25 have been considered, including the mean effective drop / particle diameter, liquid / total water content, and temperature appropriate to the flight conditions (for example, configuration, speed, angle-of-attack, and altitude).

To demonstrate unlimited operation of an air intake system in icing conditions, the system should:

- either operate fully evaporative, or
- any ice accretion, including runback ice, which forms should result in less ice than the engine has been demonstrated to ingest per CS-E 780.

The test duration may be reduced if a repeatable build and shed cycle is demonstrated.

It has been historically shown that an air intake thermal IPS designed to be evaporative for the critical points in Appendix C continuous maximum icing conditions, and running wet in Appendix C intermittent maximum icing conditions, provides satisfactory performance. If the air intake is running wet in continuous maximum icing conditions, then the applicant should calculate the amount of runback ice that would accumulate during any relevant flight phase and compare that to the maximum certified ingestion capability of the engine per CS-E 780.

Scenario to be considered:

The applicant should justify the icing scenarios to be considered when determining the critical ice accretion conditions. The flight phases as defined in Part II of Appendix C and Part II of Appendix O could be used to support the justification.

For holding ice accretion, the applicant should determine the effect of a 45-minute holding in continuous maximum icing conditions of Appendix C. The analysis should assume that the aeroplane remains in a rectangular “race track” pattern, with all turns being made within the icing cloud. Therefore, no horizontal extent correction should be used for this analysis.

If ETOPS certification is desired, the applicant should consider the maximum ETOPS diversion scenarios.

1.2 Two Minutes Delayed Selection of Air intake IPS Accretion Analysis

It should be demonstrated that the ice accretion is acceptable after a representative delay in the selection of the ice protection systems, such as might occur during inadvertent entry into the conditions. In lack of other evidence, a delay of two minutes to switch on the IPS should be assumed. For thermal IPS, the time for the IPS to warm up should be added.

Applicants should calculate the amount of air intake lip ice that forms using a continuous maximum condition from Appendix C to CS-25, with a liquid water content factor of one. Of the total lip ice, only the ice on the inner barrel side of the stagnation point would be ingested into the engine. Applicants may assume that 1/3 of the ice on the air intake perimeter is ingested as one piece.

1.3 Ice accretion sources

Examples of airframe sources of ice accretion include the radome, the spinner, the antenna and the inboard section of the wing for aft fuselage mounted engines.

Clear ice may also occur on the wing upper surfaces when cold-soaked fuel (due to aircraft prolonged operation at high altitude) is in contact with the fuel tanks’ upper surfaces, or cold soaked structural part is in contact with upper surfaces, and the aeroplane is exposed to conditions of atmospheric moisture (for example, fog, precipitation, and condensation of humid air) at ambient temperatures above freezing. This atmospheric moisture, when in contact with cold wing surfaces, may freeze. Simultaneous ice shedding from both wings of an aeroplane may damage surrounding components or structure parts and result in ice ingestion damage and power/thrust loss in all engines during take-off of flight for aeroplanes with aft fuselage mounted engines.

Identification of Engine Air intake ice accretion sources includes, for Appendix O to CS-25 icing environment, an assessment of air intake differing impingement limits, catch efficiency, distribution effects, and water contents. The applicant should evaluate the potential ice accumulation aft of the engine air intake protected surfaces for the possibility of ice ingestion by the engine.

The applicant should assess the ice accumulations and compare them on the basis of the size or the kinetic energy of the ice slab. It is possible to show that ice accumulations are smaller in size and therefore have equal or less kinetic energy than the CS-E 780 ice ingestion demonstration. Alternatively, kinetic energy may be used as an acceptable method for comparing the airframe ice source to the results of the CS-E 780 ice ingestion demonstration. Any kinetic energy method must be agreed to by the Agency.

1.4 Ice Detection

1.4.1 Upper wing mounted ice detection systems

For aircraft with aft fuselage mounted engines equipped with upper wing mounted ice detection systems to warn the flight crew of clear ice build-up on the upper surface of the wings, applicants should demonstrate that any undetected ice, including ice formed from cold-soaked fuel, is not greater than the ice ingestion demonstrated for CS-E 780 compliance.

1.4.2 Primary Ice Detection System (PIDS).

The relevant provisions of the AMC 25.1419 paragraph (d) apply.

In addition, if a detection threshold exists in the PIDS (in terms of Liquid Water Content (LWC), amount of ice accretion, etc…) it must be demonstrated that the ice accretion that will occur before the actual detection threshold is reached is consistent with CS-E 780 ice ingestion demonstration. Prolonged exposure (up to a 45-minute holding configuration in continuous maximum condition from Appendix C to CS-25) shall be considered at the limit of the detection threshold to evaluate a conservative amount of ice accretion.

For aft fuselage mounted engines, both the engine air intake and the part of the wing in front of the engines should be considered. A conservative assumption is that the ice accretion may detach from both sites simultaneously and be ingested by the engines when the IPS is switched on.

1.5 Appendix P Icing Environment and Pitot-style air intakes design

The results of FAA aerofoil testing in a mixed phase icing environment indicate that these icing conditions do not appreciably accrete on unheated aircraft wings. Furthermore the testing showed that exposure to mixed phase environment results in the same or less ice accretion than exposure to supercooled liquid water environment with the same Total Water Content (TWC). The overall power required by the running-wet ice protection system was essentially unchanged between all-liquid and mixed-phase conditions.

However, in the running-wet mode, the local power density was much higher around the stagnation area in the mixed-phase conditions, compared to the purely liquid conditions. This is due to the power required to offset the thermodynamic heat-of-fusion necessary to melt the impacting ice particles that either fully or partially stick to the surface.

This may also explain why Pitot-style air intakes have not proved to be susceptible to mixed phase ice accretion within the air intake, and why Appendix C to CS-25 compliance methods adequately address those air intakes. Engines designed with reverse flow air intakes, or with air intakes involving considerable changes in airflow direction should be shown to comply with Appendix P to CS 25.

Compliance for Pitot-style air intakes, without considerable changes in airflow direction, may be shown through qualitative analysis of the design and supported by similarity to previous designs that have shown successful service histories.

1.6 Falling and Blowing Snow

1.6.1 CS 25.1093(b)(1) requires that each engine, with all icing protection systems operating, operate satisfactorily in falling and blowing snow throughout the flight power/thrust range, and ground idle. Falling and blowing snow is a weather condition which needs to be considered for the powerplants and essential Auxiliary Power Units (APUs) of transport category aeroplanes.

1.6.2 All engine air intakes, including those with plenum chambers, screens, particle-separators, variable geometry, or any other feature, such as an oil-cooler, struts or fairings, which may provide a potential accumulation site for snow, should be evaluated.

1.6.3 Although snow conditions can be encountered on the ground or in flight, there is little evidence that snow can cause adverse effects in flight on turbojet and turbofan engines with traditional Pitot style air intakes where protection against icing conditions is provided. However, service history has shown that inflight snow (and mixed phase) conditions have caused power interruptions on some turbine engines and APUs with air intakes that incorporate plenum chambers, reverse flow, or particle separating design features.

1.6.4 For turbojet and turbofan engines with traditional Pitot (straight duct) type air intakes, icing conditions are generally regarded as a more critical case than falling and blowing snow. For these types of air intake, compliance with the icing specifications (at least including the icing environment of Appendix C to CS-25) will be accepted in lieu of any specific snow testing or analysis.

1.6.5 For non-Pitot type air intakes, demonstration of compliance with the falling and blowing snow specification on ground should be conducted by tests and/or analysis. If acceptable powerplant operation can be shown in the following conditions, no take-off restriction on the operation of the aeroplane in snow will be necessary.

a. Visibility: 0.4 Km or less as limited by snow, provided this low visibility is only due to falling snow (i.e. no fog). This condition corresponds approximately to 1 g/m^3.

b. Temperatures: − 3 °C to + 2 °C for wet (sticky) snow and – 9 °C to – 2 °C for dry snow, unless other temperatures are found to be critical (e.g. where dry snow at a lower temperature could cause runback ice where it contacts a heated surface).

c. Blowing snow: Where tests are conducted, the effects of blowing snow may be simulated by taxiing the aircraft at 15 to 25 kts, or by using another aircraft to blow snow over the test powerplant. This condition corresponds approximately to 3 g/m^3.

d. Duration: It must be shown that there is no accumulation of snow or slush in the engine, air intake system or on airframe components, which would adversely affect engine operation during any intended ground operation. Compliance evidence should consider a duration which corresponds to the achievement of a steady state condition of accretion and (possible) shedding. Any snow shedding should be acceptable to the engine.

e. Operation: The methods for evaluating the effects of snow on the powerplant should be agreed by the Agency. All types of operation likely to be used on the ground should be considered for the test (or analysis). This should include prolonged idling and power transients consistent with taxiing and other ground manoeuvring conditions. Where any accumulation does occur, the engine should be run up to full power, to simulate take-off conditions and demonstrate that no hazardous shedding of snow or slush occurs. Adequate means should be used to determine the presence of any hazardous snow accumulation.

f. Snow concentration corresponding to the visibility prescribed is often extremely difficult to locate naturally and it is often difficult to maintain the desired concentrations for the duration of testing. Because of this, it is likely that exact target test conditions will not be achieved for all possible test conditions. Reasonable engineering judgment should be used in accepting critical test conditions and alternate approaches, with early coordination between the applicant and the Agency addressing these realities.

1.6.6 For in-flight snow (and mixed phase) conditions, some non-Pitot type air intakes with reverse flow particle separators have been found to accumulate snow/ice in the pocket lip (sometimes referred to as the “bird catcher” section) just below the splitter which divides the engine compressor from the air intake bypass duct. Eventually, the build-up of snow in the pocket (which can melt and refreeze into ice) either spans across to the compressor air intake side of the splitter lip or, the snow/ice build-up is released from the pocket and breaks up whereupon some of the ice pieces can be re-ingested into the compressor side of the inlet. The ingestion of this snow/ice has caused momentary or permanent flameouts and in some cases, foreign object damage to the compressor.

Some aeroplane manufacturers have tried to correct this condition by increasing the amount and/or frequency of applied thermal heat used around the pocket, splitter, and bypass sections of the air intake. However, short of modifying the engine ice protection systems to the point of operating fully evaporative, these fixes have mostly failed to achieve acceptable results.

1.6.7 Aeroplanes with turbine engine or essential APU air intakes which have plenum chambers, screens, particle separators, variable geometry, or any other feature (such as an oil cooler) which may provide a hazardous accumulation site for snow should be qualitatively evaluated for in-flight snow conditions. The qualitative assessment should include:

1) A visual review of the installed engine and air intake (or drawings) to identify potential snow accumulation sites,

2) A review of the engine and engine air intake ice protection systems to determine if the systems were designed to run wet, fully evaporative, or to de-ice during icing conditions, and

3) Unless the air intake ice protection means (e.g. thermal blanket, compressor bleed air, hot oil) operates in a fully evaporative state in and around potential air intake accumulation sites, inlet designs with reverse flow pockets exposed directly to in-flight snow ingestion should be avoided.

Flight testing may be necessary to validate the qualitative assessment.

2. Testing

The engine air intakes may be tested with the engine and propeller where appropriate in accordance with the specifications of CS-E 780 and AMC E 780.

Where the air intake is assessed separately (e.g. icing wind tunnel evaluation of IPS performance, lack of suitable test facilities for engine and air intake, change in the design of the air intake, air intake different from one tested with the engine), it should be shown that the effects of air intake icing would not invalidate the engine tests of CS-E.

Factors to be considered in such evaluations are:

- distortion of the airflow and partial blockage of the air intakes,
- the shedding into the engine of air intakes ice of a size greater than the engine has been shown to ingest per CS-E 780,
- the icing of any engine sensing devices, other subsidiary air intakes or equipment contained within the air intake, and
- the time required to bring the protective system into full operation.

In establishing compliance with the requirements of CS 25.1093(b)(1), reference should be made to AMC 25.1419, paragraph (b), for the assessment of the Appendix C icing environment. In conjunction with the CPA, a thorough validation of the IPS may include in particular the following aspects:

- flight tests in dry air with ice protection equipment operating,
- flight tests in icing conditions, natural or artificial, and
- ground tests in icing wind tunnel.

In establishing compliance with the requirements of CS 25.1093(b)(1), reference should be made to AMC 25.1420, paragraph (d), for the assessment of the Appendix O icing environment.

2.1 Icing wind tunnel tests

Icing wind tunnels provide the ability to simulate natural icing conditions in a controlled environment and they have also been used in particular to evaluate performance of ice protection systems (IPS), such as pneumatic and thermal systems.

When the tests are conducted in non-altitude conditions, the system power supply and the external aerodynamic and atmospheric conditions should be so modified as to represent the required altitude condition as closely as possible.

Where an altitude facility is available, the altitudes to be represented should be consistent with the icing scenario considered. The appropriate inlet incidences or the most critical incidence should be simulated.

Icing tests may be performed in sea level facilities. In order to compensate for the altitude effects, consideration is given to the necessary amendments to the test parameters in order to achieve an adequate evaluation.

Flight conditions may need to be corrected to allow simulation in a wind tunnel. To achieve this, the location of the stagnation point on the inlet lip and the amount of water runback at the throat should be maintained between flight and wind tunnel conditions. Other test parameters, such as static or total air temperature, may require similitude adjustments to achieve the best match of icing condition parameters, such as those described in FAA AC 20-73A.

For each test, the ice protection supply should be representative of the minimum engine power/thrust for which satisfactory operation in icing conditions is claimed.

At the conclusion of each test, the applicants should assess the ice accumulations and compare them with the amount of ice the engine has satisfactorily demonstrated to ingest during engine certification (CS-E 780).

Test results may be used to validate the CPA in term of ice accretion prediction.

For the evaluation of the performance of the IPS, either the critical points determined by a CPA or the conditions defined in Table 1 below may be used to simulate CS-25 Appendix C conditions:

Table 1 – Appendix C test conditions

Ambient Air Temperature ° C	Altitude		Liquid Water Content g/m^3		Mean Effective Droplet Diameter µm
	Ft	m	(a) Continuous Max	(b) Intermittent Max	
– 10	17 000	5 182	0.6	2.2	20
– 20	20 000	6 096	0.3	1.7	
– 30	25 000	7 620	0.2	1.0	

Note: The conditions of water concentration required by these tests are somewhat more severe than those implied by the Appendix C to CS-25 so as to provide margins.

A separate test should be conducted at each temperature condition of Table 1 above, the test being made up of repetitions of one of the following cycles:

1) 28 km (15.1 NM) in the conditions of Table 1, column (a), appropriate to the temperature, followed by 5 km (2.7 NM) in the conditions of Table 1, column (b), appropriate to the temperature, for a total duration of 30 minutes, or

2) 6 km (3.2 NM) in the conditions of Table 1, column (a), appropriate to the temperature, followed by 5 km (2.7 NM) in the conditions of Table 1, column (b), appropriate to the temperature, for a total duration of 10 minutes.

Each test should be run at, or should simulate, different engine power/thrust conditions, including the minimum power/thrust for which satisfactory operation in icing conditions is claimed.

Flight Idle power/thrust should be assessed against the conditions defined in Table 1 both for Column (a) and Column (b).

If there is a minimum power/thrust required for descent to ensure satisfactory operation in icing conditions, the increase to that minimum power/thrust in icing conditions should be automatic when the IPS is switched on, and this minimum power/thrust associated with descent in icing conditions should be assessed against the conditions in Table 1 above.

The test duration expressed above assume that steady state conditions (ice shedding cycles) are established. If this is not the case, the test should continue until a maximum duration of 45 minutes when using test 1) above or 15 minutes when using test 2) above, except for descent where the test duration may be limited to the time needed to cover an anticipated descent of 3 000 m.

Where an altitude facility is available, the altitudes to be represented should be as indicated in Table 1.

2.2 Delayed activation of the air intake IPS

When the ingestion tests under CS-E 780 do not adequately represent the particular airframe installation, then the delayed IPS activation test should be considered, even for aircraft equipped with PIDS to consider possible manual IPS activation in “degraded” mode.

Either by separate tests, or in combination with those of paragraph 2.1 above, it should be demonstrated that the ice accretion is acceptable after a representative delay in the selection of the IPS, such as might occur during inadvertent entry into the conditions. In lack of other evidence, a delay of two minutes to switch on the IPS should be assumed when exposed to Continuous Maximum exposure of Appendix C to CS-25. For thermal IPS, the time for the IPS to warm up should be added.

Similar to the accepted compliance with CS-E 780 ice ingestion tests, the use of engine auto-ignition and recovery systems are allowed to show compliance with the delayed activation tests of CS-25, as long as these automatic systems cannot be easily turned off by the flight crew.

In the case of De-iced air intakes (designed for a cyclic shedding of ice from the engine air intake into the engine) which incorporate, as part of their design, an air intake particle-separator that stops the ingestion of ice into the core of the engine, engine auto-recovery systems should not be a compensating design feature utilized to minimize the negative effects of an inadequate particle-separating air intake that is not in full compliance with CS 25.1093.

2.3 Natural Icing Flight Tests

Natural icing flight tests may also be used to show compliance with CS 25.1093(b)(1).

In this context, natural icing flight tests are intended to demonstrate that the engine is capable of operating throughout its flight power/thrust range (including idling), without an adverse effect. This includes the accumulation of ice on the engine, air intake system components, or airframe components that would have an adverse effect on the engine operation or cause a serious loss of power or thrust.

In addition to proving that the engine air intake icing analysis model is accurate, several other key issues exist, which the natural ice encounter may address. These include:

- the adequacy of flight crew procedures when operation in icing conditions,

- the acceptability of control indications to the flight crew as the aeroplane responds to engine fan blade ice shedding during various conditions,
- the performance of the engine vibration indication system, as well as other engine indication systems, and
- the confirmation that the powerplant installation performs satisfactorily while in icing conditions. This whole powerplant installation includes the engine, air intake, and the IPS system.

2.4 Testing in Non-Representative Conditions

When damage results from icing test conditions that fall significantly outside Appendices C, O and P to CS-25 icing envelopes, or when the aeroplane flight test is conducted in an abnormal manner and results in excessive ice shed damage, this may result in a test failure relative to the pre-test pass or fail criteria. Any abnormal conditions should be discussed with the Agency to determine if the test can be deemed “passed.” An example of an abnormal operation could be flying with one engine at idle while the aircraft is operated in level flight.

(b) Compliance with CS 25.1093(b)(2)

Ground taxi exposure to Appendices C and O to CS-25

1. Critical Points Analysis (CPA).

The temperatures should result from a CPA, considering the full range of temperatures specified in CS 25.1093(b)(2), conducted to determine the critical ice accretion conditions for the air intake.

2. Ground taxi exposure to Appendix O conditions.

The service experience indicates that engine fan damage events exist from exposure to SLD during ground taxi operations. For this reason, an additional condition of a 30-minute, idle power/thrust exposure to SLD on the ground must be addressed. Applicants should include the terminal falling velocity of SLD (for example, freezing rain, freezing drizzle) in their trajectory assessment, relative to the protected sections of the air intake. The 100 micron minimum mean effective diameter (MED) is selected as a reasonable achievable condition, given current technology. To certify by analysis the applicant should evaluate the Appendix O drop sizes up to a maximum of 3 000 microns particle size to find a critical condition.

3. Operating limitation.

The conditions defined in CS 25.1093(b)(2), in terms of time and temperature, should be considered as limitations necessary for the safe operation in freezing fog, and made available to the crew in the Aeroplane Flight Manual (refer to CS 25.1581).

Nevertheless, the applicant may use an analysis to substantiate safe operation of the engine at temperatures below the demonstrated minimum temperature. No limitation would then be required in the Aeroplane Flight Manual.

AMC – SUBPART F

Delete AMC to 25.1323(i) and 25.1325(b) as follows:

~~**AMC to 25.1323(i) and 25.1325(b)**~~

~~**Airspeed Indicating System**~~

~~1 Tests should be conducted to the same standard as recommended for turbine engine air intakes (see AMC 25.1093(b)(1)) unless it can be shown that the items are so designed and located as not to be susceptible to icing conditions. Ice crystal and mixed ice and water cloud will need to be considered where the system is likely to be susceptible to such conditions.~~

~~2 However, in conducting these tests due regard should be given to the presence of the aeroplane and its effect on the local concentration of the cloud.~~

Create a new AMC 25.1324 as follows:

AMC 25.1324

Flight instrument external probes

CS 25.1324 requires each flight instrument external probes systems, including, but not necessarily limited to Pitot tubes, Pitot-static tubes, static probes, angle of attack sensors, side slip vanes and temperature probes, to be heated or have an equivalent means of preventing malfunction in the heavy rain conditions of table 1 of CS 25.1324 and in the icing conditions as defined in the Appendices C and P, and in Appendix O (or a portion of Appendix O) of CS-25.

It is unlikely that the icing conditions critical to the equipment will be encountered during flight tests. Consequently, it is anticipated that tests should be conducted in wind tunnel simulated icing environment to supplement the icing flight test data (natural or tanker) as necessary.

The following AMC provides some guidance related to the test setup and the conditions to be tested.

Note: Engine sensors such as pressure/temperature probes must meet CS-E certification specifications. However, when the signals from these sensors are used by the aeroplane system(s), the aeroplane manufacturer must ensure that the involved engine sensor meets CS 25.1324 specifications. Coordination of this activity should be ensured with the engine manufacturer.

1. Acronyms

SAT: Static Air Temperature

LWC: Liquid Water Content

MVD: Median Volume Diameter

IWC: Ice Water Content

MMD: Median Mass Dimension

L(i): “Liquid” supercooled water conditions

M(i): Mixed phase icing conditions: icing conditions that contain both supercooled water and ice crystals.

G(i): Glaciated conditions: icing conditions totally composed of ice crystals.

R(i): Rain conditions

SD: supercooled droplet

SLD: supercooled large drop

WC: water content

2. Wind Tunnels

All conditions must be appropriately corrected to respect the similarity relationship between actual and wind tunnel conditions (due to pressure and scale differences for example). It is the applicant responsibility to determine and justify the various derivations and corrections to be made to the upstream conditions in order to determine actual test conditions (local and scaled). When the tests are conducted in non-altitude conditions, the system power supply and the external aerodynamic and atmospheric conditions should be so modified as to represent the required altitude condition as closely as possible.

The icing wind tunnel calibration should have been verified, in accordance with SAE ARP 5905 with an established programme to maintain calibration of the facility. Calibration records should be examined to ensure the local liquid water concentration at the location of the probe complies with values required in the test specification.

3. Test setup

The test setup installation in the wind tunnel must be shown to be equivalent to the installation on the aircraft. In particular, the probe must be installed in such a way that the heat sink capacity of the mount is equal to or greater than the aircraft installation.

Surface temperature measurements of the probe mounting are typically made during icing wind tunnel tests to verify thermal analysis and to allow extrapolation to conditions not reachable due to the wind tunnel limitations.

4. Local conditions

The Water Content (WC) values provided in this AMC or in the Appendices C, O and P to CS-25 are upstream values, independent of the aircraft installation. Local WC values (at the probe location) need to be derived from the upstream values according to the streamline behaviour around the aircraft. Overconcentration of the WC at the probe location may occur due to the aerodynamic effects of the fuselage in particular.

Local conditions should be determined based on many parameters which could include:

- Aircraft specific
  - Aircraft fuselage shape
  - Probe location on aircraft fuselage (X, Y, Z coordinates)
  - Aircraft speed and altitude (Climb, Cruise, Descent …)
- Environmental Conditions specific
  - Type (SD, SLD, Crystals, Rain)
  - Size (from 0 to 2 000 micron)
  - Density

- Probe specific:
  - — mast/strut length

Concerning the type and size of the particles, the local WC should be computed considering the full distribution of the particles sizes that is actually present in the real atmosphere, even if the wind tunnel tests are then performed at a given single size (20 micron for supercooled droplets, 150 micron for ice crystals, 500 to 2 000 micron for rain drops). The local conditions may also be affected by the “bouncing effect” and “shattering effect” for solid particles or the “splashing effects” for large liquid particles. As no model exists today to represent ice particles trajectories and these particular effects, an assessment based on the best available state of the art shall be made.

5. Operational Conditions

The conditions are to be tested at several Mach and Angle of Attack (AoA) values in order to cover the operational flight envelope of the aircraft. It is the applicant responsibility to select and justify, for each of the conditions listed in each Cloud Matrix below, the relevant operational conditions to be tested (Mach, AoA and Mode…).

It is expected that several operational conditions will be identified for each environmental conditions but exhaustive testing is not intended.

6. Power supply

The heating power supply used during the tests should be the minimum value expected at the probe location on the aircraft. It is commonly accepted to test the probe at 10 % below the nominal rated voltage.

7. Flight deck indication

When a flight instrument external probe heating system is installed, CS 25.1326 requires an alert to be provided to the flight crew when that flight instrument external probe heating system is not operating or not functioning normally.

All performances of the probe ice protection system, in particular the icing tests described in this AMC are expected to be demonstrated with equipment selected with heating power set to the minimum value triggering the flight deck indication.

8. Test article selection

To be delivered, an article has to meet an Acceptance Test Procedure (ATP) established by the equipment supplier. The ATP is a production test performed on each item to show it meets the performance specification. Both the performance of the ice protection system and the icing tests described hereafter are expected to be demonstrated with an equipment selected at the lowest value of the ATP with respect to the acceptability of the heating performance. This can be accomplished by adjusting the test voltage, heating cycles and/or any other applicable parameters, to simulate the lowest performing probe. Note that this has to be applied in addition to the power supply reduction mentioned in paragraph 6 above.

9. Mode of Operation

The modes of operation of the probe are to be assessed in the two following tests. However, depending on the mode of operation of the heating systems, other intermediate modes may have to be tested (e.g. if heating power is varied as a function of the outside temperature, etc.)

a. Anti-icing test:

During this test, the icing protection of the probe (typically resistance heating) is assumed to be switched “on” prior exposure to icing conditions.

b. De-icing test:

During this test, the icing protection of the probe (typically resistance heating) should be ‘off’ until 0.5 inch of ice has accumulated on the probe. For ice crystal tests in de-icing mode, since no accretion is usually observed, an agreed ‘off’ time duration should be agreed before the test. In the past, a one-minute time duration without heating power has been accepted. This mode need not be tested if, in all operational scenarios (including all dispatch cases), the probe heating systems are activated automatically at aircraft power ‘On’ and cannot be switched to manual operation later during the flight.

10. Supercooled Liquid (SL) Conditions

The following proposed test points are intended to provide the most critical conditions of the complete CS-25 Appendix C icing envelope, however, a Critical Points Analysis (CPA) may be used to justify different values.

10.1 - Stabilized conditions

Table 1: Stabilized Liquid icing test conditions

Test #	**SAT (°C)**	**Altitude Range**		**LWC(*) (g/m^3)**	**Duration (min)**	**MVD(*) (µm)**
SL1	– 20	0 to 22000 ft.	0 to 6706 m	0.22 to 0.3	15	15 to 20
SL2	– 30	0 to 22000 ft.	0 to 6706 m	0.14 to 0.2	15	15 to 20
SL3	– 20	4000 to 31000 ft.	1219 to 9449m	1.7 to 1.9	5	15 to 20
SL4	– 30	4000 to 31000 ft.	1219 to 9449 m	1 to 1.1	5	15 to 20

(*) Note:

The upstream LWC values of the table are based on CS-25 Appendix C and correspond to a droplet diameter of 20 µm or 15 µm. Considering that the local collection efficiency is function of the MVD and the probe location with respect to the boundary layer, and that the upstream LWC value is higher for an MVD of 15 µm as compared to 20 µm, the applicant shall establish the conditions leading to the highest local LWC at probe location and test accordingly.

It is acceptable to run the tests at the highest determined local LWC but using a droplet diameter of 20 µm since most of the wind tunnel are calibrated for that value.

10.2 - Cycling conditions

A separate test should be conducted at each temperature condition of Table 2 below, the test being made up of repetitions of either the cycle:

a. 28 km in the conditions of column (a) appropriate to the temperature, followed by 5 km in the conditions of column (b) appropriate to the temperature, for a duration of 30 minutes, or

b. 6 km in the conditions of column (a) appropriate to the temperature, followed by 5 km in the conditions of column (b) appropriate to the temperature, for a duration of 10 minutes.

Table 2: Cycling Liquid icing test conditions

Test #	**SAT (°C)**	**Altitude Range**		**LWC (g/m³)**		**MVD (µm)**
		(ft)	**(m)**	**(a)**	**(b)**	
SL6	− 10	17 000	5182	0.6	2.2	20
SL7	− 20	20 000	6096	0.3	1.7	
SL8	− 30	25 000	7620	0.2	1.0	

11. Supercooled Large Drop Liquid Conditions

Based on the design of the probe, the drop size may not be a significant factor to consider as compared to the other parameters and in particular the Liquid Water Content (LWC). The SLD LWC defined in Appendix O (between 0.18 and 0.44 g/m^3) are largely covered by the Appendix C continuous maximum LWC (between 0.2 and 0.8 g/m^3) and the Appendix C intermittent maximum LWC (between 0.25 and 2.9 g/m^3).

Testing SLD conditions may not be necessary if it can be shown that the Supercooled Liquid Conditions of Appendix C are more critical. If some doubt exists, the applicant shall propose a set of critical test points to cover adequately the Icing Environment defined in the Appendix O.

12. Mixed Phase (M) and Glaciated (G) Conditions

The applicant should propose a set of critical test points to cover adequately the Icing Environment as proposed in Appendix P of CS-25.

Testing should be performed at representative altitude as the effect of altitude on probe behaviour is not yet fully understood, unless demonstration can be made that application of scaling laws leads to conservative approach of testing.

The following considerations shall be taken into account.

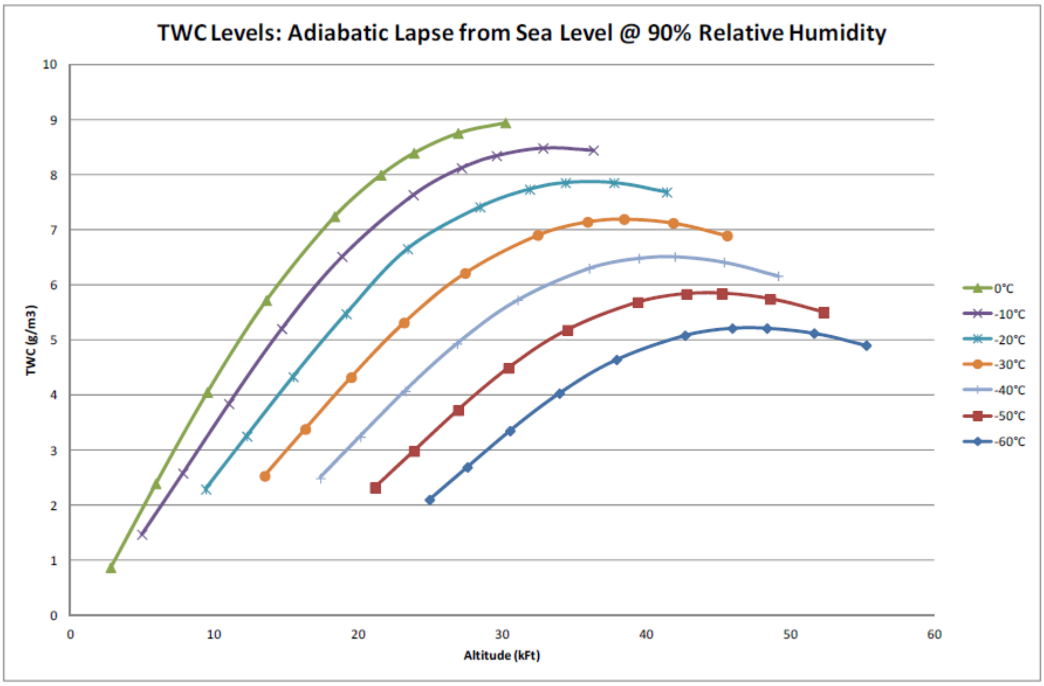
12.1 - Glaciated Conditions

As indicated in the Appendix P, the total water content (TWC) in g/m^3 has been assessed 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 (NM).

In service occurrences show that several pitot icing events in Glaciated Conditions, above 30 000 ft are outside of the Appendix P domain in term of altitude and outside air temperature. In that context, the Appendix P, Figure 1 (Convective cloud ice crystal envelope) should be enlarged to encompass ISA +30°C conditions. Furthermore, a reported event occurred at a temperature of – 70 °C. Testing may not be possible at such a low temperature due to simulation tool limitations. However, the presence of Ice Crystals has been observed, and it is anticipated that an extrapolation of existing test data at higher temperature should allow assessing the predicted performance of the probe heating down to this minimum temperature.

In addition, based on several sources of information including the EUROCAE WG-89, the Agency is of the opinion that the standard cloud of 17.4 NM and the associated average TWC concentration values provided by Appendix P may not provide the most conservative conditions for Flight Instrument External Probes testing.

The 'max' or 'peak' TWC concentration values should be considered instead of the '17.4 NM' values provided by the Appendix P. These 'max' or 'peak' values are available in FAA document DOT/FAA/AR-09/13. They correspond to the '17.4 NM' values multiplied by a factor of 1.538 (1/0.65). The 'max' concentration values (TWC) are provided below:

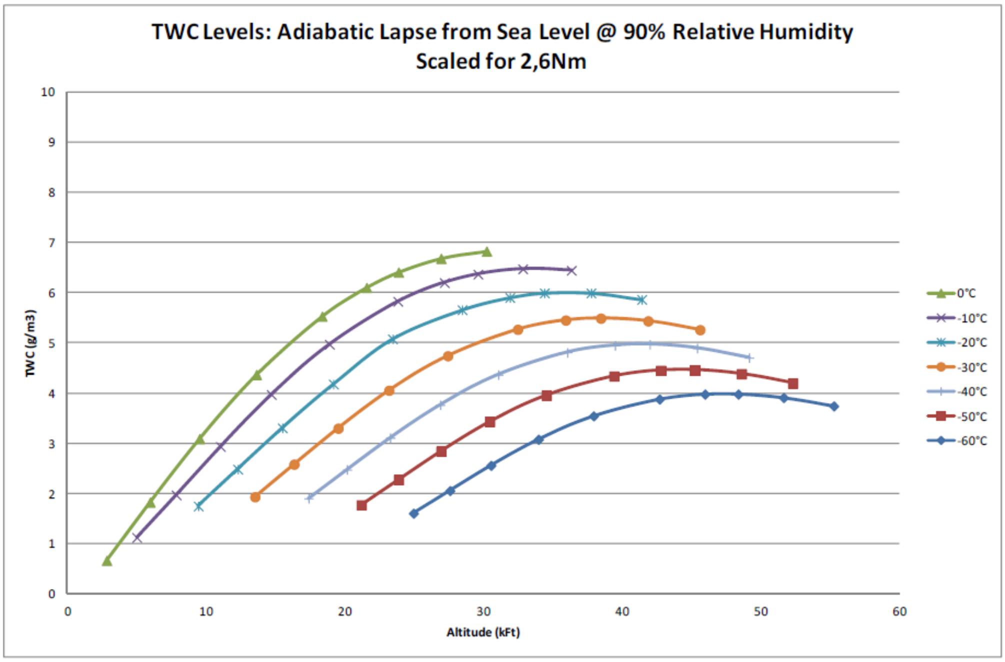


12.2 - Mixed Phase Conditions

In service occurrences show several pitot icing events in Mixed phase conditions, between 20 000 and 30,000 feet, outside of the Appendix P domain in term of altitude and outside air temperature.

Based on several sources of information including the EUROCAE WG-89, the Agency is of the opinion that the '2.6 NM' TWC concentration values should be considered instead of the '17.4 NM' values, as the CS-25 Appendix C Intermittent conditions provide data for a 2.6 NM cloud.

The '2.6 NM' values are given by the '17.4 NM' values scaled by the F factor for 2.6 NM clouds which is 1.175 and are provided below:



It is commonly recognised that below -40°C no liquid conditions exist anymore. Therefore testing in mixed phase conditions does not need to consider temperatures below -40°C.

12.3 - Ice Particles

Several methods of generating ice particles are used in testing and produce a wide range of particle sizes. Some methods of generating ice particles results in irregular shapes which are difficult to quantify in terms of mean particle diameter. It is acceptable to specify ice particle sizes based on the available range of ice particle generation techniques in the MMD range of 50 to 200 µm as provided in Appendix P to CS-25. Higher values may be used if justified.

For mixed phase icing, the heat requirements are driven primarily by the quantity of ice collected in the probe rather than the size of the ice particles. Supercooled liquid droplet MVD size of 20 µm should be used.

12.4 - Duration

For each condition a minimum of two minutes exposure time should be tested. This is the minimum time needed to reach a steady state and stabilised condition.

12.5 - Total Air Temperature probe design consideration

It is recognised that due to the intrinsic function of the total air temperature probes it may not be possible to design the temperature sensor with sufficient heating capability to ensure both adequate protection across the complete icing environment of CS-25 Appendix P and accurate temperature measurements. In this case, it may be acceptable that the temperature probe is not fully protected over a portion of the Appendix P icing environment provided that the malfunction of the probe will not prevent continued safe flight and landing. System safety assessments must include common mode failure conditions. Mitigation for potential icing related failures at the aircraft level should be accomplished as required by the Air Data System and/or by the primary data consumers. Examples of mitigation methods include comparing air data from multiple sources and from sources of dissimilar technologies.

13. Rain (R) Conditions

Flight instrument external probes must be evaluated in the heavy rain conditions provided in Table 1 of CS 25.1324. A test temperature below 10°C is considered acceptable. Testing may be performed at a higher temperature if it can be demonstrated that the increase in evaporation rate due to the higher ambient temperature does not decrease the severity of the test.

The efficiency of the drainage of the probe may depend on the aircraft airspeed. The applicant should, therefore, consider testing conditions including, at a minimum, low and high airspeed values in the rain conditions envelope.

14. Pass/fail criteria

The pass/fail criteria of a given test are as follows:

The output of the probe should quickly stabilize to the correct value after the start of an anti-icing test or once the icing protection is restored in a de-icing test. This value has to be agreed before the test between the applicant and the Agency, and it must stay correct as long as the icing protection is maintained. The measurement is considered to be correct if any observed fluctuation, when assessed by the applicant, has no effect at the aircraft level.

In addition, for pitot probes and especially during ice crystal or mixed phase conditions tests, it should be observed that the measured pressure is not ‘frozen’ (pressure signal without any noise, i.e. completely flat), which would indicate an internal blockage resulting in a captured pressure measurement.

After each test, any water accumulating in the probe connection line should be collected and assessed. The amount of water trapped in the probe (i.e. in the line conveying the air to the electronics) should not interfere with the output correctness when the probe is installed on the aeroplane.

Create a new AMC 25.1326 as follows:

AMC 25.1326

Flight instrument external probes heating systems alert

CS 25.1326 requires that if a flight instrument external probe heating system is installed, an alert must be provided to the flight crew when the flight instrument external probes heating system is not operating or not functioning normally.

It is expected that probe heating system failures are indicated to the flight crew if such failures have an impact on the performance of the heating system to the extent of having an “effect on operational capability or safety” (see CS 25.1309).

In accordance with CS 25.1309(c) and CS 25.1322(b), a Caution category of alert is required by CS 25.1326 for immediate crew awareness and subsequent crew action.

It should be assumed that icing conditions exist during the failure event. The decision to provide heating system failure indication should not be based on the numerical probability of the failure event. If the failure could potentially have hazardous or catastrophic consequences, then this failure must be indicated.

The reliability of the system performing the probe heating system failure detection and alerting should be consistent with the safety effect induced by the failure. Refer to AMC 25.1309, chapter 9(c) for more detailed guidance.

Amend AMC N°1 to CS 25.1329 as follows:

AMC No. 1 to CS 25.1329

Flight Guidance System

…

2 RELATED CERTIFICATION SPECIFICATIONS

CSs

The following are related CS standards:

CS 25.115	Take-off flight path
CS 25.302	Interaction of systems and structures
CS 25.671	Control systems, General
CS 25.672	Stability augmentation and automatic and power-operated systems
CS 25.677	Trim systems
CS 25.777	Cockpit controls
CS 25.779	Motion and effect of cockpit controls
CS 25.781	Cockpit control knob shape
CS 25.901	Powerplant, General, Installation–
CS 25.903	Powerplant, General, Engines
CS 25.1301	Equipment, General, Function and installation–
CS 25.1309	Equipment, systems, and installations
CS 25.1322	Warning, caution, and advisory lights
CS 25.1419	Ice protection
CS 25.1420	Supercooled large drop icing conditions
CS 25.1581	Aeroplane Flight Manual, General
CS-AWO	All Weather Operations

…

8.2.1 Flight Director Engagement

A means ~~may~~should be provided for each pilot to select (i.e., turn on) and deselect the flight director for display on their primary flight display (e.g., attitude display). The selection status of the flight director and the source of flight director guidance should be clear and unambiguous. Failure of a selected flight director should be clearly annunciated.

…

8.3.1 Autothrust Engagement

The autothrust engagement controls should be accessible to each pilot. The autothrust function ~~should~~must provide the flight crew positive indication that the system has been engaged (see CS 25.1329(i)).

…

9.1 FGS Controls

The FGS controls should be designed and located to provide convenient operation to each crewmember and they must be designed to ~~prevent~~ minimize crew errors, confusion and inadvertent operation (CS 25.1329(i)). To achieve this, CS 25.1329 (f) requires that command reference controls to select target values (e.g., heading select, vertical speed) should operate as specified in CS 25.777(b) and 25.779(a) for cockpit controls. The function and direction of motion of each control must be readily apparent or plainly indicated on, or adjacent to, each control if needed to prevent inappropriate use or confusion (CS 25,1329(f)). CS 25.781 also provides requirements for the shapes of the knobs. The design of the FGS should address the following specific considerations:

…

10.1 Normal Performance

The FGS should provide guidance or control, as appropriate, for the intended function of the active mode(s) in a safe and predictable manner within the aeroplane's normal flight envelope.

The FGS should be designed to operate in all aeroplane configurations for its intended use within the aeroplane's normal flight envelope to ~~provide acceptable~~ provide acceptable performance for the following types of environmental conditions:

- Winds (light and moderate)
- Wind gradients (light and moderate)

NOTE: In the context of this AMC, "wind gradient" is considered a variation in wind velocity as a function of altitude, position, or time.

- Gusts (light and moderate)
- Turbulence (light and moderate)
- Icing ~~(trace, light, moderate)~~ – all icing conditions covered by Appendix C to CS-25 and applicable icing conditions covered by Appendix O to CS-25, with the exception of "asymmetric icing" discussed under "Rare Normal Conditions" in Section 10.2 below.

…

Create a new AMC 25.1403 as follows:

AMC 25.1403

Wing icing detection lights

Unless operations at night in icing conditions are prohibited by an operating limitation, CS 25.1403 requires that a means be provided, during flight at night, to illuminate or otherwise determine ice formation on parts of the wings that are critical from the standpoint of ice accumulations.

a. If the flight crew cannot see the wings, one acceptable means of compliance with this regulation would be to install an ice evidence probe in a position where the flight crew can observe ice accumulation. The applicant should substantiate that formation of ice on this device precedes formation of ice on the wings or occurs simultaneously with it. Consideration should be given to the need for illuminating the ice evidence probe.

b. Wing icing detection lights should be evaluated both in and out of clouds during night flight to determine that the component of interest is adequately illuminated without excessive glare, reflections, or other distractions to the flight crew. These tests may be accomplished during the aeroplane certification flight tests. Typically, aeroplane-mounted illumination has been used to comply with this regulation. Use of a hand-held flashlight has not been considered acceptable because of the associated workload. The appropriate manual should identify the ice characteristics which the flight crew is expected to observe as well as the action the flight crew must perform if such ice is observed.

Replace the current AMC 25.1419 by the following:

AMC 25.1419

Ice Protection

If certification for flight in icing conditions is desired, the aeroplane must be able to safely operate throughout the icing envelope defined in Appendix C.

In the context of this AMC, the wording *"relevant icing environment"* means the Appendix C icing conditions.

CS 25.1419 provides specific airframe requirements for certification for flight in the icing conditions defined in Appendix C. Additionally, for other parts of the aeroplane (i.e., engine, engine inlet, propeller, flight instrument external probes, windshield) there are more specific icing related CS-25 specifications and associated acceptable means of compliance.

Other icing related specifications must be complied with, even if the aeroplane is not certificated for flight in icing:

- CS 25.629(d)(3)
- CS 25.975(a)(1)
- CS 25.1093(b)
- CS 25.1324
- CS 25.1325(b)
- CS 25.1326
- CS 25J1093(b)

Additional information for showing compliance with the aeroplane performance and handling qualities requirements for icing certification may be found in AMC 25.21(g)

(a) CS 25.1419(a) Analysis

The applicant should prepare analysis to substantiate the choice of ice protection equipment for the aeroplane. Such analysis should clearly state the basic protection required and the assumptions made, and delineate methods of analysis used. All analysis tools and methods should be validated by tests or should have been validated by the applicant on a previous certification program. The applicant who uses a previously validated method should substantiate why that method is applicable to the new program.

1. Analytical Simulation Methods

Analytical simulation methods for icing include impingement and accretion models based on computational fluid dynamics. The applicant will typically use these methods to evaluate protected as well as unprotected areas for potential ice accretions. Analytical simulation provides a way to account for the variability in drop distributions. It also makes it possible to examine impingement in relation to visual icing cues and to analyse the location of detection devices for detrimental local flow effects.

2. Analysis of areas and components to be protected

In evaluating the aeroplane's ability to operate safely in the relevant icing environment, and in determining which components will be protected, the applicant should examine relevant areas to determine the degree of protection required. An applicant may determine that protection is not required for one or more of these areas or components. If so, the applicant's analysis should include the supporting data and rationale for allowing those areas or components to remain unprotected.

The applicant should show that:

- the lack of protection does not adversely affect handling characteristics or performance of the aeroplane, as required by CS 25.21(g),
- the lack of protection does not cause unacceptable affects upon the operation and functioning of affected systems and equipment,
- the lack of protection does not affect the flight instrument external probes systems, and
- shedding of ice accreting on unprotected areas will not create unacceptable damages to the engines or the surrounding components which would prevent continued safe flight and landing.

3. Impingement Limit Analysis

The applicant should prepare a drop trajectory and impingement analysis of:

- wings,
- horizontal and vertical stabilizers,
- engine air intakes,
- propellers,
- any means used to detect ice accretion (ice detector, visual cues) and
- all other critical surfaces upon which ice may accrete.

This analysis should consider the various aeroplane operational configurations, phases of flight, and associated angles of attack.

The impingement limit analysis should establish upper and lower aft drop impingement limits that can then be used to establish the aft ice formation limit and its relationship to the Ice Protection Systems (IPS) coverage.

Water content versus drop size relationships defined in Appendix C, Figures 1 and 4 are defined in terms of mean effective drop diameter. CS-25 does not require consideration of specific distributions for Appendix C icing conditions.

In determining the rates of catch, the full spectrum of the droplet sizes should be considered but in determining impingement areas, a maximum droplet size of 50 µm need only be considered for compliance to CS 25.1419.

4. Ice Shedding Analysis

For critical ice shedding surfaces an analysis must be performed to show that ice shed from these surfaces will not create unacceptable damages which would prevent continued safe flight and landing.

Airframe ice shedding may damage or erode engine or powerplant components as well as lifting, stabilizing, and flight control surface leading edges. Fan and compressor blades, impeller vanes, inlet screens and ducts, and propellers are examples of powerplant components subject to damage from shedding ice. For fuselage-mounted turbojet engines (and pusher propellers that are very close to the fuselage and well aft of the aeroplane's nose), ice shedding from the forward fuselage and from the wings may cause significant damage. Ice shedding from components of the aeroplane, including antennas, should not cause damage to engines and propellers that would adversely affect engine operation or cause an unacceptable loss of power or thrust (compliance with CS 25.1093(b)).

The applicant should also consider aeroplane damage that can be caused by ice shedding from the propellers.

Control surfaces such as elevators, ailerons, flaps, and spoilers, especially those constructed of thin metallic, non-metallic, or composite materials, are also subject to damage.

Currently available trajectory and impingement analysis may not adequately predict such damage. Unpredictable ice shedding paths from forward areas such as radomes and forward wings (canards) have been found to negate the results of these analysis.

For this reason, a damage analysis should consider that the most critical ice shapes will shed and impact the areas of concern.

5. Thermal Analysis and Runback Ice

An analysis shall be performed to predict the effectiveness of the thermal IPS (hot air or electrical). Design objectives (fully evaporative or running wet) shall be assessed against the relevant icing environment.

Water not evaporated by thermal ice protection systems and unfrozen water in near-freezing conditions (or in conditions when the freezing fraction is less than one) may run aft and form runback ice. This runback ice can then accumulate additional mass from direct impingement.

Runback ice should be determined and should be considered when determining critical ice shapes. Simulated runback ice shapes may be used when evaluating effects of critical ice shapes. Computer codes may be unable to estimate the characteristics of the runback water or resultant ice shapes (rivulets or thin layers), but some codes may be able to estimate the mass of the runback ice. Thus runback ice should be determined experimentally, or the mass determined by computer codes with assumptions about runback extent and thickness similar to those used successfully with prior models.

The applicant should consider potential hazards resulting from the shedding of runback ice.

6. Power Sources

The applicant should evaluate the power sources in the IPS design (e.g. electrical, bleed air, or pneumatic sources). An electrical load analysis or test should be conducted on each power source to determine that it is adequate to operate the IPS as well as to supply all other essential electrical loads for the aeroplane throughout the aeroplane flight envelope. The effect of an IPS component failure on availability of power to other essential loads should be evaluated in accordance with CS 25.1309. All power sources affecting engines or engine IPS for multiengine aeroplanes must comply with the engine isolation requirements of CS 25.903(b).

7. Artificial ice shapes and roughness

AMC 25.21(g) contains guidance on icing exposure during various phases of flight that should be considered when determining artificial ice shapes and surface roughness. The shape and surface roughness of the ice should be developed and substantiated with acceptable methods. When developing critical ice shapes, the applicant should consider ice accretions that will form during all phases of flight and those that will occur before activation and proper functioning of the ice protection system.

If applicable, runback, residual, and inter-cycle ice accretions should also be considered.

The applicant should substantiate the drop diameter (mean effective, median volume), liquid water content, and temperature that will cause formation of an ice shape critical to the aeroplane's performance and handling qualities.

Ice roughness used should be based on icing tunnel, natural icing, or tanker testing, or the guidance in AMC 25.21(g), Appendix 2.

8. Similarity Analysis

(i) For certification based on similarity to other type-certificated aeroplanes previously approved for flight in icing conditions, the applicant should specify the aeroplane model and the component to which the reference of similarity applies. The applicant should show specific similarities in the areas of physical, functional, thermodynamic, ice protection system, and aerodynamic characteristics as well as in environmental exposure. The applicant should conduct analysis to show that component installation, operation, and effect on the aeroplane's performance and handling are equivalent to that of the same or similar component in the previously approved configuration.

(ii) A demonstration of similarity requires an evaluation of both system and installation differences. Differences should be evaluated for their effect on IPS functionality and on safe flight in icing. If there is uncertainty about the effects of the differences, the applicant should conduct additional tests and/or analysis as necessary and appropriate to resolve the open issues.

(iii) CS 25.1419(b) requires flight testing in measured natural icing conditions. Flight test data from previous certification programs may be used to show compliance with CS 25.1419(b) if the applicant can show that the data is applicable to the aeroplane in question. If there is uncertainty about the similarity analysis, the applicant should conduct flight tests in measured natural icing conditions for compliance with CS 25.1419(b).

Note: The applicant must possess all the data to substantiate compliance with applicable specifications, including data from past certifications upon which the similarity analysis is based.

(b) CS 25.1419(b) Testing

The aeroplane should be shown to comply with certification specifications when all IPS are installed and functioning when operating normally and under certain failure conditions. This can normally be accomplished by performing tests in natural or simulated icing conditions to either validate analysis or to test those conditions found to be most critical to basic aeroplane aerodynamics, IPS design, and powerplant functions. All IPS equipment should perform their intended functions throughout the entire operating envelope.

The primary purposes of flight testing are to:

- Determine that the IPS is acceptably effective and performs its intended functions during flight as predicted by analysis or ground testing,
- Evaluate any degradation in performance and flying qualities,
- Verify the adequacy of flightcrew procedures as well as limitations for the use of the IPS in normal, abnormal, and emergency conditions,
- Confirm that the powerplant installation as a whole (engine, propeller, inlet, anti-ice system, etc.) performs satisfactorily in icing conditions, and
- Validate the ice accretion size, location, texture and other general characteristics.

Performance and handling qualities specifications are identified in CS 25.21(g). Flight tests to show compliance with these requirements are addressed in AMC 25.21(g).

<u>1. Dry air flight tests with ice protection equipment operating</u>

The first flight tests conducted to evaluate the aeroplane with the IPS operating are usually dry air flight tests. The initial dry air tests are conducted to:

- Verify that the IPS does not affect flying qualities of the aeroplane in clear air, and
- Obtain a thermal profile of an operating thermal IPS to substantiate its thermal performance.

Several commonly used IPS and components are discussed below to illustrate typical dry air flight test practices. Other types of equipment should be evaluated as their specific design dictates.

1.1 Thermal ice protection leading edge systems

Dry air flight tests are conducted to verify the system design parameters and thermal performance analysis.

Normally, instruments are installed on system components to measure the anti-icing mass flow rate or energy input (for electrical systems), supply air temperature, and surface temperatures. The dry air test plan generally includes operating conditions such as the climb, holding, and descent phases of a normal flight profile. Since the presence of moisture can affect surface temperatures, tests should be conducted where no visible moisture is present.

Measurements of supply air mass flow rate, energy input, and air temperature allow determination of how much heat is available to the system. The adequacy of the IPS can then be demonstrated by comparing the measured data to the theoretical analysis.

Surface temperatures measured in the dry air, for example, can be useful in extrapolating the maximum possible leading edge surface temperature in-flight, the heat transfer characteristics of the system, and the thermal energy available for the IPS. Supply air temperatures or energy input may also be used to verify that the IPS materials were appropriately chosen for the thermal environment.

1.2 Bleed air systems

Effects of bleed air extraction on engine and aeroplane performance, if any, should be examined and included in the Aeroplane Flight Manual (AFM) performance data. The surface heat distribution analysis should be verified for varying flight conditions including climb, cruise, hold, and descent. Temperature measurements may be necessary to verify the thermal analysis. In accordance with provisions of CS 25.939(a), the maximum bleed air for ice protection should have no detrimental effect on engine operation throughout the engine's power range.

1.3 Pneumatic leading edge boots

Tests should demonstrate a rise and decrease in operating pressures, which results in the effective removal of ice. This pressure rise time, as well as the maximum operating pressure for each boot, should be evaluated throughout the altitude range defined in the relevant icing environment. The appropriate speed and temperature limitation (if any) on boot activation should be included in the AFM. Boot inflation should have no significant effect on aeroplane performance and handling qualities.

1.4 Fluid anti-icing/de-icing systems

Flight testing should include evaluation of fluid flow paths to confirm that adequate and uniform fluid distribution over the protected surfaces is achieved. A means of indicating fluid flow rates, fluid quantity remaining, etc., should be evaluated to determine that the indicators are plainly visible to the pilot and that the indications provided can be effectively read. The AFM should include information advising the flight crew how long it will take to deplete the amount of fluid remaining in the reservoir.

2. Dry air flight tests with predicted artificial ice shapes and roughness

The primary function of dry air flight tests with artificial ice shapes is to demonstrate the ability of the aeroplane to operate safely with an accumulation of critical ice shapes based on exposure to icing conditions. The specific flight tests used to evaluate aeroplane performance and handling qualities are addressed in AMC 25.21(g).

For failure conditions of the IPS that are not extremely improbable, validation testing may be required to demonstrate that the effect on safety of flight (as measured by degradation in flight characteristics) is commensurate with the failure probability. The applicant may use dry air flight tests with predicted critical failed IPS ice shapes, which may include asymmetric ice shapes, to demonstrate acceptable operational safety.

3. Icing flight tests

Flight tests in measured natural icing and tests performed with artificial icing tools, such as icing tankers, are normally used to demonstrate that the IPS performs during flight as predicted by analysis or other testing. Such tests are also used to confirm analysis used in developing the various components, such as ice detectors, and ice shapes. CS 25.1419 requires measured natural icing flight tests within the icing conditions of CS-25, Appendix C. The natural icing flight tests are accomplished to corroborate the general nature of the effects on aeroplane handling characteristics and performance determined with artificial ice shapes (see AMC 25.21g), as well as to qualitatively assess the analytically predicted location and general physical characteristics of the ice accretions. If necessary, there should be a means to record ice accumulations to allow the size, location, shape, extent and general nature of the ice to be approximated. Various means can be used to aid this, such as a rod or fence mounted on the aerofoil and black or brightly coloured paint on the aerofoil to increase the contrast between the ice accretion and the aerofoil and aid the determination of the ice shape size.

3.1 Instrumentation

The applicant should plan sufficient instrumentation to allow documentation of important aeroplane, system, and component parameters, as well as icing conditions encountered. The following parameters should be considered:

1. Altitude.

2. Airspeed.

3. Engine power level or speed.

4. Propeller speed and pitch, if applicable.

5. Temperatures that could be affected by ice protection equipment or ice accumulation or that are necessary for validation of analysis, such as the temperatures of Static air, Engine components, Electrical generation equipment, Surfaces, Structural components.

6. Liquid water content. This should be measured over the complete water drop size distribution.

7. Median volume drop diameter and drop diameter spectra. When measurement of the icing environment drop diameter is necessary, instrumentation used for measuring drop sizes should be appropriate for the icing environment considered.

3.2 Artificial icing

Flight testing in artificial icing environments, such as behind icing tankers, is one way to predict capabilities of individual elements of the ice protection equipment and to determine local ice shapes.

Since the ice plume has a limited cross-section, testing is usually limited to components, such as heated pitot tubes, antennas, air inlets including engine induction air inlets, empennage, aerofoil sections, and windshields. Calibration and verification of the icing cloud produced by the tanker should be accomplished as necessary for meeting test objectives.

Use of an icing tanker can provide high confidence in local icing effects. But obtaining small drop sizes may be difficult with some spray nozzles. As a result, these methods could produce larger ice build-ups and different ice shapes than those observed in natural Appendix C icing conditions.

Icing tanker techniques can be used in a manner similar to icing tunnel testing with respect to ice shape development. The plume may be of sufficient size that it could be applied to sections of the airframe to examine any potential hinge moment or C_{Lmax} (maximum lift coefficient) effects from ice accretions behind protected areas.

This method also has the advantage of being able to combine the effects of thermal systems (such as runback) with direct accretion to simulate resulting ice accumulations.

Atmospheric effects such as humidity and drop residence time (time required to bring the drop to static temperature) should be considered in this type of testing.

3.3 Appendix C natural icing flight testing

CS 25.1419(b) requires measured natural icing flight tests. Flight tests in measured natural icing conditions are intended to verify the ice protection analysis, to check for icing anomalies, and to demonstrate that the IPS and its components function as intended.

The aeroplane should be given sufficient exposure to icing conditions to allow extrapolation to the envelope critical conditions by analysis. Test data obtained during these exposures may be used to validate the analytical methods used and the results of any preceding artificial icing tests.

Flight testing in natural icing conditions should also be used to verify AFM procedures for activation of the IPS, including recognition and delay times associated with IPS activation. Such testing should verify the analytically predicted location and general physical characteristics of the ice accretions. Critical ice accumulations should be observed, where possible, and sufficient data taken to allow correlation with dry air testing. Remotely located cameras either on the test aeroplane or on a chase aeroplane have been used to document ice accumulations on areas that cannot be seen from the test aeroplane's flight deck or cabin.

For an aeroplane with a thermal de-icing system, the applicant should demonstrate the effectiveness of the de-icing operation either in artificial icing conditions or during a natural icing flight test certification program. The tests usually encompass measurements of the surface temperature time history. This time history includes the time at which the system is activated, the time at which the surface reaches an effective temperature, and the time at which the majority of ice is shed from the leading edge. Any residual or intercycle ice accretions should be documented. The data should be recorded in the flight test report.

For anti-icing/de-icing fluid systems, fluid flow paths should be determined when the fluid is mixed with impinging water during system operation.

4. Icing wind tunnel tests

Icing wind tunnels provide the ability to simulate natural icing conditions in a controlled environment. Scale models may be used with appropriate scaling corrections, if the scale testing on the component has been validated with full-scale testing or analysis. Hybrid models, with the full-scale leading edge extending beyond the impingement limits, may also be used. The applicant may use these models to estimate impingement limits, examine visual icing cues, and evaluate ice detection devices.

A variety of icing conditions can be simulated, depending on the icing wind tunnel.

Icing wind tunnels have been used to evaluate ice shapes on unprotected areas and on or aft of protected areas, such as inter-cycle, residual, and runback ice. They have also been used to evaluate performance of IPS, such as pneumatic and thermal systems.

For the evaluation of the performance of the IPS, a critical points analysis can be used to identify critical test conditions under which an IPS should be tested in an icing tunnel. In lieu of a critical points analysis the following conditions have been successfully used in the past to simulate the Appendix C conditions:

4.1 Continuous Maximum Condition

Atmospheric Temperature (°C)	Liquid Water Content (g/m^3)
0	0·8
–10	0·6
–20	0·3
–30	0·2

The test should be run until steady state conditions are reached. The steady state can be identified by the protected surfaces being completely free of ice or the total ice accretion being contained by repetitive shedding either naturally or enforced by cyclic operation of the IPS. If the steady state cannot be reached, the duration of the run should be limited to 45 minutes.

4.2 Intermittent Maximum Conditions

The encounters considered should include three clouds of 5 km horizontal extent with Intermittent Maximum concentrations as in the following table separated by spaces of clear air of 5 km.

Atmospheric Temperature (°C)	Liquid Water Content (g/m^3)
0	2·5
–10	2·2
–20	1·7
–30	1·0

For both the Continuous maximum and Intermittent Conditions, an MVD of 20 µm should be used.

5. Dry air wind tunnel tests

Dry air wind tunnel testing using scaled models and artificial ice shapes has been used to determine if ice protection on particular components (horizontal/vertical plane or wing sections) is required. The scaling, including the effect of the roughness of the ice, should be substantiated using methods found acceptable to the Agency.

(c) CS 25.1419(c) Caution information

CS 25.1419(c) requires that Caution information be provided to alert the flight crew when the IPS is not functioning normally. In this context, Caution information is considered to be a general term referring to an alert rather than referring specifically to a Caution level alert. Crew alerting should be provided for failure conditions of the IPS in accordance with CS 25.1309(c) and CS 25.1322. It should be assumed that icing conditions exist during the failure event. In accordance with CS 25.1419(c), the decision to provide an alert must not be based on the numerical probability of the failure event. However, the type of alert provided should be based on the failure effects and necessary crew action to be performed in response.

1) Sensor(s) used to identify a failure condition should be evaluated to ensure that they are properly located to obtain accurate data on the failure of the IPS.

2) The indication system should not be designed so that it could give the flight crew a false indication that the system is functioning normally because of a lack of an alert. The applicant should submit data to substantiate that this could not happen. For example, if a pneumatic de-icing system (boots) requires a specific minimum pressure and pressure rise rate to adequately shed ice, an alert should be provided if that minimum pressure and pressure rise rate are not attained. Without an alert, the flight crew may erroneously believe that the boots are operating normally when, in fact, they might not be inflating with sufficient pressure or with a sufficient inflation rate to adequately

shed ice. The applicant should also consider the need for an alert about ice forming in the pneumatic system that can result in low pneumatic boot pressures or an inadequate pressure rise rate.

(d) CS 25.1419(e) Ice Detection

1. Compliance with CS 25.1419(e)(1) and (e)(2).

These subparagraphs provide alternatives to CS 25.1419(e)(3) which specifies operation of the IPS based on icing conditions . These alternatives require either a primary ice detection system, or substantiated visual cues and an advisory ice detection system. CS 25.1419(e)(2) requires defined visual cues for recognition of the first sign of ice accretion on a specified surface combined with an advisory ice detection system that alerts the flight crew to activate the airframe ice protection system. The following conditions should be considered when determining compliance with CS 25.1419(e)(2):

- The advisory ice detection system annunciates when icing conditions exist or when the substantiated visual cues are present.
- The defined visual cues rely on the flight crew's observation of the first sign of ice accretion on the aeroplane and do not depend on the pilot determining the thickness of the accretion.
- The flight crew activates the ice protection system when they observe ice accretion or when the ice detector annunciates ice, whichever occurs first.

1.1 Ice detection system (IDS)

1.1.1 Primary Ice Detection System (PIDS)

A PIDS must either alert the flight crew to operate the IPS using AFM procedures or automatically activate the IPS before an unsafe accumulation of ice on the airframe, engine components, or engine air inlets occurs. The primary ice detection system must perform its intended function for the aeroplane configurations, phases of flight, and within the relevant icing environment.

1.1.2 Advisory Ice Detection System (AIDS)

The AIDS, in conjunction with visual cues, such as visible ice accretion on referenced or monitored surfaces, should advise the flight crew to initiate operation of the IPS using AFM procedures. An AIDS is not the prime means used to determine if the IPS should be activated. When there is an AIDS installed on an aeroplane, the flight crew has primary responsibility for determining when the IPS must be activated; an AIDS that would automatically activate the IPS(s) would not be accepted. Although the flight crew has primary responsibility for determining when the IPS must be activated, if the aeroplane is certificated in accordance with CS 25.1419(e)(2), the AIDS is required (i.e. not optional) and must perform its intended function for the aeroplane configurations, for its phases of flight, and within the relevant icing environment.

1.1.3 Performance and Installation of the ice detection system (IDS)

(i) An IDS should be capable of detecting the presence of icing conditions or actual ice accretion under all atmospheric conditions defined in the relevant icing environment.

It should be demonstrated that the presence of ice crystals mixed with supercooled liquid water does not lead to unacceptable supercooled liquid water ice detection performance degradation, when assessed at aircraft level.

For IDS capable of detecting the presence of ice on a monitored surface, the IDS should always detect when ice is present on the monitored surface whether or not icing conditions are within the relevant icing environment and the IDS should not indicate the presence of ice when no ice is present.

(ii) The applicant should accomplish a drop impingement analysis and/or tests to ensure that the ice detector(s) are properly located. The ice detector should be located on the airframe surface where the sensor is adequately exposed to the icing environment. The applicant should conduct flow field and boundary-layer analysis of candidate installation positions to ensure that the ice detector sensor is not shielded from impinging water drops. The IDS should be shown to operate in the range of conditions defined by the icing environment. Performance of the IDS is affected by the physical installation and can only be verified after installation. It should be shown by analysis and/or flight test that the location(s) of the detection systems sensor(s) is adequate to cover all aeroplane operational configurations, phases of flight, airspeeds, associated angles of attack and sideslip.

A combination of tests and analysis is required to demonstrate performance of the ice detector as installed on the aeroplane. This could include icing tunnel and icing tanker tests to evaluate ice detector performance. The applicant may use drop impingement analysis to determine that the ice detector functions properly over the drop range of the icing environment when validated through natural or artificial icing tests (e.g. tanker, icing tunnel). The applicant should demonstrate that the aeroplane can be safely operated with the ice accretions formed up to the time the ice protection system becomes effective, following activation by the ice detector. The detector and its installation should minimize nuisance warnings.

(iii) Evidences should be provided that the system is qualified under the appropriate standards, and in addition, it should be demonstrated that when installed on the aeroplane the IDS can detect under:

- Light icing conditions (minimum detectability),
- Heavy glaze ice conditions (warm runback), and
- Cold, high-LWC (Liquid Water Content) conditions (thermal load).

(iv) The maximum detection threshold should be established. The threshold level chosen to activate the ice detection and annunciation system should be guided by the assurance that:

- The aeroplane has adequate controllability and stall warning margins with the ice accretions that exist on the unprotected and protected surfaces prior to normal activation of the IPS(s);
- The amount of ice accreted can be safely eliminated by the IPS(s). It should be demonstrated that when the amount of ice that is accreted on the protected surfaces is shed, no unacceptable damages occur to the airframe or the engines;
- The system will not be overly sensitive, but sensitive enough to readily detect sudden exposure; and
- If the thickness of accreted ice is in excess of the maximum detection threshold on the monitored surface, the IDS should continue to indicate the presence of ice.

(v) If the IDS ice detection logic is inhibited during certain flight phases, handling qualities and performance should be demonstrated, assuming that the ice protection systems are inoperative and the aeroplane is operating in conditions conducive to icing.

(vi) If an accretion-based technology is used for ice detection, and if the IDS cannot detect ice in some condition where ice accretes on critical aircraft surfaces:

- For PIDS, the applicant should either show that the aeroplane can be operated safely with the ice accretions, or the IPS(s) should be forced to operate within the envelope of non-detection of the PIDS.

- For AIDS, if such icing conditions may go undetected by the flight crew (absence of visual cues for these conditions), then the IPS(s) should be forced manually to operate within the envelope of non-detection of the AIDS.

Alternatively, the installation of an icing conditions detector (i.e. one that detects both moisture and temperature), or additional substantiation with the resulting undetected ice accretions, may be required.

(vii) Preferably, the IDS should be turned on automatically at aeroplane power-up, and an alert should be provided if the IDS is turned off.

(viii) If the PIDS has automatic control of the IPS(s), it should be possible to de-select the automatic feature and to revert to an advisory system.

(ix) During the certification exercise, the proper operation of the IDS should be monitored especially by comparison with other icing signs (visual cues, ice accretion probe, etc.). Cloud conditions of the icing encounter should be measured and recorded. When multiple ice detectors are used in an IDS, signals from each ice detector should be recorded during icing tests to verify whether the ice detectors are fully redundant in the whole Appendix C and flight envelope or rather have their own detection threshold to cover the whole Appendix C and flight envelope.

1.1.4 Aeroplane Flight Manual (AFM)

AFM procedures have to be established to cover system malfunction and actions to be taken by the flight crew when alerted by the system. The AFM should at least address the following:

- Pre-flight check, if required, to verify the correct functioning of the IDS,
- Operational use of the IDS and limitations, and
- Appropriate flight crew procedure(s) in case of failure indication(s).

1.1.5 Ice detection system safety considerations

The applicant should accomplish a functional hazard assessment to determine the hazard level associated with failure of the ice detection system (refer to AMC 25.1309).

The probability of encountering the icing conditions defined in Appendix C to CS-25 should be considered to be 1.

The un-annunciated failure of a PIDS is assumed to be a catastrophic failure condition, unless characteristics of the aeroplane in icing conditions without activation of the aircraft IPS(s) are demonstrated to result in a less severe hazard category. When showing compliance to CS 25.1309 and when considering PIDS integrating multiple ice detectors, it should be assumed that the loss of one ice detector leads to the loss of the primary ice detection function, unless it is demonstrated during flight tests that all ice detectors have comparable ice detection performance. After the loss of one ice detector, the applicant may choose to revert to an advisory ice detection system; in this case the applicant should substantiate visual cues and AFM procedures in compliance with CS 25.1419(e)(2).

If visual cues are the primary means of ice detection, the pilots retain responsibility to monitor and detect ice accretions when an AIDS is installed. However, the natural tendency of flight crews to become accustomed to using the AIDS elevates the importance of the detector and increases the need to make flight crews aware of an AIDS failure. Therefore, an un-annunciated failure of the AIDS should be considered as at least a major failure condition unless substantiated as meriting a lower failure condition classification.

For the identification of conditions conducive to airframe icing in the frame of CS 25.1419(e)(3), the temperature cue used in combination with visible moisture has to be considered as a primary parameter, and the display of erroneous too high temperature to the flight crew, which potentially leads to non-activation of the IPS, should be considered as a catastrophic failure condition, unless substantiated as meriting a lower failure condition classification.

1.2 Visual cues

Visual cues can be either direct observation of ice accretions on the aeroplane's protected surfaces or observation of ice accretions on reference surfaces. The first indications of any of the following are examples of what could potentially be used as visual cues:

- Accretions forming on the windshield wiper posts (bolt or blade).
- Accretions forming on propeller spinner.
- Accretions forming on radome.
- Accretions on the protected surfaces.

If accretions on protected surfaces cannot be observed, a reference system would be necessary if compliance with CS 25.1419(e)(2) is sought. The applicant should consider providing a reference surface that can be periodically de-iced to allow the flight crew to determine if the airframe is continuing to accumulate ice.

Without a means to de-ice the reference surface, as long as ice is present on the reference surface: :

- The IPS should operate in presence of conditions conducive to icing (AFM procedure based on visible moisture and temperature); the IPS may be switched off after leaving conditions conducive to icing, even though ice may still be present on the reference surface; or
- The IPS should operate continuously , even if additional ice is not accumulating.

When ice accretion is no longer present on the reference surface, the next activation of the IPS can again be triggered by the presence of ice accreting on this reference surface.

As the freezing fraction drops below 1, although some reference surfaces may not build up ice, ice may begin to accumulate on protected surfaces of the aeroplane. The applicant should substantiate, for all the icing conditions defined in the relevant icing environment, that the reference surface accumulates ice at the same time as or prior to ice accumulating on the protected surfaces.

1.2.1 Field of view

Visual cues should be developed with the following considerations:

a. Visual cues should be within the flight crew's primary field of view, if possible. If cues are outside the primary field of view, they should be visible from the design eye point and easily incorporated into the flight crew's vision scan with a minimum of head movement while seated and performing their normal duties.

b. Visual cues should be visible during all modes of operation (day, night, and in cloud).

1.2.2 Verification

During the certification process, the applicant should verify the ability of the crew to observe the visual cues. Visibility of the visual cues should be evaluated from the most adverse flight crew seat locations in combination with the range of flight crew heights, within the approved range of eye reference point locations, if available. A visual cue is required for both the left and right seats. If a single visual cue is used, it should be visible from each seat. The adequacy of the visual cue should be evaluated in all expected flight conditions, and in particular the capability of detecting clear ice should be verified. The applicant may carry out night evaluations with artificial accretions to assess visibility in and out of cloud. Visual cues should be substantiated by tests and analysis, including tests in measured natural icing.

2. Compliance With CS 25.1419(e)(3)

This subparagraph of CS 25.1419 provides an alternative to the PIDS and visual cues plus the AIDS as defined in CS 25.1419(e)(1) and (e)(2). This alternative requires operation of the IPS when the aeroplane is in conditions conducive to airframe icing during all phases of flight.

2.1 Temperature cue.

The temperature cue used in combination with visible moisture should consider static temperature variations due to local pressure variations on the airframe. If the engine IPS and the airframe IPS are both activated based on visible moisture and temperature, a common conservative temperature for operation of both systems should be used. For example, if the engine IPS is activated at + 5 ºC static air temperature or less, the airframe IPS should be activated at the same temperature, even if it is substantiated that the airframe will not accrete ice above + 2 ºC static air temperature. This would ease the flight crew workload and increase the probability of procedural compliance.

2.2 Either total or static temperatures are acceptable as cues. If static is used, a display of static air temperature should be provided to allow the flight crew to easily determine when to activate the systems. As an alternative, a placard showing corrections for the available temperature, to the nearest degree Celsius, can be used, so the flight crew can determine the static air temperature in the region of interest (that is, around 0 ºC).

2.3 Aeroplane Flight Manual (AFM).

The Limitations section of the AFM should identify the specific static or total air temperature and visible moisture conditions that must be considered as conditions conducive to airframe icing and should specify that the IPS must be operated when these conditions are encountered.

(e) CS 25.1419(f)

This subparagraph of CS 25.1419 states that requirements of CS 25.1419(e)(1), CS 25.1419(e)(2) or CS 25.1419(e)(3) are applicable to all phases of flight unless it can be shown that the IPS need not be operated. To substantiate that the IPS need not be operated during certain phases of flight, the applicant should consider ice accretions that form during these phases, without the IPS operating, and establish that the aeroplane can safely operate in the relevant icing environment

(f) CS 25.1419(g)

This subparagraph of CS 25.1419 requires that after the initial activation of the IPS:

- The IPS must operate continuously, or
- The aeroplane must be equipped with a system that automatically cycles the IPS, or
- An ice detection system must be provided to alert the flight crew each time the IPS must be cycled.

Some examples of systems that automatically cycle the IPS are:

- A system that senses ice accretion on a detector and correlates it to ice accretion on a protected surface. This system then cycles the IPS at a predetermined rate.
- A system that uses a timer to cycle the IPS. The applicant should substantiate that the aeroplane can safely operate with the ice accretions that form between the time one de-icing cycle is completed and the time the next cycle is initiated. If more than one cycling time is

provided to the flight crew (for example choosing between a 1- or 3-minute intervals), it should be substantiated that the flight crew can determine which cycle time is appropriate.

- A system that directly senses the ice thickness on a protected surface and cycles the IPS.

A common attribute of the above systems is that the pilot is not required to manually cycle the IPS after initial activation.

Some types of ice detection systems that alert the flight crew each time the IPS must be cycled could operate in a manner similar to the automatic systems discussed above, except that the crew would need to manually cycle the system. Flight crew workload associated with such a system should be evaluated. Because of flight crew workload and human factors considerations, a timed system without an ice sensing capability should not be used to meet this requirement. The ice shedding effectiveness of the selected means for cycling the ice protection system should be evaluated during testing in natural icing conditions. All inter-cycle and runback ice should be considered when showing compliance with CS 25.21(g).

(g) CS 25.1419(h)

CS 25.1419(h) requires that AFM procedures for operation of the IPS, including activation and deactivation, must be established. Procedures for IPS deactivation must be consistent with the CS 25.1419(e) requirements for activation of the IPS. The exact timing of deactivation should consider the type of ice protection system (e.g., de-icing, anti-icing, or running wet) and all delays in deactivation necessary to ensure that residual ice is minimized. Pneumatic boots should be operated for three complete cycles following the absence of the cues used for activation. However, if the aeroplane's stall protection system reverts from an icing schedule to a non-icing schedule when the airframe IPS is deactivated, AFM procedures should state that the airframe IPS should not be deactivated until the flight crew are certain that the critical wing surfaces are free of ice.

Create a new AMC 25.1420 as follows:

AMC 25.1420

Supercooled large drop icing conditions

If certification for flight in icing conditions is sought, in addition to the requirements of CS 25.1419, the aeroplane must be capable of operating in accordance with subparagraphs (a)(1), (a)(2), or (a)(3) of CS 25.1420.

Besides being able to operate safely in Appendix C icing conditions, the aeroplane must also be able to safely operate in or exit the icing conditions defined by CS-25, Appendix O. The applicant, however, has several certification options available for Appendix O icing conditions. The aeroplane can be certified for:

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

In the context of this AMC:

- *'Relevant icing environment'* means the Appendix O or a portion of the Appendix O as applicable.

- *'All icing conditions'* means Appendix C and Appendix O icing environment.
- *'Simulated Icing Test'* means testing conducted in simulated icing conditions, such as in an icing tunnel or behind an icing tanker.
- *'Simulated Ice Shape'* means an ice shape fabricated from wood, epoxy, or other materials by any construction technique.

CS 25.1420 provides specific airframe requirements for certification for flight in the icing conditions defined in Appendix O. Additionally, for other parts of the aeroplane (i.e. engine, engine inlet, propeller, flight instrument external probes, windshield) there are more specific icing related CS-25 specifications and associated acceptable means of compliance.

Appendix O Spectra

Appendix O defines freezing drizzle and freezing rain environments by using four spectra of drop sizes with associated liquid water content (LWC) limits. An FAA detailed report on the development of Appendix O is available from the FAA William J. Hughes Technical Center (reference report DOT/FAA/AR-09/10, dated March 2009). Following are the four drop size spectra:

a) **Freezing drizzle environment with a median volume diameter (MVD) less than 40 microns (μm).** In addition to drizzle drops, which are defined as measuring 100 to 500 μm in diameter, this environment contains drops less than 100 μm, with a sufficient number of drops less than 40 μm so the MVD is less than 40 μm.

b) **Freezing drizzle environment with an MVD greater than 40 μm.** In addition to freezing drizzle drops, this environment contains smaller drops, with diameters less than 100 μm.

c) **Freezing rain environment with an MVD less than 40 μm.** In addition to freezing rain drops, which are defined as measuring more than 500 μm in diameter, this environment also contains smaller drops of less than 500 μm with a sufficient number of drops less than 40 μm so the MVD is less than 40 μm.

d) **Freezing rain environment with an MVD greater than 40 μm**. In addition to freezing rain drops, this environment also contains smaller drops of less than 100 μm.

Caution information:

CS 25.1420 describes requirements that are in addition to the requirements in CS 25.1419 for certain aeroplanes and does not contain a requirement complementary to CS 25.1419(c). Instead, it relies on compliance with CS 25.1309(c) to ensure that adequate warning is provided to the flight crew of unsafe system operating conditions. Warning information required by CS 25.1309(c), to alert the flight crew of unsafe system operating conditions, is applicable to design features installed to meet the additional requirements in CS 25.1420 and must be provided in accordance with CS 25.1322.

(a) CS 25.1420(a)(1) Detect Appendix O icing conditions and safely exit all icing conditions

When complying with CS 25.1420(a)(1), the applicant must provide a method for detecting that the aeroplane is operating in Appendix O icing conditions. Following detection, the aeroplane must be capable of operating safely while exiting all icing conditions until landing.

Substantiated methods of alerting flight crews when Appendix O icing conditions are encountered are required. It is acceptable to use an ice detection system that detects accretions behind the aeroplane's protected areas. Considerations in paragraph (b) below, related to CS 25.1420(a)(2) acceptable means of alerting flight crews when Appendix O icing conditions are encountered, are also relevant for this paragraph.

(b) CS 25.1420(a)(2) Operate safely throughout a portion of Appendix O icing conditions

If the applicant seeks certification for safe operation in portions of Appendix O icing conditions, such as freezing drizzle only, or during specific phases of flight, CS 25.1420(a)(2) applies. If this option is chosen, following detection of conditions that exceed the selected portion of Appendix O, the aeroplane must be capable of operating safely while exiting all icing conditions until landing.

Substantiated methods of alerting flight crews when those portions of Appendix O are exceeded are required.

Certification for flight in a portion of Appendix O icing conditions depends upon the applicant substantiating an acceptable way for the flight crew to distinguish the portion of Appendix O conditions for which the aeroplane is certified from the portion of Appendix O conditions for which the aeroplane is not approved. Certification for a portion of Appendix O allows latitude for certification with a range of techniques. Ice shapes will need to be developed to test for the portion of the envelope for which approval is sought, as well as for detecting and exiting icing conditions beyond the selected portion. The icing conditions the aeroplane may be certified to fly through may be defined in terms of any parameters that define Appendix O conditions and could include phase of flight limits, such as take-off or holding, in Appendix O or a portion of Appendix O. For example, an aeroplane may be certificated to take off in portions of Appendix O conditions, but not be certificated for holding in those same conditions. Substantiated means must be provided to inform flight crews when the selected icing conditions boundary is exceeded. The applicant must show compliance with CS 25.21(g) for exiting the restricted Appendix O icing conditions. Ice shapes to be tested are those representing the critical Appendix O icing conditions during recognition and subsequent exit from those icing conditions.

Ice shapes developed using the approved portion of the icing envelope should account for the range of drop distribution and water content and consider the proposed method for identifying icing conditions that must be exited. The definition of the certificated portion of Appendix O for a particular aeroplane should be based on measured characteristics of the selected icing environment and be consistent with methods used for developing Appendix O. Initial certification for flight in a portion of Appendix O conditions will likely include all of freezing drizzle or all of freezing rain. Such certification could be restricted to operation in Appendix O conditions by phase of flight.

Methods of defining the selected Appendix O icing conditions boundary should be considered early in the certification process, with concurrence from the Agency.

Determining whether the selected Appendix O icing conditions boundary has been exceeded can potentially be accomplished using:

- substantiated visual cues,
- an ice detection system, or
- an aerodynamic performance monitor.

The relevant AFM section(s) (possibly the limitation and the emergency procedure) should detail the method to warn the flight crew that the certified icing envelope has been exceeded.

1. Substantiated visual cues

Substantiated visual cues can range from direct observation of ice accretions aft of the aeroplane’s protected surfaces to observation of ice accretions on reference surfaces. Methods used to substantiate visual cues should be agreed upon with the Agency. Responding to a visual cue should not require the flight crew to judge the ice to be a specific thickness or size.

Examples of potential visual cues are accretions forming on the side windshields, the sides of nacelles, the propeller spinners aft of a reference point, the radomes aft of a reference point, and/or aft of protected surfaces.

Visual cues should be developed with the following considerations:

(i) Visual cues should be within the flight crew's primary field of view if possible. If outside the primary field of view, the visual cues should be visible from the design eye point and easily incorporated into the flight crew's visual scan with a minimum of head movement while seated and performing their normal duties.

(ii) Visual cues should be visible during all modes of operation (day, night) without use of a handheld flashlight.

During the certification process, the applicant should verify the ability of the crew to observe visual cues or reference surfaces. Visibility of the visual cues should be evaluated from the most adverse flight crew seat locations in combination with the range of flight crew heights, within the approved range of eye reference point locations, if available. A visual cue is required for both the left and right seats. If a single visual cue is used, it should be visible from each seat. Consideration should be given to the difficulty of observing clear ice. The adequacy of the detection method should be evaluated in all expected flight conditions. The applicant may carry out night evaluations with simulated ice shapes to assess visibility in and out of cloud.

Visual cues should be substantiated by tests and analysis, including tests in measured natural icing, or icing tanker tests, or potentially through icing wind tunnel tests. The applicant should consider the drop distributions of Appendix O when developing the visual cue, and the applicant should substantiate that these cues would be present in all the restricted Appendix O icing conditions. If a reference surface is used, the applicant should substantiate that it accumulates ice at the same time as or prior to ice accumulation on the critical surfaces.

AMC 25.21(g) should be reviewed for guidance on the time flight crews need to visually detect Appendix O icing conditions.

2. Ice detection systems

An ice detection system installed for compliance with CS 25.1420(a) is meant to determine when conditions have reached the boundary of the Appendix O icing conditions in which the aeroplane has been demonstrated to operate safely. The applicant should accomplish a drop impingement analysis and/or tests to ensure that the ice detector is properly located to function during the aeroplane operational conditions and in Appendix O icing conditions. The applicant may use analysis to determine that the ice detector is located properly for functioning throughout the drop range of Appendix O icing conditions when validated with methods described in document SAE ARP5903 “Drop Impingement and Ice Accretion Computer Codes”, dated October 2003. The applicant should ensure that the system minimizes nuisance warnings when operating in icing conditions.

The low probability of finding conditions conducive to Appendix O ice accumulation may make natural icing flight tests a difficult way to demonstrate that the system functions in conditions exceeding Appendix C. The applicant may use flight tests of the aeroplane under simulated icing conditions (icing tanker). The applicant may also use icing wind tunnel tests of a representative aerofoil section and an ice detector to demonstrate proper functioning of the system and to correlate signals provided by the detectors with the actual ice accretion on the surface.

3. Aerodynamic performance monitor (APM)

A crew alerting system using pressure probes and signal processors could be developed for quantifying pressure fluctuations in the flow field from contamination over the wing surface. This technology does exist, but full development is necessary before incorporating it into the crew alerting system.

(c) CS 25.1420(a)(3) Operate safely throughout all Appendix O icing conditions

CS 25.1420(a)(3) applies when the applicant seeks certification for all of the icing conditions described in Appendix O. An aeroplane certified to CS 25.1420(a)(3) must be capable of safely operating throughout the conditions described in Appendix O and does not need a means to distinguish Appendix O conditions from Appendix C conditions. The provisions in CS 25.1419 which require a method to detect icing conditions and activate the ice protection system are still applicable. If the aeroplane is certified for unrestricted flight in Appendix O conditions, the ice detection method must be substantiated to function throughout Appendix O. In effect, when CS 25.1420(a)(3) is chosen, the aeroplane is certificated for flight in icing without any specific aeroplane flight manual procedures or limitations to exit icing conditions.

If the AFM performance data reflects the most critical ice accretion (Appendix C and Appendix O) and no special normal or abnormal procedures are required in Appendix O conditions, then a means to indicate when the aeroplane has encountered Appendix O icing conditions is not required. However, a means to alert the flight crew that the airplane has encountered icing conditions is still required in accordance with CS 25.1419.

(d) CS 25.1420 (b)

1. Analysis

AMC 25.1419(a) applies and in addition, the following should be considered specifically for compliance with CS 25.1420(b):

1.1 Analysis of areas and components to be protected.

In assessing the areas and components to be protected, considerations should be given on the fact that areas that do not accrete ice in Appendix C conditions may accrete ice in the Appendix O conditions.

1.2 Failure analysis

Applying the system safety principles of CS 25.1309 is helpful in determining the need for system requirements to address potential hazards from an Appendix O icing environment. The following addresses application of the CS 25.1309 principles to Appendix O conditions and may be used for showing compliance with CS 25.1309.

1.2.1 Hazard classification

Assessing a hazard classification for compliance with CS 25.1309 is typically a process combining quantitative and qualitative factors based on the assessment of the failure conditions and the associated severity of the effects. If the design is new and novel and has little similarity to previous designs, a hazard classification based on past experience may not be appropriate. If the design is derivative in nature, the assessment can consider the icing event history of similarly designed aeroplanes and, if applicable, the icing event history of all conventional design aeroplanes. The applicant should consider specific effects of supercooled large drop icing when assessing similarity to previous designs.

1.2.2 Qualitative Analysis

The following qualitative analysis may be used to determine the hazard classification for an unannunciated encounter with Appendix O icing conditions. The analysis can be applied to aeroplanes shown to be similar to previous designs with respect to Appendix O icing effects, and to which the icing event history of all conventional design aeroplanes is applicable.

1.2.2.1 Assumptions

The aeroplane is certificated to either:

a. Detect Appendix O icing conditions and safely exit all icing conditions after detection of Appendix O icing conditions, or

b. Safely operate in a selected portion of Appendix O icing conditions and safely exit all icing conditions after detection of Appendix O icing conditions beyond those for which it is certificated.

The ‘unannunciated encounter with Appendix O’ refers to Appendix O icing conditions in which the aeroplane has not been shown to operate safely.

The airframe and propulsion ice protection systems have been activated prior to the unannunciated encounter.

1.2.2.2 Service history

The applicant may use service history, design, and installation appraisals to support hazard classifications for CS 25.1309. Service history may be appropriate to support a hazard classification if a new or derivative aeroplane has similar design features to a previously certificated aeroplane. Service history data are limited to the fleet of aeroplane type(s) owned by the applicant.

1.2.2.3 Historical perspective

While definitive statistics are not available, a historical perspective can provide some guidance. Many aeroplanes flying through icing have been exposed to supercooled large drop conditions without the pilot being aware of it. The interval of exposure to the supercooled large drop conditions may have varied from a brief amount of time (such as could occur during a vertical transition through a cloud) to a more sustained exposure (such as during a hold). Severity of the exposure conditions in terms of water content may have varied significantly. Therefore, the hazard from encountering supercooled large drop conditions may be highly variable and dependent on various factors.

1.2.2.4 Icing event history of conventionally designed aeroplanes certificated before the introduction of CS 25.1420

Given the volume of aeroplane operations and the number of reported incidents that did not result in a catastrophe, a factor of around 1 in 100 is a reasonable assumption of probability for a catastrophic event if an aeroplane encounters Appendix O conditions in which it has not been shown capable of safely operating. An applicant may assume that the hazard classification for an unannunciated encounter with Appendix O conditions while the ice protection system is activated is Hazardous in accordance with AMC 25.1309, provided that the following are true:

- The aeroplane is similar to previous designs with respect to Appendix O icing effects, and
- The applicant can show that the icing event history of all conventionally designed aeroplanes is relevant to the aeroplane being considered for certification.

1.2.2.5 Hazard assessment

If an aeroplane is not similar to a previous design, an assessment of the hazard classification may require more analysis or testing. One method of hazard assessment would be to consider effects of ice accumulations similar to those expected for aeroplanes being certified under CS 25.1420. Such ice shapes may be defined from a combination of analysis and icing tanker or icing wind tunnel testing. Aerodynamic effects of such shapes could be evaluated with wind tunnel testing or, potentially, computational fluid dynamics. Hazard classification typically takes place early in a certification program. Therefore, a conservative assessment may be required until sufficient supporting data is available to reduce the hazard classification.

1.2.3 Probability of encountering Appendix O icing conditions

Appendix C was designed to include 99 percent of icing conditions. Therefore, the probability of encountering icing outside of Appendix C drop conditions is on the order of 10^{-2}. The applicant may assume that the average probability for encountering Appendix O icing conditions is 1×10^{-2} per flight hour. This probability should not be reduced based on phase of flight.

1.2.4 Numerical safety analysis.

For the purposes of a numerical safety analysis, the applicant may combine the probability of equipment failure with the probability, defined above, of encountering Appendix O icing conditions. If the applicant can support a hazard level of 'Hazardous' using the above probability (10^{-2}) of encountering the specified supercooled large drop conditions, the probability of an unannunciated failure of the equipment that alerts the flight crew to exit icing conditions should be less than 1×10^{-5}.

1.2.5 Assessment of visual cues.

Typical system safety analysis do not address the probability of crew actions, such as observing a visual cue before performing a specified action. As advised in AMC 25.1309, quantitative assessments of crew errors are not considered feasible. When visual cues are to be the method for detecting Appendix O conditions and determining when to exit them, the applicant should assess the appropriateness and reasonableness of the specific cues. Reasonable tasks are those for which the applicant can take full credit because the tasks can realistically be anticipated to be performed correctly when required. The applicant should assess the task of visually detecting Appendix O conditions to determine if it could be performed when required. The workload for visually detecting icing conditions should be considered in combination with the operational workload during applicable phases of flight. The applicant may assume that the flight crew is already aware that the aeroplane has encountered icing. The assessment of whether the task is appropriate and reasonable is limited to assessing the task of identifying Appendix O accumulations that require exiting from the icing conditions.

1.3 Similarity

On derivative or new aeroplane designs, the applicant may use similarity to previous type designs which have proven safe operation in SLD icing conditions, meanwhile the effects of differences will be substantiated. Natural ice flight testing may not be necessary for a design shown to be similar. At a minimum, the following differences should be addressed:

- Aerofoil size, shape, and angle of attack.
- Ice Protection System (IPS) design.
- Flight phases, operating altitude and airspeed.
- Centre of gravity.
- Flight control system.
- Engine and propeller operation.

The guidance provided in AMC 25.1419(a)(8) applies.

The applicant must possess all the data required to substantiate compliance with applicable specifications, including data from past certifications upon which the similarity analysis is based.

2. Tests

CS 25.1420 requires two or more means of compliance for approval of flight in icing. It is common to use a combination of methods in order to adequately represent the conditions and determine resulting degradation effects with sufficient confidence to show compliance.

Some of the guidance contained in paragraph (b) of AMC 25.1419 may be relevant to this paragraph. In addition, with respect to natural icing flight testing in the Appendix O icing environment, CS 25.1420 does not specifically require measured natural icing flight tests. However, flight testing in measured natural Appendix O icing conditions may be necessary to:

(i) verify the general physical characteristics and location of the simulated ice shapes used for dry air testing, and in particular, their effects on aeroplane handling characteristics.

(ii) determine if ice accretes on areas where ice accretion was not predicted.

(iii) verify adequate performance of ice detectors or visual cues.

(iv) conduct performance and handling quality tests as outlined in AMC 25.21(g).

(v) evaluate effects of ice accretion not normally evaluated with simulated ice shapes (on propeller, antennas, spinners, etc.) and evaluate operation of each critical aeroplane system or component after exposure to Appendix O icing conditions.

Flight testing in natural Appendix O conditions would unlikely be necessary unless the aeroplane will be certified for continued operation within a portion or all of appendix O conditions. For aeroplanes to be certified to a portion or all of Appendix O, where natural Appendix O icing conditions flight testing is performed, measurement and recording of drop diameter spectra should be accomplished.

Flight testing in natural Appendix O icing conditions should be accomplished for aeroplane derivatives whose ancestor aeroplanes have a service record that includes a pattern of accidents or incidents due to in flight encounters with Appendix O conditions.

(e) CS 25.1420(c)

CS 25.1420(c) requires that aeroplanes certified in accordance with subparagraph CS 25.1420(a)(2) or (a)(3) comply with the requirements of CS 25.1419 (e), (f), (g), and (h) for the icing conditions defined in Appendix O in which the aeroplane is certified to operate.

Paragraphs (d), (e), (f), and (g) of AMC 25.1419 apply.

AMC – SUBPART J

Replace the existing AMC 25J1093(b) by the following:

AMC 25J1093(b)

Essential APU air intake system de-icing and anti-icing provisions

1. General

In establishing compliance with the requirements of CS 25J1093(b), reference should be made to AMC 25.1093(b). All the reference made to “engine” may be transposed to “essential APU”. Engine test (especially CS-E 780) may refer to essential APU icing test done for the APU certification, if any.

When the air intake is assessed separately, it should be shown that the effects of air intake icing would not invalidate the icing tests of CS-APU. Factors to be considered in such evaluation are:

a. Distortion of the airflow and partial blockage of the air intake.

b. The shedding into the APU of air intake ice of a size greater than the APU has been shown to ingest.

c. The icing of any APU sensing devices, other subsidiary air intakes or equipment contained within the air intake.

d. The time required to bring the protective system into full operation

2. Operating limitations

The conditions defined in CS 25J1093(b)(2), in terms of time and temperature, should be considered as limitations necessary for the safe operation in freezing fog, and made available to the crew in the Aeroplane Flight Manual (refer to CS 25.1581).

Nevertheless, the applicant may use an analysis to substantiate safe operation of the APU at temperatures below the demonstrated minimum temperature. No limitation would then be required in the Aeroplane Flight Manual.

Any additional substantiation provided by the applicant to demonstrate the capability of an extended exposure beyond the conditions defined in CS 25J1093(b)(2), based on further testing and/or analysis, will be considered by the Agency.