1.2.2.5 Hazard assessment

If an aeroplane is not similar to a previous design, an assessment of the hazard classification may require more analysis or testing. One method of hazard assessment would be to consider effects of ice accumulations similar to those expected for aeroplanes being certified under CS 25.1420. Such ice shapes may be defined from a combination of analysis and icing tanker or icing wind tunnel testing. Aerodynamic effects of such shapes could be evaluated with wind tunnel testing or, potentially, computational fluid dynamics. Hazard classification typically takes place early in a certification program. Therefore, a conservative assessment may be required until sufficient supporting data is available to reduce the hazard classification.

1.2.3 Probability of encountering the icing conditions represented by Appendix O

Appendix C was designed to include 99 percent of icing conditions. Therefore, the probability of encountering icing outside of Appendix C drop conditions is on the order of 10^{-2}. The applicant may assume that the average probability for encountering the icing conditions represented by Appendix O is 1 x 10^{-2} per flight hour. This probability should not be reduced based on phase of flight.

1.2.4 Numerical safety analysis.

For the purposes of a numerical safety analysis, the applicant may combine the probability of equipment failure with the probability, defined above, of encountering Appendix O icing conditions. If the applicant can support a hazard level of 'Hazardous' using the above probability (10^{-2}) of encountering the specified supercooled large drop conditions, the probability of an unannunciated failure of the equipment that alerts the flight crew to exit icing conditions should be less than 1 x 10^{-5}.

1.2.5 Assessment of visual cues.

Typical system safety analysis do not address the probability of crew actions, such as observing a visual cue before performing a specified action. As advised in AMC 25.1309, quantitative assessments of crew errors are not considered feasible. When visual cues are to be the method for detecting Appendix O conditions and determining when to exit them, the applicant should assess the appropriateness and reasonableness of the specific cues. Reasonable tasks are those for which the applicant can take full credit because the tasks can realistically be anticipated to be performed correctly when required. The applicant should assess the task of visually detecting Appendix O conditions to determine if it could be performed when required. The workload for visually detecting icing conditions should be considered in combination with the operational workload during applicable phases of flight. The applicant may assume that the flight crew is already aware that the aeroplane has encountered icing. The assessment of whether the task is appropriate and reasonable is limited to assessing the task of identifying Appendix O accumulations that require exiting from the icing conditions.

1.3 Similarity

On derivative or new aeroplane designs, the applicant may use similarity to previous type designs which have been certified for operation in SLD icing conditions, meanwhile the effects of differences will be substantiated. Natural ice flight testing may not be necessary for a design shown to be similar.

The guidance provided in AMC 25.1419(a)(8) applies.

The applicant must possess all the data required to substantiate compliance with applicable specifications, including data from past certifications upon which the similarity analysis is based.

2. Tests

CS 25.1420 requires two or more means of compliance for approval of flight in icing, except when a comparative analysis is used to show compliance. It is common to use a combination of methods in order to adequately represent the conditions and determine resulting degradation effects with sufficient confidence to show compliance.

Some of the guidance contained in paragraph (b) of AMC 25.1419 may be relevant to this paragraph. In addition, with respect to natural icing flight testing in the Appendix O icing environment, CS 25.1420 does not specifically require measured natural icing flight tests. However, flight testing in measured natural Appendix O icing conditions may be necessary to:

(i) verify the general physical characteristics and location of the simulated ice shapes used for dry air testing, and in particular, their effects on aeroplane handling characteristics.

(ii) determine if ice accretes on areas where ice accretion was not predicted.

(iii) verify adequate performance of ice detectors or visual cues.

(iv) conduct performance and handling quality tests as outlined in AMC 25.21(g).

(v) evaluate effects of ice accretion not normally evaluated with simulated ice shapes (on propeller, antennas, spinners, etc.) and evaluate operation of each critical aeroplane system or component after exposure to Appendix O icing conditions.

Flight testing in natural Appendix O conditions would unlikely be necessary unless the aeroplane will be certified for continued operation within a portion or all of appendix O conditions. For aeroplanes to be certified to a portion or all of Appendix O, where natural Appendix O icing conditions flight testing is performed, measurement and recording of drop diameter spectra should be accomplished.

Flight testing in natural Appendix O icing conditions should be accomplished for aeroplane derivatives whose ancestor aeroplanes have a service record that includes a pattern of accidents or incidents due to in flight encounters with Appendix O conditions.

(e) CS 25.1420(c)

CS 25.1420(c) requires that aeroplanes certified in accordance with subparagraph CS 25.1420(a)(2) or (a)(3) comply with the requirements of CS 25.1419(e), (f), (g), and (h) for the icing conditions defined in Appendix O in which the aeroplane is certified to operate.

Paragraphs (d), (e), (f), and (g) of AMC 25.1419 apply.

If applicable, a comparative analysis, as defined in AMC 25.1420(f), may be used to show compliance.

(f) CS 25.1420(d) Comparative analysis

For showing compliance with the CS-25 certification specifications relative to SLD icing conditions as represented by Appendix O, the applicant may use a comparative analysis to show similarity of a new or derivative aeroplane model to existing model(s) with features and/or margins which are deemed to have contributed to a safe fleet history in all icing conditions.

When using comparative analysis as a means of compliance, flight testing in measured natural SLD icing conditions and/or flight testing with simulated ice shapes defined in accordance with Appendix O — part II is not required. Nevertheless, other types of tests may be required.

1. Definitions

— Accident: The definition of the term 'accident' is provided in ICAO Annex 13, Chapter 1.

— Certification ice shapes/ice shape data: Ice shapes or ice shape data used to show compliance with certification specifications for flight in icing conditions. As used in this document, these are the ice shapes or data used to represent the critical ice shapes with the intent that they convey the ice that represents the most adverse effect on performance and flight characteristics. The data which is used to represent these shapes may be comprised of flight test data (artificial or natural ice), wind tunnel data, analytical data, or combinations of the above as allowed during previous certification projects.

— Comparative analysis:

  — The use of analyses to show that an aeroplane is comparable to models that have previously been certified for operation in icing conditions via the environment represented by Appendix C and have a proven safe operating history in any supercooled liquid water icing conditions, but that may not have already been explicitly certified for operation in the icing environment represented by Appendix O.

  — Key elements:

    — The new or derivative model is certifiable for Appendix C icing conditions,

    — Aeroplane models previously certified for Appendix C icing conditions are used to establish a reference fleet,

    — The new or derivative model has similar design features and/or margins for key parameters relative to the reference fleet,

    — The reference fleet has a safe fleet history in supercooled liquid water icing conditions.

— Events: Within this document the word 'event' means 'accident and/or serious incident' as defined in ICAO Annex 13, Chapter 1. For the purpose of identifying serious incidents with respect to the in-service history used for the comparative analysis, this should include reports where the flight crew encountered difficulties controlling the aeroplane, or temporarily lost its control, when flying in icing conditions.

— Key parameters: Parameters deemed to have contributed to the safe operation in icing conditions of the reference fleet. These parameters should be defined and provided by the applicant for each of the topics addressed using the comparative analysis. They should be agreed with the Agency.

— Reference fleet: The fleet of previously certified aeroplanes used to establish safe fleet history in order to enable the use of comparative analysis as a means of compliance.

— Serious incident: The definition of the term 'serious incident' is provided in ICAO Annex 13, Chapter 1.

— Similarity analysis:

  — The direct comparison of a new or derivative aeroplane model to models already certified for operation in the icing environment of Appendix C and/or Appendix O. The similarity can be established for the aeroplane, the systems and/or the components.

  — Key elements:

    — Similar design features,

    — Similar performance and functionality.

2. Introduction

This paragraph introduces comparative analysis as a means of compliance with the CS-25 certification specifications addressing SLD icing conditions represented by Appendix O. The Agency acknowledges that there are a significant number of large aeroplane models which have an exemplary record of safe operation in all icing conditions, which inherently include SLD icing conditions. A comparative analysis provides an analytical certification path for new aeroplane models and derivatives by allowing the applicant to substantiate that a new or derivative model will have at least the same level of safety in all supercooled liquid water icing conditions that previous models have achieved.

For derivative models, the applicable certification specifications are determined through the application of the 'Changed Product Rule (CPR)'. Rather than demonstrating compliance with the certification specifications in effect at the date of application, an applicant may demonstrate compliance with an earlier amendment of the certification specifications when meeting one of the conditions provided in Part-21, point 21.A.101(b). After application of the CPR, if the derivative model must comply with an amendment that includes the SLD-related certification specifications, compliance by comparative analysis may be used.

To use a comparative analysis as means of compliance for a new or derivative aeroplane model, four main elements should be established:

a. A reference fleet with an adequately safe history in icing conditions;

b. An analysis of aeroplane design features and/or margins that are deemed to contribute to the safe history of the reference fleet.

c. A comparison showing that the new or derivative aeroplane model shares the comparable design features and/or margins, with the reference fleet.

d. The compliance of the new or derivative aeroplane model with the applicable CS-25 certification specifications relative to flight in the icing conditions defined by Appendix C.

3. Determining Adequately Safe Fleet History

In order to use a comparative analysis, a safe fleet history has to be established for the reference fleet of aeroplane model(s) to be used for comparison.

3.1 Fleet History Composition

The reference fleet should include the previous aeroplane model(s) sharing the design features and/or margins that will be used to substantiate the comparative analysis. The applicant should present to the Agency any known supercooled-liquid-water-icing-related accidents or serious incidents of the reference fleet. The applicant should present an analysis of any such events and explain how the identified root causes were addressed. Unless it can be justified, credit should not be taken for those flights of any aeroplane model that has experienced accidents or serious incidents due to flight in supercooled liquid water icing conditions. If design changes were made to correct deficiencies that contributed to or caused the accidents or serious incidents, including those which may have occurred in SLD, credit for flights may be taken only for the fleet of aeroplanes that have the changes incorporated (i.e. post-modification number of flights).

3.2 Use of Fleet History Data Not Owned by the Applicant

The use of fleet history data from the fleets of other certificate holders for Supplemental Type Certificate, new Type Certificate, or Major change to Type Certificate applications may be accepted by the Agency when formal agreements between the applicant and the certificate holder permitting the use of the relevant fleet history are in place. The Agency will determine the acceptability and the applicability of the data.

3.3 Applicability of Fleet History for the Certification Options of CS 25.1420(a)

When compiling data for aeroplane model(s) which will comprise the applicant's reference fleet, operational limitations or restrictions imposed by either the AFM(s) or the operating manuals furnished by the TC holder for the model(s), should be considered. Relevant operational limitations existing for the reference fleet (e.g. AFM or operating manual prohibition against take-off into freezing drizzle or light freezing rain, direction to avoid such conditions in flight, directions to exit severe icing, etc.) will limit the certification options available for the use of a comparative analysis.

If the aeroplane model(s) proposed to be included in the applicant's reference fleet has (have) limitations or restrictions applicable to SLD, the certification options for which comparative analysis could be used are limited to CS 25.1420(a)(1) or (a)(2). The applicant should demonstrate within the comparative analysis that the means of ice and/or icing condition detection for the reference fleet remain valid and are applicable to the new or derivative aeroplane.

3.4 Safe Fleet History Requirements

The reference fleet should have accumulated two million or more flights in total with no accidents or serious incidents in supercooled liquid water icing conditions aloft.

4. Compliance with the Applicable CS-25 Certification Specifications Relative to Appendix C Icing Conditions

A comparative analysis is an acceptable means of compliance only with the CS-25 certification specifications relative to Appendix O icing conditions. The use of a comparative analysis is not an option for showing compliance with CS-25 certification specifications relative to Appendix C icing conditions.

5. Conducting Comparative Analysis

If a safe fleet history in icing conditions can be substantiated, and compliance with the CS-25 certification specifications for safe flight in Appendix C icing conditions can be shown, then the reference fleet can be used for comparative analysis. The substantiation of the reference fleet's design features and/or margins which have contributed to the safe fleet history can be used for a new or derivative model having comparable design features and/or margins, to show compliance with the CS-25 certification specifications relative to flight in SLD icing conditions. When conducting a comparative analysis, the effects of key parameters for individual components or systems should be considered at the aeroplane level. A different design feature or margin may be shown to be acceptable when considered at the aeroplane level, taking into account the other aircraft design features and margins that are deemed to contribute to safe flight in icing conditions. The following aspects should be addressed:

a. Ice protection systems,

b. Unprotected components,

c. Ice or icing conditions detection,

d. Ice accretion and ice shedding sources,

e. Performance and handling characteristics,

f. Aeroplane Flight Manual information,

g. Additional considerations — Augmenting comparative analysis

5.1 Applicable CS-25 certification specifications

The applicable certification specifications relative to SLD icing are listed in Table 1 below. This guidance is applicable to these certification specifications.

Table 1: List of applicable CS 25 certification specifications

Reference	Title
CS 25.21(g)	Performance and Handling Characteristics in Icing Conditions
CS 25.629	Aeroelastic stability requirements
CS 25.773(b)(1)(ii)	Pilot compartment view — icing conditions
CS 25.773(b)(4)	Pilot compartment view — non-openable windows
CS 25.929(a)	Propeller de-icing
CS 25 1093(b)	Powerplant icing — turbine engines
CS 25.1324	Flight instrument external probes
CS 25.1329	Flight Guidance System
CS 25.1403	Wing icing detection lights
CS 25.1420	Supercooled large drop icing conditions

5.2 Ice Protection Systems

The applicant should demonstrate similar levels of protection against the effects of ice accretion at the aeroplane level in the icing conditions of Appendix C. In doing so, the applicant should consider the ice protection system performance, modes of operation and the other factors identified by the applicant that contribute to the overall safety of the aeroplane for flight in the icing conditions of Appendix C. The assessment could include, but is not necessarily limited to, an analysis of the protection limits relative to supercooled liquid water impingement limits, runback and residual ice, as applicable.

5.3 Failure Analysis

The reference fleet will have been certified considering only the supercooled liquid water icing conditions of Appendix C and will have demonstrated an adequate level of safety when flying in both Appendix C and SLD icing conditions. Therefore, if a comparative analysis is used as a means of compliance with the CS-25 certification specifications relative to Appendix O icing conditions, the ice protection system for a new or derivative aeroplane, and the related equipment or components comprising the system, should demonstrate a reliability level consistent with a Functional Hazard Assessment (FHA) as per CS 25.1309(b). The classification and assessment of failure conditions need only consider the effects of Appendix C icing conditions.

5.4 Ice or Icing Conditions Detection

If the new or derivative model being certified has similar ice and/or icing conditions detection means as the reference fleet, including installation and operational considerations (e.g. flight crew procedures), then a comparative analysis may be used to show compliance with Appendix O-related certification specifications.

If the applicant chooses to introduce a new ice and/or icing conditions detection technology and show compliance at the aeroplane level based on a reference fleet with unrestricted operations, and the applicant is seeking certification by comparative analysis for unrestricted operations in SLD icing conditions for the new or derivative model per CS 25.1420(a)(3), the new ice and/or icing conditions detection technology should be installed and operate in a manner that results in equivalent ice and/or icing conditions detection performance. This may include additional qualification to the icing conditions represented by Appendix C.

If the certification option chosen requires a differentiation between icing conditions (CS 25.1420(a)(1) or (a)(2)), then either the reference fleet should have demonstrated the ability to detect that the aeroplane is operating in conditions that exceed the conditions selected for certification (i.e. for CS 25.1420(a)(1), any Appendix O icing conditions; and for CS 25.1420(a)(2), the icing conditions that are beyond the selected portion of Appendix O), or the ice and/or icing conditions detection means should be substantiated for detection of the applicable Appendix O icing conditions at the aeroplane level.

If the reference fleet has achieved the required number of flights to enable the use of a comparative analysis to show compliance with the CS-25 certification specifications relative to Appendix O, then Appendix C may be used to show compliance with the certification specifications related to ice accretions before the ice protection system has been activated and is performing its intended function (e.g. CS 25.1419(e), CS 25.143(j) and CS 25.207(h)).

5.5 Unprotected Components

For systems that are required to operate in Appendix O icing conditions but do not require ice protection provisions, for example the Autopilot (CS 25.1329), wing illumination lights (CS 25.1403), unprotected environmental control system (ECS) intakes (CS 25.1420), etc., a comparative analysis may be used if design features are shown to be similar to those of the reference fleet.

5.6 Ice Accretion and Ice Shedding Sources

If a comparative analysis is used as the means of compliance with the CS-25 certification specifications relative to Appendix O icing conditions, certification ice shapes/ice data determined for Appendix C icing conditions are acceptable without additional Appendix O considerations. The locations where ice accretions may occur on the new or derivative model should be reviewed and compared to those of the reference fleet. The following aspects should be considered:

i. An analysis showing that, in Appendix C icing conditions, the propulsion system and APU installation are such that the geometry and water catch of potential sources of ice shedding are similar to those used to establish the reference fleet history database.

ii. A comparison of the location of, or the methodology for locating, flight instrument external probes to assure that the effect of airframe ice accretion forward of the probes will be comparable for the new or derivative model with that of the reference fleet relative to safe flight in the icing conditions of Appendix C.

iii. For aeroelastic analyses, performance of an analysis showing ice accretion consistency (location and volume), defined using the icing conditions of Appendix C.

5.7 Aeroplane Performance and Handling Characteristics

The comparative analysis should substantiate that the effects of ice accretion and the agreed key parameters of the new or derivative model are comparable to those of the reference fleet. The applicant should substantiate by analysis, test, or a combination of both, that the new or derivative aeroplane will have similar margins to those of the reference fleet for flight in the icing conditions of Appendix C.

The following paragraphs provide guidance on how to achieve the above:

— Aeroplane performance,

— Aeroplane controllability and manoeuvrability,

— Aeroplane trim,

— Aeroplane stability,

— Aeroplane stalls.

5.7.1 Performance

The effects on aeroplane performance of the certification ice shapes/ice shape data determined for flight in the icing conditions of Appendix C for the new or derivative model should be comparable to those of the reference fleet. A comparison of ice accretion effects on lift and drag may be used in this analysis.

If comparable effects to those of the reference fleet cannot be shown, then the applicant should show how margins similar to those of the reference fleet are restored for the new or derivative model by other means that compensate for the effect (e.g. airspeed increase, sizing criteria, or other aeroplane limitations).

5.7.2 Controllability and Manoeuvrability

The effectiveness of the control surfaces and the control forces for the new or derivative model, with the certification ice shapes/ice shape data for flight in the icing conditions of Appendix C, should be comparable to those of the reference fleet. If critical Appendix C ice shapes affect the control surface effectiveness or control forces in a manner which may be different to that of the reference fleet, then the applicant should show how the control effectiveness and forces are retained.

The manoeuvrability associated with the certification ice shapes/ice shape data determined for the icing conditions of Appendix C should be comparable to those of the aeroplanes which comprise the reference fleet. If critical Appendix C ice shapes affect manoeuvrability in a manner which may be different to that of the reference fleet, then the applicant should show how the margins are retained (speed increase, etc.).

5.7.3 Trim

In addition to showing that trim capability for the new or derivative model, with the certification ice shapes/ice shape data for flight in the icing conditions of Appendix C, is comparable to that of the reference fleet, the margins between the required trim in the most critical conditions and the trim capability in Appendix C icing conditions should be comparable to those of the reference fleet.

5.7.4 Stability

The aeroplane stability associated with the certification ice shapes/ice shape data determined for the icing conditions of Appendix C should be comparable to those of the reference fleet. If this cannot be shown, then the applicant should show how similar stability margins are retained (speed increase, sizing criteria, other aircraft limitations, etc).

5.7.5 Stalls

a. Stall warning and protection features

Stall warning, stall protection, and/or airspeed awareness methods, devices, and/or systems as applicable should be shown by comparative analysis to be similar in function or improved relative to those of the reference fleet.

b. Stall warning margins

Stall warning margins established with the certification ice shapes/ice shape data associated with flight in the icing conditions of Appendix C should be comparable to those of the reference fleet.

c. Stall characteristics

The stall characteristics demonstrated by the new or derivative model with the certification ice shapes/ice shape data for flight in the icing conditions of Appendix C should be comparable to those of the reference fleet.

d. Aeroplane with Flight Envelope Protection

It should be shown that the new or derivative aeroplane and the reference fleet aeroplane(s) high angle-of-attack protection systems have a comparable ability to accommodate any reduction in stalling angle of attack with the certification ice shapes/ice shape data for flight in the icing conditions of Appendix C relative to the clean aeroplane.

The high angle-of-attack characteristics demonstrated with the certification ice shapes/ice shape data for flight in the icing conditions of Appendix C should be comparable to those of the reference fleet.

5.8 Aeroplane Fight Manual Information

If the certification option chosen for the new or derivative model being certified (CS 25.1420(a)(1), (a)(2), or (a)(3)) is consistent with the operation of the reference fleet, then the information to be provided in the AFM may be based on that provided in the reference fleet AFM(s) or other operating manual(s) furnished by the TC holder.

5.9 Additional Considerations — Augmenting Comparative Analysis

In addition to the use of design features and/or margins, to substantiate a new or derivative design by comparative analysis, the applicant may augment the comparative analysis with other methodologies (e.g. test, analysis or a combination thereof). The new methodologies should be agreed with the Agency.

[Amdt 25/16]
[Amdt 25/18]

CS 25.1421 Megaphones

ED Decision 2003/2/RM

If a megaphone is installed, a restraining means must be provided that is capable of restraining the megaphone when it is subjected to the ultimate inertia forces specified in CS 25.561(b)(3).