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 icing conditions. 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. AMC 25.1420(f) provides guidance for comparative analysis as an acceptable means of compliance to meet these requirements.

1.5 Section 6 provides an acceptable flight test programme where flight testing is selected by the applicant and agreed by the 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. Part-CAT[1], CAT.OP.MPA.250) 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 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.

4.1.7 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.

4.1.8 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 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 analyses 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 may be accomplished through 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. For the Appendix O icing conditions, the applicant may use a comparative analysis. AMC 25.1420(f) provides guidance for comparative analysis.

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 $1 \times 10_{-2}$ 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 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 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 automatic flight control systems operation. 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. Information to be provided in the AFM may be based on the information provided in the reference fleet AFM(s), or other operating manual(s) furnished by the TC holder, when comparative analysis is used as the means of compliance.

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 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.