U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: PERFORMANCE AND HANDLING CHARACTERISTICS IN THE ICING CONDITIONS SPECIFIED IN PART 25, APPENDIX C

Date: 9/10/07
Initiated By: ANM-110

AC No: 25-25

1. WHAT IS THE PURPOSE OF THIS AC? This advisory circular (AC) describes an acceptable means for showing compliance with the airplane certification requirements related to performance and handling characteristics of transport category airplanes for flight in the icing conditions defined in appendix C of Title 14, Code of Federal Regulations (14 CFR) part 25. Part 25 contains the airworthiness standards applicable to transport category airplanes. The means of compliance described in this document provide guidance to find compliance relative to airplane performance and handling characteristics in appendix C icing conditions.

2. WHO DOES THIS AC APPLY TO?

a. The guidance provided in this document is directed at airplane manufacturers, modifiers, foreign regulatory authorities, and Federal Aviation Administration (FAA) transport airplane type certification engineers, flight test pilots, and their designees.

b. This material is neither mandatory nor regulatory in nature and does not constitute a regulation. It describes acceptable means, but not the only means, for demonstrating compliance with the applicable regulations. The FAA will consider other methods of demonstrating compliance that an applicant may elect to present. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. On the other hand, if we become aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation or design changes as a basis for finding compliance.

c. This material does not change, create any additional, authorize changes in, or permit deviations from, regulatory requirements.

/s/ Ali Bahrami
Ali Bahrami
Manager, Transport Airplane Directorate
Aircraft Certification Service

CONTENTS

APPENDIX 1 AIRFRAME ICE ACCRETIONS

APPENDIX 2 SIMULATED ICE ACCRETIONS

APPENDIX 3 DESIGN FEATURES

APPENDIX 4 RELATED REGULATIONS AND ADVISORY CIRCULARS

APPENDIX 5 ACRONYMS

TABLES

1. REQUIREMENTS AND GUIDANCE.

a. General.

(1) For an airplane to be certified for flight in icing conditions, § 25.21(g)(1) requires the airplane to meet certain performance and handling qualities requirements of part 25 subpart B while operating in the atmospheric icing environment defined in appendix C to part 25. Appendix 1 of this AC provides detailed guidance for determining ice accretions that can be used for showing compliance.

(2) Certification experience has shown that it is usually unnecessary to consider ice accumulation on the propeller, induction system, or engine components of an inoperative engine when demonstrating airplane handling qualities. Similarly, the mass of any accreted ice need not normally be considered.

(3) The requirements and guidance for flight in icing conditions also applies to the operation of the airplane after leaving icing conditions until it is determined that no ice accretions remain on the airplane's critical surfaces.

(4) Ice-contaminated tailplane stall (ICTS) refers to a phenomenon that has been identified as a causal factor in several airplane incidents and accidents. It results from airflow separation on the lower surface of the tailplane due to the presence of ice. This 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 airplane configuration (for example, extending flaps, which increases the downwash angle at the tail or the pitch trim required) or flight conditions (for example, a high approach speed, gusts, or maneuvering). An ICTS is characterized by a reduction or loss of pitch control or pitch stability while in, or after recently leaving, icing conditions. A flight test procedure for determining susceptibility to ICTS is presented in paragraph 3i(4), Low g Maneuvers and Sideslips, of this AC.

(a) For airplanes 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 that is beyond the capability of the flightcrew to overcome. On some airplanes, ICTS has been caused by a lateral flow component coming off the vertical stabilizer, as may occur in sideslip conditions or due to a gust with a lateral component.

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

b. Proof of Compliance, § 25.21(g).

(1) Demonstration of compliance with certification requirements for flight in icing conditions may be accomplished by any of the means discussed in paragraph 2a, Acceptable Means of Compliance – General, of this AC.

(2) Certification experience has shown that for airplanes of conventional design, it is not usually necessary to perform additional detailed substantiation of compliance with the requirements of the following sections of part 25 for flight in icing conditions:

§ 25.23	Load distribution limits
§ 25.25	Weight limits
§ 25.27	Center of gravity limits
§ 25.29	Empty weight and corresponding center 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
§ 25.255	Out-of-trim characteristics

(3) If different stall warning system or stall identification system activation settings are used for flight in icing conditions (for example, if the stall warning or stall identification system activation settings are changed when the ice protection system is activated), it is acceptable to return to the non-icing settings when the critical wing surfaces are free of ice accretions. The applicant should validate that the means used to determine when the critical wing surfaces are free of ice accretions is reliable under all expected operating conditions.

c. Propeller Speed and Pitch Limits, § 25.33. Certification experience in meeting § 25.33 has shown that it may be necessary to impose additional propeller speed limits for operations in icing conditions.

d. Performance – General, § 25.101.

(1) This regulation states that the propulsive power or thrust available for each flight condition must be appropriate to the airplane operating limitations and normal procedures for flight in icing conditions.

(2) In general, it is acceptable to determine the propulsive power or thrust available by suitable analysis, substantiated when required by appropriate flight tests (for example, when determining the power or thrust available for showing compliance with § 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.

(3) 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 the engine induction system and other engine components, and the 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 provided in the Airplane Flight Manual (AFM) for flight in icing conditions.

(4) 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 conservative analysis or by flight test. Certification experience has also shown that runback ice may be critical for propellers. Therefore, runback ice on the propeller should be addressed, which may call for airplane performance checks in natural icing conditions or the use of an assumed (conservative) loss in propeller efficiency.

(5) Apart from the use of appropriate speed adjustments to account for operation in icing conditions, any changes in the procedures established for takeoff or go-around should be agreed to by the responsible aircraft certification office (ACO).

e. Stall Speed, § 25.103. Certification experience in meeting this requirement has shown that for airplanes of conventional design it is not necessary to separately determine the effects of Mach number on stall speeds for the airplane with ice accretions.

f. Failure Conditions, § 25.1309.

(1) The failure modes of the ice protection system and the resulting effects on airplane handling and performance should be analyzed in accordance with § 25.1309. In determining the probability of a failure condition, it should be assumed that the probability of entering icing conditions is considered to be one. The ice accretion to use for failures of the ice protection system is defined in appendix 1, paragraph 3 of this AC.

> **NOTE:** This guidance is not intended to apply to failures of other systems (or the engines) that may indirectly affect airplane handling and performance in icing conditions due to any effects of those failures on an otherwise normally functioning ice protection system. In this case, the ice protection system itself is considered to be operating normally, although performance of its anti-ice or deice function may be degraded.

(2) For probable failure conditions that are:

(a) not annunciated to the flightcrew, or

(b) annunciated to the flightcrew but the associated procedure does not require exiting the icing conditions, the guidance in this AC for a normal (that is, non-failure) condition is applicable with the failure ice accretion.

(3) For probable failure conditions that are annunciated to the flightcrew, and the associated operating procedure requires the airplane to leave the icing conditions as soon as practicable, it should be shown that the airplane'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 § 25.1309. The operating procedures and related speeds may restrict the airplane's operating envelope, but the size of the restricted envelope should be consistent with the safety analysis.

(4) For failure conditions that are improbable but not extremely improbable, the analysis and substantiation of continued safe flight and landing required by § 25.1309 should take into consideration whether the failure is annunciated, and what associated operating procedures and speeds would be used following the failure condition.

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

(1) The ice protection systems may not adequately perform their anti-ice or deice functions at some engine power or thrust settings. This may result in establishing a minimum useable power or thrust setting for operation in icing conditions, which can affect descent or

approach capabilities. The effect of power or thrust setting should also be considered in determining the applicable ice accretions. For example, at low engine power or thrust, a thermal bleed air system may not be able to evaporate the liquid water completely after melting the ice, resulting in the potential for runback ice.

(2) Ice blockage of control surface gaps, or freezing of seals causing increased control forces, control restrictions, or blockage.

(3) Ice blockage of unprotected inlets and vents that may affect the propulsive thrust available, aerodynamic drag, powerplant control and cooling, or flight controls.

(4) Airspeed, altitude, or angle of attack sensing errors due to ice accretion forward of the sensors (for example, radome ice). Dynamic pressure operated control feel systems using separate sensors may also be affected.

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

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

(7) Flight guidance and automatic flight control systems operation. See AC 25.1329-1B, Approval of Flight Guidance Systems, for guidance on compliance with § 25.1329 for flight in icing conditions, including stall and maneuverability evaluations with the airplane under flight guidance system control.

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

h. Airplane Flight Manual, § 25.1581 through § 25.1587.

(1) Section 25.1581 states that an Airplane Flight Manual (AFM) must be furnished with each airplane and must contain information that is necessary for safe operation because of design, operating, or handling characteristics.

(2) To comply with this requirement, the AFM Limitations section should include the following:

(a) The limitations required to ensure safe operation in icing conditions.

(b) Performance limitations should be presented for flight in icing that reflect any effects on lift, drag, thrust, and operating speeds related to operating in icing conditions. These limitations may be presented in the AFM performance section and included as limitations by specific reference in the AFM Limitations section.

(c) Any airspeed limitations associated with flight in icing conditions should be presented, such as the minimum airspeed for each normal airplane configuration in icing conditions.

(d) The AFM Limitations section should include, as applicable, a statement similar to the following:

> In icing conditions, the airplane 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.

(e) For turbojet airplanes without leading edge high-lift devices, unless the applicant shows that the airplane retains sufficient stall and stall warning margins during takeoff with residual ice contamination, or that such contamination would be otherwise detected and removed before takeoff, the AFM Limitations section should contain statements similar to the following:

> Takeoff may not be initiated unless the flightcrew verifies that a visual and tactile (hands on surface) check of the wing upper surfaces and leading edges have been accomplished, and the wing is free of frost, ice, or snow in conditions conducive to ice/frost/snow formation. Conditions conducive to ice/frost/snow formation exist whenever the outside air temperature is below 6 degrees C (42 degrees F) <u>and</u> either:
> (1) visible moisture is present in the air or on the wing,
> (2) the difference between the dew point temperature and the outside air temperature is less than 3 degrees C (5 degrees F), or
> (3) standing water, slush, ice, or snow is present on taxiways or runways.

<u>1</u> Residual ice contamination is contamination that is difficult to detect through visual observation alone. If deicing is performed before takeoff, residual ice contamination is the contamination that may remain after deicing or the contamination that may form after deicing. For test or analysis purposes, sandpaper ice can be used to evaluate the effects of residual ice on stall and stall warning speed margins.

<u>2</u> Stall and stall warning speed margins are considered adequate if the stall speed does not increase by more than 3 knots calibrated airspeed (CAS) or 3 percent of V_{SR} and compliance with § 25.207(e) and (f) can be shown with residual ice contamination on the wing leading edge and upper surface. Potential means for increasing stall and stall warning speed margins, if necessary, include reducing the peak angle of attack reached during the takeoff by using increased rotation and V_2 takeoff speeds, reducing the takeoff rotation pitch rate, or reducing the target pitch attitude.

<u>3</u> An acceptable means for showing, without a visual and tactile check, that residual ice contamination could be detected and removed would be an airplane operated in

accordance with § 121.629(c) and that has a wing ice protection system or primary wing ice detection system that can be used while the airplane is on the ground. In this case, the AFM Limitations section should include a statement similar to the following:

> The wing ice protection system or ice detection system [whichever is applicable] must be operating until immediately before starting the takeoff roll whenever conditions conducive to ice/frost/snow formation exist.

(3) To comply with § 25.1583, the AFM Operating Procedures should include the following:

(a) The flight in icing conditions operating procedures should include normal operation of the ice protection system and operation of the airplane following ice protection system failures. Any changes in procedures for other airplane system failures that affect the capability of the airplane to operate in icing conditions should be included.

(b) The normal operating procedures should reflect the procedures used to certify the airplane for flight in icing conditions. This includes configurations, speeds, ice protection system operation, and powerplant and systems operation for takeoff, climb, cruise, descent, holding, go-around, and landing.

(c) For turbojet airplanes without leading edge high-lift devices, unless the applicant shows that the airplane retains sufficient stall and stall warning margins during takeoff with residual ice contamination, the AFM normal operating procedures section should contain a statement similar to the following along with the procedures to be followed to ensure that such contamination is detected and removed prior to takeoff:

> 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 takeoff.

(d) Non-normal operating procedures should include the procedures to be followed in the event of annunciated ice protection system failures and suspected unannunciated failures. If flight in icing conditions results in any changes to other non-normal procedures contained in the AFM, these changes should also be included.

(4) Performance Information, § 25.1587: Performance information, derived in accordance with subpart B of part 25, should be provided in the AFM for all relevant phases of flight.

2. ACCEPTABLE MEANS OF COMPLIANCE – GENERAL.

a. General.

(1) This section describes acceptable methods and procedures that an applicant may use to show that an airplane meets the performance and handling requirements of subpart B in the atmospheric conditions of appendix C to part 25.

(2) Compliance with § 25.21(g)(1) should be shown by one or more of the methods listed in this section as agreed to by the responsible aircraft certification office (ACO).

(3) The compliance process should address all phases of flight, including takeoff, climb, cruise, holding, descent, landing, and go-around, as appropriate to the airplane type, considering its typical operating regime.

(4) The design features described in appendix 3 of this AC should be considered when determining the extent of the substantiation program.

(5) Appropriate means for showing compliance include the items listed in Table 1. These compliance means are explained in more detail in the following sections of this AC.

TABLE 1

Means for Showing Compliance

ITEM	DESCRIPTION
Flight Testing	Flight testing in dry air using simulated ice accretions or with ice accretions created in natural icing conditions.
Wind Tunnel Testing and Analysis	An analysis of results from wind tunnel tests with simulated or actual ice accretions.
Engineering Simulator Testing and Analysis	An analysis of results from engineering simulator tests.
Engineering Analysis	An analysis that may include the results from executing an icing computer code found acceptable by the responsible ACO.
Ancestor Airplane Analysis	An analysis of results from a closely related ancestor airplane (that is, from an airplane model from which this airplane model is a derivative).

(6) Various factors that affect ice accretion on the airframe are discussed in appendix 1 of this AC.

(7) An acceptable methodology for developing simulated ice accretions is given in appendix 2 of this AC.

b. Flight Testing.

(1) General. Section 21.35 requires applicants to perform all flight tests that the Administrator finds necessary to show compliance with the applicable requirements of part 25.

(a) The extent of the flight test program should consider the results of certification flight tests conducted with the non-contaminated airplane and the design features of the airplane as discussed in appendix 3 of this AC.

(b) It is not necessary to repeat, on the airplane with ice accretions, the extensive performance and handling characteristics test program that is conducted with the non-contaminated airplane. A suitable program sufficient to demonstrate compliance with the requirements can be established from experience with airplanes of similar size, and from review of design features of the ice protection system, control system, wing, horizontal, and vertical stabilizer, and the performance and handling characteristics of the non-contaminated airplane. In particular, it is not necessary to investigate all weight and center-of-gravity combinations when results from the non-contaminated airplane clearly indicate the most critical combination to be tested. It is not necessary to investigate the flight characteristics of the airplane with ice accretions at high altitude (that is, above the highest altitude for the atmospheric icing envelope specified in appendix C to part 25). An example of an acceptable flight test program is provided in paragraph 3, Acceptable Means of Compliance—Flight Test Program, of this AC.

(c) Certification experience has shown that flight tests are usually necessary to evaluate the consequences of ice protection system failures on handling characteristics and performance, and to demonstrate that the airplane is capable of continued safe flight and landing.

(2) <u>Flight Testing Using Approved Simulated Ice Accretions.</u>

(a) The performance and handling tests may be based on flight testing in dry air using simulated ice accretions that have been agreed to by the responsible ACO.

(b) Additional limited flight tests should be conducted in natural icing conditions, as discussed in paragraph 2b(3)(b), below.

(3) <u>Flight Testing In Natural Icing Conditions.</u>

(a) If flight testing with ice accretions obtained in natural atmospheric icing conditions is used as the primary means of showing compliance, all relevant meteorological conditions (including liquid water content (LWC) and median volumetric diameter (MVD)) should be measured and recorded. The tests should ensure good coverage of appendix C to part 25 conditions and, in particular, the critical conditions for the airplane. The conditions for accreting ice (including the icing atmosphere, airplane configuration, speed, and duration of exposure) should be agreed to by the responsible ACO.

(b) If flight testing with simulated ice accretions is used as the primary means of showing compliance, additional limited flight tests should be conducted with ice accretions obtained in natural icing conditions. The objective of these tests is to corroborate the simulated ice accretions, and the handling characteristics and performance results obtained in flight testing with the simulated ice accretions. It is not necessary to measure the atmospheric meteorological characteristics (that is, LWC and MVD) of these flight test icing conditions. For derivative airplanes with similar aerodynamic characteristics and ice protection systems to the ancestor airplane, it may not be necessary to carry out additional flight tests in natural icing conditions if such tests have been already performed with the ancestor airplane.

c. Wind Tunnel Testing and Analysis. Analysis of the results of dry air wind tunnel testing of models with the simulated ice accretions defined in part 25, appendix C, part II - Airframe ice accretions for showing compliance with subpart B, may be used to help substantiate acceptable performance and handling characteristics.

d. Engineering Simulator Testing and Analysis. The results of an engineering simulator analysis of an airplane that includes the effects of the ice accretions defined in part 25, appendix C, part II may be used to help substantiate acceptable 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, or engineering judgment.

e. Engineering Analysis. An engineering analysis that includes the effects of the ice accretions defined in part 25, appendix C, part II may be used to help substantiate acceptable performance and handling characteristics. The effects of the ice accretions 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, or engineering judgment.

f. Ancestor Airplane Analysis.

(1) An ancestor airplane analysis that includes the effect of the ice accretions as defined in part 25, appendix C, part II may be used to help substantiate acceptable performance and handling characteristics. This analysis should consider the similarity of the airplane configuration, operating envelope, performance and handling characteristics, and ice protection system of the ancestor airplane.

(2) The analysis may include flight test data, dry air wind tunnel test data, icing tunnel test data, engineering simulator analysis, service history, or engineering judgment.

3. ACCEPTABLE MEANS OF COMPLIANCE – FLIGHT TEST PROGRAM.

a. General.

(1) This section provides guidance for developing an acceptable flight test program if flight testing is selected by the applicant and agreed to by the responsible ACO as being the primary means for showing compliance with the airplane performance and handling qualities requirements for flight in icing conditions.

(2) Section 25.21(a)(1) states that compliance with each requirement of subpart B must be shown by tests upon an airplane of the type for which certification is requested, or by calculations based on, and equal in accuracy to, the results of testing. In accordance with § 25.21(a)(1), compliance must be shown with at least the same degree of confidence that testing would provide.

(3) This test program 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 accordance with part II(a) of appendix C to part 25, however, 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. 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.

(4) Unless otherwise specified, the speeds (for example, V_{SR}, V_{REF}, V_2, etc.) referenced in the flight tests described below refer to the speeds used with the appropriate ice accretion on the airplane.

b. Stall Speed, § 25.103.

(1) The stall speed for intermediate high lift configurations (for example, for takeoff configurations) can normally be obtained by interpolation. However, if a stall identification system (for example, a stick pusher) firing point is set as a function of the high lift configuration or the firing point is reset for icing conditions, or if significant configuration changes occur with extension of trailing edge flaps (such as extension of wing leading edge high lift devices), additional tests may be necessary.

(2) Acceptable Test Program. The following represents an example of an acceptable test program subject to the provisions outlined above:

(a) Forward center-of-gravity position appropriate to the airplane configuration.

(b) The stall test altitude used in non-icing tests.

(c) Trim at an initial speed of 1.13 to 1.30 V_{SR}. Decrease speed at a rate not to exceed 1 knot per second until an acceptable stall identification is obtained.

1 High lift devices retracted configuration, final takeoff ice.

2 High lift devices retracted configuration, en route ice.

3 Holding configuration, holding ice.

4 Lowest lift takeoff configuration, holding ice.

5 Highest lift takeoff configuration, takeoff ice.

6 Highest lift landing configuration, holding ice.

c. Accelerate–Stop Distance, § 25.109. To comply with this requirement, the effect of any increase in V_1 due to takeoff in icing conditions may be determined by a suitable analysis.

d. Takeoff Path, § 25.111. In accordance with § 25.105(a), if V_{SR} in the configuration defined by § 25.121(b) with the takeoff ice accretion defined in appendix C exceeds V_{SR} for the same configuration without ice accretions by more than the greater of 3 knots or 3 percent, takeoff evaluations should be conducted to substantiate the speed schedule and distances for takeoff in icing conditions. The effect of the takeoff speed increase, thrust loss, and drag increase on the takeoff path may be determined by a suitable analysis.

e. Landing Climb: All–Engines–Operating, § 25.119. The following represents an example of an acceptable test program to show compliance with § 25.119.

(1) Holding ice.

(2) Forward center-of-gravity position appropriate to the airplane configuration.

(3) Highest lift landing configuration, landing climb speed no greater than V_{REF}.

(4) Stabilize at the specified speed and conduct 2 climbs or drag polar checks as agreed to by the responsible ACO.

f. Climb: One-Engine-Inoperative, § 25.121. The following represents an example of an acceptable test program to show compliance with § 25.121.

(1) Forward center-of-gravity position appropriate to the configuration.

(2) Stabilize at the specified speed with one engine inoperative (or simulated inoperative if all relevant effects of an inoperative engine can be taken into account) and conduct 2 climbs in each airplane configuration or drag polar checks to substantiate the asymmetric drag increment as agreed to by the responsible ACO.

(a) High lift devices retracted configuration, final takeoff climb speed, final takeoff ice.

(b) Lowest lift takeoff configuration, landing gear retracted, V_2 climb speed, takeoff ice.

(c) Approach configuration appropriate to the highest lift landing configuration, landing gear retracted, approach climb speed, holding ice.

g. En Route Flight Paths, § 25.123. The following represents an example of an acceptable test program to show compliance with § 25.123:

(1) En route ice.

(2) Forward center-of-gravity position appropriate to the airplane configuration.

(3) En route configuration and climb speed.

(4) Stabilize at the specified speed with one engine inoperative (or simulated inoperative if all relevant effects of an inoperative engine can be taken into account) and conduct 2 climbs or drag polar checks to substantiate the asymmetric drag increment as agreed to by the responsible ACO.

h. Landing, § 25.125. To comply with this regulation, the effect of landing speed increase on the landing distance may be determined by a suitable analysis.

i. Controllability and Maneuverability – General, § 25.143.

(1) A qualitative and quantitative evaluation is usually necessary to show compliance with the controllability and maneuverability requirements. Depending on how clearly compliance is demonstrated, or if the force limits or stick force per g limits of § 25.143 are being approached, additional substantiation may be necessary to ensure that the airplane complies.

(2) General Controllability and Maneuverability. The following represents an example of an acceptable test program to evaluate general controllability and maneuverability, subject to the provisions outlined above:

(a) Holding ice.

(b) Medium to light weight, aft center-of-gravity position, symmetric fuel loading.

(c) In the configurations listed in Table 2, below, trim at the specified speeds and conduct the following maneuvers:

1 30-degree banked turns left and right with rapid reversals;

2 A pull-up to 1.5 g (except that this may be limited to 1.3 g at V_{REF}), and a pushover to 0.5 g (except that the pushover is not required at V_{MO} and V_{FE}); and

3 Deploy and retract deceleration devices.

TABLE 2

Controllability & Maneuverability - Trim Speeds

Configuration	Trim Speed
High lift devices retracted configuration:	1.3 V_{SR}, and V_{MO} or 250 KIAS, whichever is less
Lowest lift takeoff configuration:	1.3 V_{SR}, and V_{FE} or 250 KIAS, whichever is less
Highest lift landing configuration:	V_{REF}, and V_{FE} or 250 KIAS, whichever is less

(d) Lowest lift takeoff configuration: At the greater of 1.13 V_{SR} or V_{2MIN}, with one engine inoperative (simulated), conduct 30-degree banked turns left and right with normal turn reversals and, in wings-level flight, a 5-knot speed decrease and increase.

(e) Conduct an approach and go-around with all engines operating using the Airplane Flight Manual (AFM) approach and go-around procedure.

(f) Conduct an approach and go-around with one engine inoperative (simulated) using the AFM one-engine-inoperative approach and go-around procedure.

(g) Conduct an approach and landing using the AFM approach and landing procedure. In addition, satisfactory controllability should be demonstrated during a landing at V_{REF} minus 5 knots. These tests should be done at heavy weight and forward center-of-gravity.

(h) Conduct an approach and landing with one engine inoperative (or with one engine simulated to be inoperative if all effects associated with an engine failure can be taken into account) using the procedure provided in the AFM.

(3) Evaluation of Lateral Control Characteristics. Aileron hinge moment reversal and other lateral control anomalies have been identified as causal factors in icing accidents and incidents. The following maneuver, along with the evaluation of lateral controllability during a deceleration to the stall warning speed covered in paragraph 3q(2)(e) of this AC and the evaluation of static lateral-directional stability covered in paragraph 3o of this AC, is intended to determine the susceptibility of the airplanes to aileron hinge moment reversals or other adverse effects on lateral control characteristics due to ice accretion.

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

(b) Landing configuration, holding ice accretion, medium to light weight, forward center-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 airplane in the other direction.

3 Maintain the control input as the airplane 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 airplane 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.

(4) Low g Maneuvers and Sideslips. The following represents an example of an acceptable test program for showing compliance with controllability requirements in low g maneuvers and in sideslips to evaluate susceptibility to ice-contaminated tailplane stall.

(a) Section 25.143(i)(2), states: “It must be shown that a push force is required throughout a pushover maneuver down to a zero g load factor, or to 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 maneuver without exceeding a pull control force of 50 pounds; . . .” An example of another design characteristic of the flight control system that would limit the lowest obtainable load factor would be a g-limiting envelope protection system.

(b) For sideslips, per § 25.143(i)(3), "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." (See paragraph 3o(1) of this AC for lateral-directional aspects). Abrupt changes 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. It can be easily managed by a pilot of average skill, alertness, and strength. Control forces in excess of those permitted by § 25.143(c) would be considered excessive.

(c) Test maneuvers used to show compliance with the regulatory requirements re-stated in paragraphs (a) and (b) above, should be conducted using the following ice accretions, configurations, and procedures:

<u>1</u> Holding ice. For airplanes with unpowered elevators, these tests should also be performed with sandpaper ice.-

<u>2</u> Medium to light weight, the most critical center-of-gravity position, symmetric fuel loading, and the highest lift landing configuration.

<u>3</u> Test maneuver for showing compliance with § 25.143(i)(2): Start with the airplane in trim, or as nearly as possible in trim, at the most critical of the trim speeds specified below. Pull up to a suitable pitch attitude, then push over in a continuous maneuver (without changing trim) to reach zero g normal load factor or, if limited by elevator control authority (or other design characteristic), the lowest load factor obtainable at the target speed, as the airplane's pitch attitude passes approximately through level flight (that is, through the horizon). Perform this maneuver with idle power or thrust and with go-around power or thrust.

- 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} - 20 knots.

<u>4</u> Test maneuver for showing compliance with § 25.143(i)(3): Conduct steady heading sideslips to full rudder input, 180 pounds rudder force, or full lateral control authority (whichever comes first) at a trim speed of 1.23 V_{SR} and the power or thrust for a minus 3 degrees flight path angle.

(5) <u>Controllability Prior to Activation and Operation of the Ice Protection System.</u> The following represents an example of an acceptable test program for showing compliance with the controllability requirements for flight in icing conditions before the ice protection system has been activated and is performing its intended function.

(a) If activation of the ice protection system depends on visual recognition of a *specified amount of ice* (not just the first indication of icing) accreted on a reference surface (for example, on an ice accretion probe or the wing leading edge), paragraphs 3i(1), (2), and (3) of this AC are applicable with the ice accretion prior to normal system operation.

(b) If activation of the ice protection system depends on a means of recognition other than that defined in paragraph (a) above, it is acceptable to demonstrate adequate controllability with the ice accretion prior to normal system operation, as follows. In the configurations listed below, trim the airplane at the specified speed, conduct a pull-up maneuver to 1.5 g and pushover maneuver to 0.5 g, and show that longitudinal control forces do not reverse.

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

2 Landing configuration, V_{REF} for non-icing conditions, power or thrust for landing approach. If necessary, limit the pull-up maneuver to the point at which stall warning occurs.

j. Longitudinal Control, § 25.145.

(1) No specific quantitative evaluations are required for demonstrating compliance with §§ 25.145(b) and (c). Qualitative evaluations should be combined with the other testing. The results from the non-contaminated airplane 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 accretions on the airplane.

(2) Acceptable Test Program. The following represents an example of an acceptable test program for compliance with § 25.145(a):

(a) Holding ice.

(b) Medium to light weight, aft center-of-gravity position, symmetric fuel loading.

(c) In the configurations listed below, trim the airplane at 1.3 V_{SR}. Reduce speed approximately 1 knot per second using elevator control to 1 second past stall warning and demonstrate prompt recovery to the trim speed using elevator control.

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

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

k. Directional and Lateral Control, § 25.147. To show compliance with § 25.147, qualitative evaluations should be combined with the other testing (for example, the roll tests described in paragraphs 3i(2)(c)1 and 3i(2)(d)) of this AC. The results from the non-contaminated airplane 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 accretions on the airplane.

l. Trim, § 25.161.

(1) To show compliance with this requirement, qualitative evaluations should be combined with the other testing. The results from the non-contaminated airplane 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 accretions on the airplane. In addition, a specific check should be made to demonstrate compliance with § 25.161(c)(2).

(2) Acceptable Test Program. The following represents an example of an acceptable test program for compliance with § 25.161(c)(2):

(a) Holding ice.

(b) Most critical landing weight, forward center of gravity position, symmetric fuel loading.

(c) In the maximum lift landing configuration, trim the airplane at the most critical of:

1 1.3 V_{SR1} at idle power or thrust; or

2 V_{REF} with the power or thrust for a minus 3 degrees flight path angle.

m. Stability – General, § 25.171. To show compliance with this requirement, qualitative evaluations should be combined with the other testing. Any tendency to change speed when trimmed or a need for frequent trim inputs should be specifically investigated.

n. Demonstration of Static Longitudinal Stability, § 25.175.

(1) To show compliance with § 25.175, each of the following cases should be tested. In general, it is not necessary to test the cruise configuration at low speed (§ 25.175(b)(2)) or the cruise configuration with landing gear extended (§ 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 § 25.253(c)) is the lower of (1) 300 knots CAS; (2) V_{FC}; or (3) a speed at which it is demonstrated that the airframe will be free of ice accretion due to the effects of increased dynamic pressure.

(2) Acceptable Test Program. The following represents an example of an acceptable test program for demonstration of static longitudinal stability:

(a) Holding ice.

(b) High landing weight, aft center-of-gravity position, symmetric fuel loading.

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

1 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 V_{SR}.

2 Cruise: With high lift devices retracted, trim at V_{MO} or 250 knots CAS, whichever is lower.

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

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

o. Static Lateral–Directional Stability, § 25.177.

(1) Use steady heading sideslips to show compliance with the directional and lateral stability requirements. The maximum sideslip angles obtained should be recorded and may be used to substantiate a crosswind value for landing (see paragraph 3s of this AC). Section 25.177(c) requires directional and lateral control movements and forces to be substantially proportional to the angle of sideslip without reversing.

(2) Acceptable Test Program. The following represents an example of an acceptable test program for demonstration of static directional and lateral stability:

(a) Holding ice.

(b) Medium to light weight, aft center-of-gravity position, symmetric fuel loading.

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

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

2 Lowest lift takeoff configuration: Trim at the all-engines-operating initial climb speed.

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

p. Dynamic Stability, § 25.181. To show compliance with § 25.181, provided that there are no borderline compliance aspects with the non-contaminated airplane, it is not necessary to perform dynamic stability tests with ice accretions on the airplane. Qualitative evaluations should be combined with other testing. Any tendency to sustain oscillations in turbulence or difficulty in achieving precise attitude control should be investigated.

q. Stall Demonstration, § 25.201/Stall Characteristics, § 25.203.

(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 program that encompasses all weights, center-of-gravity positions, altitudes, high lift configurations, deceleration device configurations, straight and turning flight attitudes, thrust or power settings. Based on a review of the stall characteristics of the non-contaminated airplane, a reduced test matrix can be established. However, additional tests may be necessary if:

(a) the stall characteristics with ice accretion show a significant difference from the non-contaminated airplane,

(b) the testing indicates borderline compliance, or

(c) the activation point of a stall identification system (for example, a stick pusher) is reset for icing conditions.

(2) Acceptable Test Program. Turning flight stalls at decelerations greater than 1 knot per second are not required. Note that slow decelerations (much slower than 1 knot per second) may be critical on airplanes with anticipation logic in their stall protection system or on airplanes with low directional stability, where large sideslip angles could develop. The following represents an example of an acceptable test program subject to the provisions outlined above.

(a) Holding ice.

(b) Medium to light weight, aft center-of-gravity position, symmetric fuel loading.

(c) Normal stall test altitude.

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

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

2 Lowest lift takeoff configuration: Straight/Power On, Turning/Power Off.

3 Highest lift takeoff configuration: Straight/Power Off, Turning/Power On.

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

(e) For the configurations listed in paragraph 3q(2)(d)1 and 4, 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 left and right up to 10 degrees of bank using the lateral control.

r. Stall Warning, § 25.207.

(1) To show compliance with § 25.207, stall warning should be assessed in conjunction with stall speed testing and stall demonstration/characteristics testing (§§ 25.103, 25.201, and 25.203, and paragraphs 3b and 3q of this AC, respectively), and in tests with faster entry rates.

(2) Normal Ice Protection System Operation. The following represents an example of an acceptable test program for stall warning in slow-down turns of at least 1.5 g and at entry rates of at least 2 knots per second:

(a) Holding ice.

(b) Medium to light weight, aft center-of-gravity position, symmetric fuel loading.

(c) Normal stall test altitude.

(d) In the configurations listed below, trim the airplane at 1.3 V_{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 1.5 g and a deceleration of at least 2 knots per second. Decrease speed until 1 second after stall warning and recover using the same recovery maneuver as for the non-contaminated airplane.

1 High lift devices retracted configuration;

2 Lowest lift takeoff configuration; and

3 Highest lift landing configuration.

(3) Ice Accretion Prior to Activation and Operation of the Ice Protection System. The following represents acceptable means for evaluating stall warning margin for flight in icing conditions before the ice protection system has been activated and is performing its intended function.

(a) If activation of the ice protection system depends on visual recognition of a specified amount of ice (not just the first indication of icing) accreted on a reference surface (for example, an ice accretion probe or the wing leading edge), the test program for normal ice protection system operation given in the preceding paragraph continues to apply, but with the ice accretion prior to normal system operation.

(b) If activation of the ice protection system depends on means of recognition other than that defined in paragraph (a) above, it is acceptable to demonstrate adequate stall warning with the ice accretion prior to normal system operation as follows:

1 In the configurations listed in paragraphs (aa) and (bb), below, trim the airplane at 1.3 V_{SR}.

(aa) High lift devices retracted configuration: Straight/Power Off.

(bb) Landing configuration: Straight/Power Off.

2 At deceleration rates of up to 1 knot per second, reduce the speed to 1 second past stall warning, and demonstrate that stalling can be prevented using the same recovery maneuver as for the non-contaminated airplane, without encountering any adverse characteristics (for example, rapid wing roll-off). Where stall warning is provided by a different means than for the airplane without ice accretion, § 25.207(i)(2)(ii) requires a demonstration of satisfactory stall characteristics as well as the capability to prevent a stall if the pilot does not take any recovery action for at least 3 seconds after stall warning.

s. Wind Velocities, § 25.237. To show compliance with this requirement:

(1) Crosswind landings with the landing ice accretion should be evaluated on an opportunity basis.

(2) The results of the steady heading sideslip tests with landing ice may be used to establish the safe crosswind component. If the flight test data show that the maximum sideslip angle demonstrated is similar to that demonstrated with the non-contaminated airplane, and the flight characteristics (for example, control forces and deflections) are similar, then the non-contaminated airplane crosswind component is considered valid for icing conditions.

(3) If the results of the comparison discussed in paragraph 3s(2) 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:

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

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 3o of this AC).

t. Vibration and Buffeting, § 25.251. To show compliance with this requirement:

(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 3n of this AC).

(2) Demonstrate that the airplane is free from harmful vibration due to residual ice accumulation. This may be done in conjunction with the natural icing tests.

(3) An airplane with pneumatic deicing boots should be evaluated to V_{DF}/M_{DF} with the deicing boots operating (including deicing boot inflation cycles) and not operating. It is not necessary to do this demonstration with ice accretions on the airplane.

u. Natural Icing Conditions, § 25.1419(b).

(1) To show compliance with this requirement, additional flight testing should be performed.

(a) Whether the flight testing has been performed with artificial or simulated ice accretions, or in natural icing conditions, additional limited flight testing described in this section should be conducted in natural atmospheric icing conditions. If flight testing with simulated ice accretions 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 simulated ice accretions. It is not intended that natural icing flight tests validate all aspects of predicted ice accretions. The flight testing should confirm the general physical characteristics and location of the ice accretions, and their effect on airplane performance and handling characteristics. At least a qualitative assessment should be made that the artificial ice accretions are conservative relative to the ice accretions obtained in natural atmospheric icing conditions, and to confirm that ice does not accrete in unexpected places.

(b) 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 maneuvers as soon as possible after exiting the icing cloud to minimize the atmospheric influences on ice shedding.

(c) During any of the maneuvers specified in paragraph 3u(2), below, the behavior of the airplane should be consistent with that obtained with simulated ice accretions. There should be no unusual control responses or uncommanded airplane motions. Additionally, during the level turns and bank-to-bank rolls, there should be no buffeting or stall warning.

(2) Ice Accretion/Maneuvers.

(a) Holding scenario.

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

(aa) On unprotected parts: A target accretion thickness equivalent to the 45-minute dry air ice accretions on an unprotected part of the wing should be the objective. (A thickness of 2 inches is normally a minimum value, unless a lesser value is agreed to with the responsible aircraft certification office (ACO)).

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

2 For airplanes with control surfaces that may be susceptible to jamming due to ice accretion (for example, 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 – Maneuvers

Airplane Configuration	c.g.	Trim Speed	Maneuver
Flaps up, Gear up	Optional (aft range)	Holding, except 1.3 V_{SR} for the stall maneuver	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).

(b) Approach/Landing Scenario.

1 The maneuvers specified in Table 4, below, should be carried out with successive accretions in different configurations on unprotected surfaces.

2 Each test condition should be accomplished with the ice accretion that exists at that point.

3 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 - Maneuvers

Test con-dition	Ice accretion thickness (*)	Airplane configuration	c.g.	Trim speed	Maneuver
—	First 0.5 in	Flaps up, gear up	Optional (aft range)	Holding	No specific test
1	Additional 0.25 in (0.75 in. total)	First intermediate flaps, gear up	Optional (aft range)	Holding, except 1.3 V_{SR} for the deceleration maneuver	Level 40° banked turn, Bank-to-bank rapid roll, 30°- 30°, Speed brake extension and retraction (if approved), Deceleration to the speed reached 3 seconds after activation of stall warning in a 1 knot/second deceleration.
2	Additional 0.25 in (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 the speed reached 3 seconds after activation of stall warning in a 1 knot/second deceleration.
3	Additional 0.25 in (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 (1 knot/second deceleration rate, wings level, power off).

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

(3) For airplanes with unpowered elevator controls, unless the critical simulated ice accretion used to demonstrate compliance with the controllability requirement is adequately substantiated, the pushover test of paragraph 3i(4)(c)3, above, should be repeated with a thin accretion of natural ice.

(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.

v. Failure Conditions, § 25.1309. To show compliance with this requirement:

(1) For failure conditions that are annunciated to the flightcrew, credit may be taken for flightcrew action to follow the established operating procedures provided in the Airplane Flight Manual (AFM).

(2) Acceptable Test Program. In addition to a general qualitative evaluation, the following test program (modified as necessary to reflect the specific operating procedures) should be carried out for the most critical probable failure condition for which the associated procedure requires the airplane to exit the icing condition:

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

1 On unprotected surfaces – the holding ice accretion described in appendix 1, paragraph 2(a)(3) of this AC;

2 On normally protected surfaces that are no longer protected – the failure ice accretion described in appendix 1, paragraph 3(b) of this AC; and

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

(b) Medium to light weight, aft center-of-gravity position, symmetric fuel loading.

(c) In the configurations listed in paragraphs 1 through 3 below, trim the airplane at the specified speed. Conduct 30-degree banked turns left and right with normal reversals. Conduct a pull up maneuver to 1.5 g and a pushover maneuver to 0.5 g.

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

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

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

(d) In the configurations listed below, trim the airplane at the estimated 1.3 V_{SR}. Decrease speed at approximately 1 knot per second until 1 second after stall warning, and demonstrate prompt recovery using the same recovery maneuver as for the non-contaminated airplane. It is acceptable for stall warning to be provided by a different means (for example, by the behavior of the airplane rather than a stick shaker) for failure cases not considered probable.

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

2 Landing configuration: Straight/Power Off.

(e) Conduct an approach and go-around with all engines operating using the AFM approach and go-around 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 appropriate AFM approach and landing procedure.

(3) For improbable failure conditions, flight 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, or to verify the results of analyses or wind tunnel tests. The extent of any required flight testing should be similar to that described in paragraph 3v(2), above, or as agreed to by the responsible ACO for the specific failure condition.

APPENDIX 1

AIRFRAME ICE ACCRETIONS

1. GENERAL.

a. 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 (for example, airplane configuration, speed, angle-of-attack, altitude) and
- the icing conditions of appendix C of part 25 (for example, temperature, liquid water content (LWC), mean effective drop diameter).

b. 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 appendix C conditions that have been examined in terms of mean effective drop diameter, LWC , 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 responsible ACO.

c. See appendix R of FAA AC 20-73A, Aircraft Ice Protection, for additional detailed information about determining the applicable critical ice accretion (that is, shape and roughness).

2. OPERATIVE ICE PROTECTION SYSTEM.

a. <u>All Flight Phases Except Takeoff.</u>

(1) For unprotected parts, the ice accretion to be considered should be determined in accordance with § 25.1419.

(2) Unprotected parts consist of the unprotected airfoil leading edges and all unprotected airframe parts on which ice may accrete. The effect of ice accretion on protuberances such as antennas or flap hinge fairings need not normally be investigated. However, airplanes that are characterized by unusual unprotected airframe protuberances, for example, 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.

(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 airplane 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 airplane certification programs, the maximum pinnacle height was limited to 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, LWC, and temperature that result in the formation of an ice accretion that is critical to the airplane's performance and handling qualities. The shape and texture of the ice are important and should be agreed to by the responsible ACO.

(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 results from:

(a) The rest time of a deicing cycle. Performance may be established on the basis of a representative intercycle ice accretion for normal operation of the deicing 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 deicing cycle may be used for performance calculations.

1 Runback ice that occurs on or downstream of the protected surface.

2 Ice accretion prior to activation and operation of the ice protection system. (See paragraph 2(c) of this appendix.)

b. Takeoff Phase.

(1) For both unprotected and protected parts, the ice accretion identified in appendix C to part 25 for the takeoff phase may be determined by calculation, assuming that the takeoff maximum icing conditions defined in appendix C exist, and:

- airfoils, control surfaces and, if applicable, propellers are free from frost, snow, or ice at the start of the takeoff;
- the ice accretion starts at liftoff;
- the critical ratio of power/thrust-to-weight;
- failure of the critical engine occurs at V_{EF}; and
- flightcrew activation of the ice protection system in accordance with an AFM procedure, except that after beginning the takeoff roll no flightcrew action to activate the ice protection system should be assumed to occur until the airplane is 400 feet above the takeoff surface.

(2) The ice accretions identified in appendix C to part 25 for the takeoff phase are:

- Takeoff ice. 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 liftoff and 400 feet above the takeoff surface, assuming accretion starts at liftoff in the takeoff maximum icing conditions of appendix C, part I(c) to part 25.

- Final takeoff ice. The most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, between 400 feet and 1,500 feet above the takeoff surface, assuming accretion starts at liftoff in the takeoff maximum icing conditions of appendix C, part I(c) to part 25.

c. Ice Accretion Prior to Normal System Operation.

(1) Ice protection systems are normally operated as anti-icing systems (that is, designed to prevent ice accretion on the protected surface) or deicing systems (that is, designed to remove ice from the protected surface). In some cases, systems may be operated either as an as anti-icing system or as a deicing system. Operation of ice protection systems can also include a resetting of stall warning or stall identification system (for example, stick pusher) activation thresholds.

(2) The ice accretion prior to normal system operation should take into account the means of activating the ice protection system and the system response time. System response time is defined as the time interval between the activation of the system and its effective operation (for example, for a thermal ice protection system, the time to heat the surface and remove the ice). If activation of the ice protection system depends on flightcrew recognition of icing conditions, appropriate delays in identifying the icing conditions and activating the ice protection system should be taken into account. The airplane should be assumed to be in the continuous maximum icing conditions of appendix C to part 25 during this time.

(3) An ice detection system may be installed that will provide information either to the flightcrew or directly to the ice protection system regarding inflight 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 flightcrew following an annunciation from the primary ice detection system.

(b) An 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 flightcrew 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 flightcrew 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.

(4) The following examples indicate the ice accretion to be considered on the unprotected and normally protected aerodynamic surfaces:

(a) If activating the ice protection system depends on visual recognition of a *specified amount of ice* accreted on a reference surface (for example, an ice accretion probe or the 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 flightcrew delays in recognition of the specified ice accretion and operation of the system, determined as follows:

1 the ice accretion that would be easily recognizable by the flightcrew under all foreseeable conditions (for example, at night in clouds) as corresponding to the accretion specified for activating the ice protection system, plus

2 the ice accretion equivalent to 30 seconds of operation in the continuous maximum icing conditions of appendix C, part I(a) to part 25, plus

3 the ice accretion during the system response time.

(b) If activating the ice protection system depends on visual recognition of the first indication of ice accretion on a reference surface (for example, an ice accretion probe), the ice accretion should take into account flightcrew delays in detecting the accreted ice and activating the ice protection system, and the time it takes for the system to perform its intended function, determined as follows:

1 the ice accretion that would be easily recognizable by the flightcrew under all foreseeable conditions (for example, at night in clouds) corresponding to the first indication of ice accretion on the reference surface, plus

2 the ice accretion equivalent to 30 seconds of operation in the continuous maximum icing conditions of appendix C, part I(a) to part 25, plus

3 the ice accretion during the system response time.

(c) If activating the ice protection system depends on pilot identification of icing conditions (as defined by an appropriate static or total air temperature and visible moisture conditions), the ice accretion should take into account flightcrew delays in recognizing the presence of icing conditions and activating the ice protection system, and the time it takes for the system to perform its intended function, determined as follows:

1 the ice accretion equivalent to 30 seconds of operation in the continuous maximum icing conditions of appendix C, part I(a) to part 25, plus

2 the ice accretion during the system response time.

(d) If activating the ice protection system depends on pilot action following an annunciation from a primary ice detection system, the ice accretion should take into account flightcrew delays in activating the ice protection system, and the time it takes for the system to perform its intended function, determined as follows:

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

2 the ice accretion equivalent to 10 seconds of operation in the continuous maximum icing conditions of appendix C, part I(a) to part 25, plus

3 the ice accretion during the system response time.

(e) If activating the ice protection system is automatic following annunciation from a primary ice detection system, the ice accretion should take into account the time it takes for the automatic activation of the ice protection system and for the system to perform its intended function, determined as follows:

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

2 the ice accretion during the system response time.

(f) If the airplane is equipped with an advisory ice detection system that supplements the means of detection referenced in paragraphs (a), (b), or (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.

3. ICE PROTECTION SYSTEM FAILURE CASES.

a. Unprotected Parts. The same accretion as in paragraph 2(a), above, is applicable.

b. Protected Parts Following System Failure. The ice accretion for failures of the ice protection system is defined as follows:

(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.

(2) In the case where the failure condition is annunciated and the associated AFM procedure does not require the airplane 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.

(3) In the case where the failure condition is annunciated and the associated AFM procedure requires the airplane 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 to by the responsible ACO.

APPENDIX 2

SIMULATED ICE ACCRETIONS

1. GENERAL.

a. In general, the simulated ice accretions used for flight testing should be those that have the most adverse effects on handling characteristics. However, if analytical data show that other reasonably expected ice accretions could be generated that could produce higher performance decrements, then the ice accretion having the most adverse effect on handling characteristics may be used for performance tests only if any difference in performance can be conservatively taken into account.

b. The simulated accretions should be representative of natural icing conditions in terms of location, general shape, thickness, and texture. The determination of the form and surface texture of the ice accretion (see paragraph 2, below) should be agreed to by the responsible ACO as being representative of natural ice accretion.

c. Sandpaper ice is addressed in paragraph 3, below.

2 SHAPE AND TEXTURE OF SIMULATED ICE ACCRETION.

a. The shape and texture of the simulated ice accretion 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 (for example, from an icing tanker).

b. Unless another texture is substantiated by the applicant and agreed to by the ACO, a roughness height of 3 mm with a particle density of 8 to 10/cm^2 should be used.

3 SANDPAPER ICE.

a. Sandpaper ice is the most critical thin, rough layer of ice. Carborundum sandpaper no. 40 (that is, 40-grit carborundum sandpaper) has been used in past certification programs to represent sandpaper ice. However, as detailed in appendix R of AC 20-73A, the uniformly distributed roughness of carborundum grit may not result in aerodynamic effects similar to those of the actual intercycle ice surface roughness. The applicant should validate the use of uniformly distributed roughness to simulate sandpaper ice, particularly for intercycle ice accretions.

b. The spanwise and chordwise coverage should be consistent with the areas of ice accretion determined for the conditions of part 25, appendix C, except that, for the zero-g pushover maneuver of paragraph 3i(4)(c)3 of this AC, the sandpaper ice may be restricted to the horizontal stabilizer if this can be shown to be conservative.

c. Appendix C, part II(a) requires applicants to use the most critical ice accretion to show compliance with the applicable subpart B airplane performance and handling characteristics requirements in icing conditions. The determination of the most critical ice accretion must consider the full range of atmospheric icing conditions of part I of appendix C as well as the characteristics of the ice protection system, per § 25.21(g)(1) and appendix C, part II(a). This includes consideration of sandpaper ice (as well as any other type of ice accretion that may occur in the applicable atmospheric icing conditions), taking into account the operating characteristics of the ice protection system and the flight phase. Sandpaper ice can be particularly critical for showing compliance with either § 25.143(i)(2) or (j)(2). If sandpaper ice can be present, it must be considered in showing compliance with both of these requirements.

APPENDIX 3

DESIGN FEATURES

1 AIRPLANE CONFIGURATION AND ANCESTRY. An important design feature of an overall airplane configuration that can affect performance, controllability, and maneuverability is its size. In addition, the safety record of the airplane's closely-related ancestors may be taken into consideration.

a. Size. The size of an airplane 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 airplane size increases.

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

2 WING. Design features of a wing that can affect performance, controllability, and maneuverability include airfoil type, leading edge devices, and stall protection devices, and the lateral control system effectiveness.

a. Airfoil Type. Airfoils with significant natural laminar flow when non-contaminated may show large changes in lift and drag with ice. Conventional airfoils 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.

b. Leading Edge Devices. 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. Movement of a slat so that a gap forms may improve the situation further. Leading edge devices can also reduce the loss in angle of attack at stall due to ice.

c. Stall Protection Devices. An airplane with automatic slat activation that creates a gap may generate a greater C_{Lmax} with ice than the certified C_{Lmax} with the slat gap sealed and a non-contaminated leading edge. This may provide effective protection against degradation in stall performance or stall characteristics.

d. Lateral Control System Effectiveness. The effectiveness of the lateral control system in icing conditions can be evaluated by comparison with closely related ancestor airplanes, with consideration of the design of aerodynamic balance surfaces.

3 EMPENNAGE. The effects of size and airfoil type also apply to the horizontal and vertical tails. Other design features include tailplane design philosophy, horizontal stabilizer design, control surface actuation, control surface size, and vertical stabilizer and rudder design. 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 airplane handling and/or control characteristics rather than degraded performance.

a. 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 deicing or anti-icing system.

b. Horizontal Stabilizer Design. Cambered airfoils and/or trimmable stabilizers may reduce the susceptibility and consequences of elevator hinge moment reversal due to ice-induced tailplane stall.

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

d. 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.

e. Vertical Stabilizer and Rudder Design. The effectiveness of the vertical stabilizer and rudder in icing conditions can be evaluated by comparison with closely-related ancestor airplanes, with consideration of the design of aerodynamic balance surfaces.

4 AERODYNAMIC BALANCING OF FLIGHT CONTROL SURFACES.

a. 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.

b. 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 that 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.

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.

a. Wing Ice Protection/Detection.

(1) A primary ice detection system that automatically activates a wing deicing system may ensure that there is no significant ice accretion on wings that are susceptible to performance losses with small amounts of ice.

(2) If portions of the wing leading edge are not protected, the part that is protected may be selected to provide good handling characteristics at stall, with an acceptable performance degradation.

b. Tail Ice Protection/Detection.

(1) A primary ice detection system may automatically activate a tailplane deicing system on airplanes that do not have visible cues for system operation.

(2) An ice protection system on the unshielded aerodynamic balances of airplanes with unpowered reversible controls can reduce the risk of ice-induced aerodynamic hinge moment reversals.

APPENDIX 4

RELATED REGULATIONS AND ADVISORY CIRCULARS

Regulations. The following sections of Title 14, Code of Federal Regulations (14 CFR), part 25 are referenced in this AC. The full text of 14 CFR can be downloaded from the Internet at http://www.gpoaccess.gov/nara. A paper copy may be ordered from the Government Printing Office (GPO), Superintendent of Documents, Attn: New Orders, PO Box 371954, Pittsburgh, PA 15250-7954.

§ 25.21	Proof of compliance
§ 25.23	Load distribution limits
§ 25.25	Weight limits
§ 25.27	Center of gravity limits
§ 25.29	Empty weight and corresponding center of gravity
§ 25.31	Removable ballast
§ 25.33	Propeller speed and pitch limits
§ 25.101	Performance – General
§ 25.103	Stall speed
§ 25.105	Takeoff
§ 25.107	Takeoff speeds
§ 25.109	Accelerate-stop distance
§ 25.111	Takeoff path
§ 25.119	Landing climb: All-engines-operating
§ 25.121	Climb: One-engine-inoperative
§ 25.123	En route flight paths
§ 25.125	Landing
§ 25.143	Controllability and Maneuverability – General
§ 25.145	Longitudinal control
§ 25.147	Directional and lateral control
§ 25.161	Trim
§ 25.171	Stability – General
§ 25.175	Demonstration of static longitudinal stability
§ 25.177	Static lateral-directional stability
§ 25.181	Dynamic stability
§ 25.201	Stall demonstration
§ 25.203	Stall characteristics
§ 25.207	Stall warning
§ 25.231	Longitudinal stability and control

§ 25.233	Directional stability and control
§ 25.235	Taxiing condition
§ 25.237	Wind velocities
§ 25.251	Vibration and buffeting
§ 25.253	High-speed characteristics
§ 25.255	Out-of-trim characteristics
§ 25.1309	Equipment, systems, and installations
§ 25.1329	Flight guidance system
§ 25.1419	Ice protection
§ 25.1581	Airplane Flight Manual – General
§ 25.1583	Operating limitations
§ 25.1585	Operating procedures
§ 25.1587	Performance information
Part 25, Appendix C	

Advisory Circulars. The following ACs are related to the guidance contained in this AC. An electronic copy of the following ACs can be downloaded from the Internet at http://rgl.faa.gov. A paper copy may be ordered from the U.S. Department of Transportation, Subsequent Distribution Office, M-30, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20795.

AC 20-73A	Aircraft Ice Protection
AC 25-7A	Flight Test Guide for Certification of Transport Category Airplanes
AC 25.1309-1A	System Design and Analysis
AC 25.1329-1B	Approval of Flight Guidance Systems
AC 25.1419-1A	Certification of Transport Category Airplanes for Flight in Icing Conditions

NOTE: This list represents the latest version of each AC at the time of publication. These individual ACs may be updated in the future, such that this list may reference a specific version of an AC that has been superseded. The latest version of each AC should always be used, even though this document may reference a previous version of an AC.

APPENDIX 5

ACRONYMS

AC	Advisory Circular
ACO	Aircraft Certification Office
AFM	Airplane Flight Manual
ATTCS	Automatic Takeoff Thrust Control System
CAS	Calibrated Airspeed
CFR	Code of Federal Regulations
FAA	Federal Aviation Administration
ICTS	Ice-Contaminated Tailplane Stall
KIAS	Knots Indicated Airspeed
LWC	Liquid Water Content
MVD	Median Volumetric Diameter
C_L	Lift Coefficient
C_{LMAX}	Maximum Lift Coefficient
V_1	The maximum speed in the takeoff at which the pilot must take the first action (for example, apply brakes, reduce thrust, deploy speed brakes) to stop the airplane within the accelerate-stop distance. V_1 also means the minimum speed in the takeoff, following a failure of the critical engine at $V_{EF,}$ at which the pilot can continue the takeoff and achieve the required height above the takeoff surface within the takeoff distance.
V_2	Takeoff Safety Speed. (The target speed to be reached by the time the airplane is 35 feet above the takeoff surface.)
V_{2MIN}	Minimum Takeoff Safety Speed.
V_{CW}	Crosswind Component of Wind Speed
V_{DF}/M_{DF}	Demonstrated Flight Diving Speed
V_{EF}	Engine Failure Speed. The speed at which the critical engine is assumed to fail during takeoff.
V_{FC}	Maximum Speed for Stability Characteristics
V_{FE}	Maximum Flaps Extended Speed
V_{MO}	Maximum Operating Limit Speed
V_{REF}	Landing Reference Speed

$V_{S\ 1\text{-}g}$	1-g Stall Speed. The calibrated airspeed at which aerodynamic forces alone can support the airplane in 1-g flight.
V_{SR}	Reference Stall Speed. V_{SR} may not be less than $V_{S\ 1\text{-}g}$. For airplanes with a device that abruptly pushes the nose down at a selected angle of attack, (for example, a stick pusher), V_{SR} may not be less than 2 knots or 2 percent, whichever is greater, above the speed at which the device operates.
V_{SR1}	Reference Stall Speed in a specific configuration.