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 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.
Comparative analysis for showing compliance in SLD icing conditions	An analysis which substantiates that a new or derivative aeroplane model has at least the same level of safety in all supercooled liquid water icing conditions that a reference fleet has achieved. Guidance is provided in AMC 25.1420(f). The use of a comparative analysis is only an option for showing compliance with CS-25 specifications relative to Appendix O icing conditions; it is not an option for showing compliance with CS-25 specifications relative to Appendix C icing conditions.

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 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 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 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 volumetric 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 an ancestor aeroplane that includes the effect of the ice accretions as defined in Part II of Appendix C and Appendix O to CS-25. 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.

5.7 Comparative Analysis.

For showing compliance with the CS-25 certification specifications relative to SLD icing conditions represented by Appendix O, the applicant may use a comparative analysis. AMC 25.1420 (f) provides guidance for comparative analysis.

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 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.

6.1.4 This test programme is based on the assumption that the applicant will choose to use the holding 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 of 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) activation point is set as a function of the high lift configuration and/or the 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 V1 due to take-off in icing conditions may be determined by a suitable analysis.

6.4 Take-off Path (CS 25.111). If VSR 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 VSR 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 VREF.

d. Stabilise at the specified speed and conduct 2 climbs or drag polar checks as agreed with the 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 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 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_2 MIN, 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 CS 25.143(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).

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 CS 25.143(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 more than 1.23 V_{SR}, or

— Trim speed V_{FE}, target speed not less 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 more than 1.23 V_{SR}, or

— Trim speed V_{FE}, target speed not less 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.

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 1.3V_{SR1} with Idle power or thrust; or,

— Speed V_{REF} 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}.