European Aviation Safety Agency

21 Mar 2011

NOTICE OF PROPOSED AMENDMENT (NPA) NO 2011-03

DRAFT DECISION OF THE EXECUTIVE DIRECTOR OF THE EUROPEAN AVIATION SAFETY AGENCY

Amending Decision No. 2003/2/RM of the Executive Director of the European Aviation Safety Agency of 17 October 2003 on

Certification Specifications, including airworthiness codes and acceptable means of compliance, for large aeroplanes ("CS-25")

"Large Aeroplane Certification Specifications in Supercooled Large Drop, Mixed phase, and Ice Crystal Icing Conditions"

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A. Explanatory Note

I. General

1. The purpose of this Notice of Proposed Amendment (NPA) is to envisage amending Decision No. 2003/2/RM of the Executive Director of the European Aviation Safety Agency of 17 October 2003 on Certification Specifications, including airworthiness codes and acceptable means of compliance, for large aeroplanes ("CS-25")[1]. The scope of this rulemaking activity is outlined in Terms of Reference (ToR) 25.058 and is described in more detail below.

2. The European Aviation Safety Agency (hereinafter referred to as the Agency) is directly involved in the rule-shaping process. It assists the Commission in its executive tasks by preparing draft regulations, and amendments thereof, for the implementation of the Basic Regulation[2] which are adopted as "Opinions" (Article 19(1)). It also adopts Certification Specifications, including Airworthiness Codes and Acceptable Means of Compliance and Guidance Material to be used in the certification process (Article 19(2)).

3. When developing rules, the Agency is bound to follow a structured process as required by Article 52(1) of the Basic Regulation. Such process has been adopted by the Agency's Management Board and is referred to as "The Rulemaking Procedure"[3].

4. This rulemaking activity is included in the Agency's Rulemaking Programme for 2011-2014. It implements the rulemaking task 25.058 "Large Aeroplane Certification Specifications in Supercooled Large Drop, Mixed phase, and Ice Crystal Icing Conditions".

5. The text of this NPA has been developed by the Agency. It is submitted for consultation of all interested parties in accordance with Article 52 of the Basic Regulation and Articles 5(3) and 6 of the Rulemaking Procedure.

II. Consultation

6. To achieve optimal consultation, the Agency is publishing the draft Decision of the Executive Director on its Internet site. Comments should be provided within 3 months in accordance with Article 6 of the Rulemaking Procedure. Comments on this proposal should be submitted by one of the following methods:

CRT:	Send your comments using the Comment-Response Tool (CRT) available at **http://hub.easa.europa.eu/crt/**.
E-mail:	Comments can be sent by e-mail only in case the use of CRT is prevented by technical problems. The(se) problem(s) should be reported to the CRT webmaster and comments sent by e-mail to NPA@easa.europa.eu.
Correspondence:	If you do not have access to the Internet or e-mail, you can send your comment by mail to:

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[1] Decision as last amended by Executive Director Decision 2010/005/R of 05 August 2010 (CS-25 Amendment 9).

[2] Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC (OJ L 79, 19.03.2008, p. 1). Regulation as last amended by Commission Regulation (EC) 1108/2009 of the European Parliament and of the Council of 21 October 2009 (OJ L 309, 24.11.2009, p. 51).

[3] Management Board decision concerning the procedure to be applied by the Agency for the issuing of opinions, certification specifications and guidance material (Rulemaking Procedure), EASA MB 08-2007, 13.6.2007.

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Comments should be submitted by 22 June 2011. If received after this deadline, they might not be taken into account.

III. Comment response document

7. All comments received in time will be responded to and incorporated in a comment response document (CRD). The CRD will be available on the Agency's website and in the Comment-Response Tool (CRT).

IV. Content of the draft Opinion/Decision

8. Summary

This NPA proposes to update large aeroplanes Certification Specifications (CS-25) for flight in icing conditions. This proposal takes into account the service experience from large aeroplanes. JAA, FAA and EASA previously took special measures as a quick reaction to some events in order to minimise the safety risk from severe icing conditions (this included Airworthiness Directives for in-service aircraft and an Interim Policy for certification of new aircraft). An international working group (led by the Aviation Rulemaking Advisory Committee (ARAC), tasked by the Federal Aviation Administration (FAA), USA) worked between 1997 and 2009 to prepare recommendations for a regulation change. These recommendations have been reviewed and analysed by the Agency and an update of CS-25 is proposed. A new icing environment is proposed that includes supercooled large drops, mixed phase and ice crystal icing conditions.

The Agency also proposes a revision of the requirements for engine air intake system de-icing and anti-icing with an update of the freezing fog conditions and the introduction of falling and blowing snow conditions.

Concurrently with these changes to CS-25, the Agency also proposes to update the icing Certification Specifications for turbine engines (CS-E); these CS-E changes are proposed under NPA 2011-04.

The present NPA addresses the rule in Book 1 of CS-25. The Agency will publish another NPA dedicated to the related Book 2 advisory material (new material and modification of the existing material). The publication is expected during the second quarter of 2011.

9. The envisaged changes to Decision 2003/2/RM ("CS-25") are:

In Book 1:

Amend CS 25.21, amend CS 25.105, amend CS 25.111, amend CS 25.119, amend CS 25.121, amend CS 25.123, amend CS 25.125, amend CS 25.143, amend CS 25.207, amend CS 25.237, amend CS 25.253, amend CS 25.773, amend CS 25.903, amend CS 25.929, amend CS 25.1093, amend CS 25.1323, create a new CS 25.1324, amend CS 25.1325, amend CS 25.1326, create a new CS 25.1420, amend CS 25.1521, amend CS 25.1533, create Appendix O, create Appendix P.

10. Background

It has been evidenced that the icing environment used for certification of large aeroplanes and turbine engines needs to be expanded in order to improve the level of safety when operating in icing conditions.

On 31 October 1994, near Roselawn, Indiana-USA, an accident involving an Avions de Transport Régional ATR 72 occurred in icing conditions believed to include freezing drizzle drops. Indeed, the accident investigation led to the conclusion that freezing drizzle conditions created a ridge of ice on the wings' upper surface aft of the de-icing boots and forward of the ailerons. It was further concluded that the ridge of ice resulted in an un-commanded roll of the aeroplane. The atmospheric condition (freezing drizzle) that may have contributed to the accident is outside the existing CS-25 Appendix C icing envelope that is used for certification of large aeroplanes.

Another atmospheric icing condition which aeroplanes may experience and that is outside of the Appendix C icing envelope is freezing rain. These kinds of icing conditions constitute an icing environment known as Supercooled Large Drops (SLDs).

Following the ATR 72 accident, the National Transportation Safety Board in the USA (NTSB) recommended updating aeroplanes icing conditions specifications. Although some knowledge existed at this date about severe icing conditions, including SLD, it was not possible to immediately update the icing environment in the Certification Specifications, because there was a need to identify in detail the parameters of the relevant environmental envelopes applicable to aircraft operations and to accurately assess the associated safety risk; in addition, the methods of compliance by aircraft manufacturers with potential new icing environment requirements had to be investigated (capabilities in terms of engineering tools, ground test facilities, flight tests). This was recognised as a very complex task requiring various expertises. Therefore, an Aviation Rulemaking Advisory Committee (ARAC) was tasked by the Federal Aviation Administration (FAA) in December 1997, through its Ice Protection Harmonization Working Group (IPHWG), to perform the following actions:

- Define an icing environment that includes SLDs;
- Consider the need to define a mixed phase icing environment (supercooled liquid and ice crystals);
- Devise requirements to assess the ability of an aeroplane to either safely operate without restrictions in these conditions or safely operate until it can exit these conditions;
- Study the effects icing requirement changes could have on FAR/JAR 25.773 Pilot compartment view, 25.1323 Airspeed indicating system, and 25.1325 Static pressure systems.
- Consider the need for a regulation on ice protection for angle of attack probes.

Service experience of different engine types installed on CS-25 aircraft has also identified the potential for a multiple engine failure during take-off, after prolonged ground operation in freezing fog. A multiple engine failure during take-off would compromise safe flight and landing.

Moreover, falling and blowing snow is a weather condition, which needs to be considered for the powerplants and essential Auxiliary Power Units (APUs) of transport aeroplanes. Although snow conditions can be encountered on the ground or in flight, there is little evidence that snow can cause adverse effects in flight on turbojet and turbofan engines with traditional Pitot style inlets where protection against icing conditions is provided. However, service history has shown that in-flight snow (and mixed phase) conditions have caused power interruptions on some turbine engines and APUs with inlets that incorporate plenum chambers, reverse flow, or particle separating design features.

The proposed rule is based on the recommendations of the ARAC group. The ARAC IPHWG task 2 report rev A along with the task 2 phase IV review (submitted on 29 June 2009) are available on the FAA website[4].

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[4] Under Regulations & Policies\Advisory and Rulemaking Committees\Advisory Committees\Aviation Rulemaking Advisory Committee\Transport Airplane and Engine\Active Working Groups\Ice. Protection Harmonization.

The Agency also considered the rule proposed by FAA in their Notice of Proposed Rulemaking (NPRM) "Airplane and Engine Certification Requirements in Supercooled Large Drop, Mixed Phase, and Ice Crystal Icing Conditions" dated 29 June 2010 (Docket No. FAA-2010-0636; Notice No. 10-10). It is the objective of the Agency to harmonise as much as possible with FAA regulation. Meanwhile, some differences exist compared to the FAA proposal and they are identified and explained on the following pages.

11. Existing CS-25 Certification Specifications for operation in icing conditions

CS-25 provides for a set of requirements involving protection systems and aeroplane operation performances.

CS 25.1419 (Ice protection) requires the aeroplane to be able to "safely operate in the continuous maximum and intermittent maximum icing conditions of Appendix C".

Minimum performance and handling qualities, as well as methods to detect airframe icing and to activate and operate ice protection systems are also required in these icing conditions. These specifications were introduced respectively in CS-25 Amendment 3 (refer to NPA 16/2004 "Flight in icing conditions") and Amendment 7 (refer to NPA 2009-08 "Activation of ice protection system and update of ETSO C16 for electrically heated Pitot and Pitot-static tubes"). They can be found in the following paragraphs of Subpart B: CS 25.21(g) (Proof of compliance), CS 25.103(b)(3) (Stall speed), CS 25.105(a) (Take-off), CS 25.107(h) (Take-off speeds), CS 25.111(c)(5) (Take-off flight path), CS 25.119(b) (Landing climb: all engines operating), CS 25.121(b)(2), (c)(2)and (d)(2) (Climb: one engine inoperative), CS 25.123(b) (En-route flight paths), CS 25.125 (Landing), CS 25.143(Controllability and manoeuvrability – General), CS 25.207 (Stall warning), CS 25.237 (Wind velocities), CS 25.253(c) (High-speed characteristics).

Appendix C to CS-25 provides the atmospheric icing conditions and the ice accretions to be used for showing compliance with the requirements of CS-25 Subpart B "Flight" mentioned above.

The atmospheric conditions are defined by the variables of the cloud liquid water content and horizontal extent, the mean effective diameter of the cloud droplets, the ambient air temperature and the interrelationship of these three variables. The icing environment is also limited in terms of pressure altitude: 0-6700m (0-22,000ft) for the continuous maximum icing conditions (stratiform clouds) and 1000-9500m (3000-31,000ft) for the intermittent maximum icing (cumuliform clouds).

CS 25.1093(b) provides requirements for turbine engines air intake system de-icing and anti-icing.

CS 25.1093(b)(1) requires turbine engine safe operation throughout Appendix C icing conditions.

CS 25.1093(b)(2) defines test conditions in order to demonstrate the safe operation of the powerplant systems in freezing fog conditions at idle on ground.

12. Existing operational regulation in the European Union for flight in icing conditions

Commission Regulation (EC) No 859/2008 of 20 August 2008 provides in its Annex III common technical requirements and administrative procedures to commercial air transportation by aeroplanes.

According to OPS 1.675, the operator shall not operate an aeroplane in expected or actual icing conditions unless the aeroplane is certificated and equipped to operate in icing conditions. For night operations, the aeroplane must also be equipped with a means to illuminate or detect the formation of ice.

In addition, this regulation requires protection of the airspeed indicating system in the following cases:

For day VFR operations, OPS 1.650 requires each airspeed indicating system being equipped with a heated Pitot tube or equivalent means for preventing malfunction due to either condensation or icing for: aeroplanes with a maximum certificated take-off mass in excess of 5,700 kg or having a maximum approved passenger seating configuration of more than 9; aeroplanes first issued with an individual certificate of airworthiness on or after 1 April 1999.

For IFR or night operations, OPS 1.652 requires an airspeed indicating system with heated Pitot tube or equivalent means for preventing malfunctioning due to either condensation or icing including a warning indication of Pitot heater failure. The Pitot heater failure warning indication requirement does not apply to those aeroplanes with a maximum approved passenger seating configuration of nine or less or a maximum certificated take-off mass of 5,700 kg or less and issued with an individual Certificate of Airworthiness prior to 1 April 1998.

13. JAA, FAA and EASA actions taken to minimise the safety risk from severe icing conditions

Following the ATR 72 accident in 1994, measures were taken to minimise the potential hazard associated with certain aeroplanes operating in severe icing conditions.

Several Airworthiness Directives (AD) have been issued to require certain aeroplanes to exit severe icing conditions when visual cues indicate that these conditions exceed the capabilities of the ice protection equipment. These ADs are applicable to aeroplanes equipped with unpowered roll controls and pneumatic de-icing boots.

JAA issued interim policy INT/POL/25/11 "Severe Icing Conditions" (dated 1 October 1998) and FAA produced a generic issue paper "Roll control in Supercooled Large Droplet conditions". These policies have been applied to certify new aeroplanes equipped with unpowered roll controls and pneumatic de-icing boots, because service experience revealed issues on these types of aircraft (like the ATR 72). EASA would also use a CRI (Certification Review Item) providing Special Conditions for new certification projects based on JAA INT/POL/25/11. The intent is to ensure protection against loss of control by providing for means of detection and exiting from freezing drizzle and freezing rain conditions. However, they are not intended to certify an aeroplane for unrestricted flight in Supercooled Large Drops or any other conditions which are outside of the Appendix C icing envelope.

14. Discussion of the CS-25 rule change proposal

a. General

It is proposed to amend CS-25 to better protect large aeroplanes certificated for flight in icing conditions. The new icing environment would include Supercooled Large Drops, Mixed Phase and Ice Crystals. We also propose to update the requirements for turbine engine air intake system protection (updated freezing fog conditions and new falling and blowing snow conditions). In connection with this proposal, an amendment of CS-E to update turbine engine Certification Specifications is proposed through NPA 2011-04.

The Agency considered and analysed the IPHWG recommendations, the FAA NPRM "Airplane and Engine Certification Requirements in Supercooled Large Drop, Mixed Phase, and Ice Crystal Icing Conditions" dated 29 June 2010 (Docket No. FAA-2010-0636; Notice No. 10-10), and all the lessons from in-service large aeroplanes.

Our proposal mainly differs from the FAA's proposal on the following points:

- The new proposed SLD environment would be applicable to all new large aeroplanes (not limited to a category of large aeroplane),
- The mixed phase and ice crystals environment for flight instrument external probes: we propose to use the Part 33 Appendix D proposed by the IPHWG, which would be applicable to all flight instrument external probes (not limited to Pitot tubes and Angle of attack sensors),

- We propose to clarify and extend the existing provisions requiring alerting flight crews when an installed flight instrument external probes anti-ice or de-ice system is not operating normally.

(More explanations are provided under chapter "16.Differences compared to the FAA NPRM".)

b. Review of accidents and incidents lessons

The IPHWG reviewed icing events involving large aeroplanes and found accidents and incidents that are believed to have occurred in icing conditions that are not addressed by the current regulations. Therefore these icing conditions must be considered for introduction in the Certification Specifications for large aeroplanes.

These icing conditions resulted in flight crews losing control of their aircraft and, in some cases, engine power loss. The IPHWG events review found hull losses and fatalities associated with SLD conditions, but not for ice crystal and mixed phase conditions. The proposed rule would provide a SLD environment in an Appendix O to CS-25.

However, there have been a number of engine power loss events reports during the last two decades, which occurred in presence of ice crystals and mixed phase. Some of them involved multi-engine power loss. Although the events did not result in accidents, they are considered as a serious safety threat.

The incident history also indicates that flight crews have experienced temporary loss of or erroneous airspeed indications in severe icing conditions (in areas of deep convection). Airspeed indications on large aeroplanes are derived from the difference between two air pressures—the total pressure, as measured by a Pitot tube mounted somewhere on the fuselage, and the ambient or static pressure, as measured by a static port. The static port may be flush mounted on the aeroplane fuselage or co-located on the Pitot tube. When the static and Pitot systems are co-located, the configuration is referred to as a Pitot-static tube. Static ports are not prone to collecting ice crystals, either because of their flush mounted locations or their overall shape. Due to the way Pitot or Pitot-static tubes are usually mounted, they are prone to collecting ice crystals. Encountering high concentrations of ice crystals may lead to blocked Pitot or Pitot-static tubes because the energy necessary to melt the ice crystals can exceed the tube heating system capability, or the water formed by the melting process is not completely evacuated and it can re-freeze downstream inside the tube. Pitot or Pitot-static tube blockage can lead to errors in measuring airspeed.

The IPHWG did not identify any events due to ice accumulations on probes that are used to measure angle of attack, or other angle of attack sensors. However, the IPHWG determined there are angle of attack probe designs that are susceptible to mixed phase conditions.

Moreover, events of malfunctioning and/or damage to temperature probes have also been reported to EASA and attributed to severe adverse environment encounters.

The proposed rule would therefore require any flight instrument external probe to operate normally in a new ice crystal and mixed phase environment (proposed Appendix P of CS-25).

Some incidents have evidenced that Pitot probes heating system abnormal operating must be better monitored and indicated to the flight crews. Indeed, some failures of the heating resistance (such as an out-of-tolerance resistance) could not be detected. The existing CS-25 provisions thus need to be clarified and updated.

In addition, service history has shown that in flight snow (and mixed phase) conditions have caused power interruptions on some turbine engines and APUs with inlets that incorporate plenum chambers, reverse flow, or particle separating design features.

Finally, service experience of different engine types has identified the potential for a multiple engine failure during take-off, after prolonged ground operation in freezing fog. A multiple engine failure during take-off would compromise safe flight and landing. Recent events have occurred at both Northern European and North American airports. In one event, the damage to the engines was not detected until a number of flights later when one engine surged in cruise requiring the throttle to be retarded to idle for the remainder of the flight. Subsequent examination identified mechanical damage to the compressors of both engines. The damage was identified to have occurred during take-off after operation at idle on the ground in freezing fog conditions below –10°C for a period greater than one hour. Ice accreted on the engine static structure and subsequent acceleration to take-off caused the ice to shed, which resulted in damage to the compressor.

c. EASA certification interim measures

Related to the SLD environment, as mentioned in paragraph 13, Certification Review Items (Special Conditions) based on JAA interim policy INT/POL/25/11 "Severe Icing Conditions" (dated 01 October 1998) could be used by EASA if a relevant application was received (for aeroplanes equipped with unpowered roll controls and pneumatic de-icing boots). (Note: since the EASA creation in 2003, no application was received).

Related to Mixed Phase and Ice Crystals environment, the Agency also issued a generic CRI (Interpretative Material) entitled "Flight Instrument External Probes – Qualification in Icing Conditions". Flight instrument external probes (including, but not necessarily limited to Pitot probes, alpha vanes, side slip vanes and temperature probes) are requested to be evaluated against specified icing conditions including supercooled droplets, ice crystals, mixed phase and rain droplets. It has been introduced to certification projects by JAA since 2001. More recently, for the reasons explained before, the Agency has decided to strengthen the Interpretative Material and to develop a Special Condition which will be applicable to all new applications since 31 January 2010.

Concerning turbine engines, another CRI has been created to clarify that "Pitot" type engine intakes need to be assessed against ice crystal conditions mentioned in AMC E.780. The CRI makes clear that the existing AMC E.780 statement that this type of intake is not susceptible to ice crystal is no longer acceptable.

Freezing fog: a generic CRI is used in order to avoid any unsafe conditions resulting from prolonged exposure to freezing fog beyond the conditions demonstrated during compliance demonstration to CS-25. The conditions defined in current CS 25.1093(b)(2), in terms of time and temperature, are considered as limitations necessary for the safe operation in freezing fog, as per CS 25.1501, and they must be available to the crew in the AFM. Meanwhile, the applicant may demonstrate capability beyond the conditions of CS 25.1093(b)(2).

Falling and blowing snow: a generic CRI is used for analysis of falling and blowing snow on turbine engine and APUs. For turbojet and turbofan engines with traditional Pitot (straight duct) type inlets, icing conditions are generally regarded as a more critical case than falling and blowing snow. For these types of inlet, compliance with the icing requirements will be accepted in lieu of any specific snow testing or analysis. For non-Pitot inlet types, demonstration of compliance with the falling and blowing snow ground conditions should be conducted by tests and/or analysis. The CRI then provides the test conditions to be used by the applicant.

d. The Supercooled Large Drop (SLD) icing conditions: new Appendix O

It is proposed to create CS-25 Appendix O which would provide a new SLD environment in addition to the existing CS-25 Appendix C icing environment. The Appendix O would be structured in two parts like the existing Appendix C.

The first part would define the SLD icing conditions and the second part would define the ice accretions to be considered, based on the first part conditions.

e. The new requirements in SLD icing conditions

A) General

The proposed new CS 25.1420 would add safety requirements that must be met in SLD icing conditions for large aeroplanes to be certified for flight in icing conditions. This change would require evaluating the operation of these aeroplanes in the SLD icing environment; developing a means to differentiate between different SLD icing conditions, if necessary; and developing procedures to exit all icing conditions. The proposed rule would require consideration of the SLD icing conditions (freezing drizzle and freezing rain) defined in the proposed new CS-25 Appendix O, part I, in addition to the existing CS-25 Appendix C icing conditions. The proposed Appendix O was developed by the ARAC IPHWG, which included meteorologists and icing research specialists from industry, FAA/FAA Tech Center, Meteorological Services Canada, National Aeronautics and Space Administration (NASA) and Transport Canada/Transport Development Center. The IPHWG collected and analysed airborne measurements of pertinent SLD variables and developed an engineering standard to be used in aircraft certification. Appendix O would include drop sizes larger than those considered by the current icing Appendix C. These larger drops impinge and freeze farther aft on aeroplane surfaces than the drops defined in Appendix C and may affect the aeroplane's performance, handling qualities, flutter characteristics, and engine and systems operations. The Appendix O icing conditions, if adopted, may affect the design of aeroplane ice protection systems.

The Appendix O SLD icing conditions would be those in which the aeroplane must be able to either safely exit following the detection of any or specifically identified Appendix O icing conditions, or safely operate without restrictions. Specifically, the proposed CS 25.1420 would allow three options:

- Detect Appendix O conditions and then operate safely while exiting all icing conditions (CS 25.1420(a)(1)).
- Safely operate in a selected portion of Appendix O conditions, detect when the aeroplane is operating in conditions that exceed the selected portion, and then operate safely while exiting all icing conditions (CS 25.1420(a)(2)).
- Operate safely in all of the Appendix O conditions (CS 25.1420(a)(3)).

B) Analysis and tests requirements

To establish that an aeroplane could operate safely in the proposed Appendix O conditions described above, the proposed CS 25.1420(b) would require both analysis and one test, or more as found necessary, to establish that the ice protection for the various components of the aeroplane is adequate. The words ''as found necessary'' would be applied in the same way as they are applied in CS 25.1419(b).

During the certification process, the applicant would demonstrate compliance with the rule using a combination of analyses and test(s). The applicant's means of compliance would consist of analyses and the amount and types of testing it finds necessary to demonstrate compliance with the regulation. The applicant would choose to use one or more of the tests identified in paragraphs

CS 25.1420(b)(1) through (b)(5). Although the applicant may choose the means of compliance, it is ultimately the EASA that determines whether the applicant has performed sufficient test(s) and analyses to substantiate compliance with the rule. Similarly, the words ''as necessary,'' which appear in CS 25.1420(b)(3) and (b)(5), would result in the applicant choosing the means of compliance that is needed to support the analysis, but the EASA would make a finding whether the means of compliance is acceptable.

C) Similarity analysis

The Agency is considering the possibility of taking credit from in-service experience to demonstrate compliance with the proposed rule, as explained here below. This option could be explained and included in the AMC material. <u>We invite stakeholders to comment on this option.</u>

If an applicant has adequate data, based on extensive experience from its own CS-25 aircraft in-service fleet, a similarity analysis may be used in lieu of the analysis and tests required by CS 25.1420(b). Although SLD icing conditions are hazardous, accidents and incidents involving this type of meteorological condition mainly concern certain types of large aeroplanes; events essentially involved aeroplanes with a maximum take-off weight less than 27000 kg (60000 lbs), reversible flight controls, de-icing protection systems (e.g. de-icing boots as opposed to thermal anti-icing systems). Many currently certified large aeroplanes have been proven by their field service experience to be safe to operate in these conditions.

New large aeroplanes designs, similar to those of which have proven safe operation in SLD icing conditions, would be allowed to show compliance by comparative analysis. This comparison would only be allowed with aeroplane types held by the same applicant.

If this approach is retained, this would require adding a corresponding reference in CS 25.21(g) and CS 25.1420(b).

D) Ice protection system activation and operation

For an aeroplane certified to operate in at least a portion of the proposed Appendix O icing conditions, the proposed CS 25.1420(c) would extend the requirements of CS 25.1419(e), (f), (g), and (h) to include activation and operation of airframe ice protection systems in the Appendix O icing conditions for which the aeroplane is certified. The proposed CS 25.1420(c) would not apply to aeroplanes certified to proposed CS 25.1420(a)(1) since proposed CS 25.1420(a)(1) would require a method to identify and safely exit all Appendix O conditions.

The proposed Appendix O defines SLD conditions. It was developed by the ARAC IPHWG, which included meteorologists and icing research specialists from industry, FAA/FAA Tech Center, Meteorological Services of Canada, National Aeronautics and Space Administration (NASA), and Transport Canada/Transport Development Center. The IPHWG collected and analysed airborne measurements of pertinent SLD variables, developed an engineering standard to be used in aircraft certification, and recommended that standard to the FAA.

The SLD conditions defined in Appendix O Part I include freezing drizzle and freezing rain conditions. The freezing drizzle and freezing rain environments are further divided into conditions in which the drop median volume diameters are either less than or greater than 40 microns. Appendix O consists of measured data that was divided into drop distributions within these four icing conditions. These distributions were averaged to produce the representative distributions for each condition.

The distributions of drop sizes are defined as part of Appendix O. The need to include the distributions comes from the larger amount of mass in the larger drop diameters of Appendix O. The water mass of the larger drops affects the amount of water that impinges on aeroplane components, the drop impingement, icing limits, and the ice build-up shape.

Appendix O also provides a liquid water content scale factor that would be used to adjust the liquid water content for freezing drizzle and freezing rain. The scale factor is based on the liquid water contents of continuous freezing drizzle and freezing rain conditions decreasing with increasing horizontal extents.

Note: Figure 7 of Appendix O Part I ("Horizontal Extent") is slightly different compared to the one published in the IPHWG report. FAA published an updated curve in their NPRM based on information from the specialist (Environment Canada) author of the curve provided to the IPHWG. We use also this new curve in our proposal.

f. Performance and Handling Qualities

A) Description of the requirements

The ice accretion definitions in the proposed Appendix O Part II and the proposed revisions to the performance and handling qualities requirements for flight in icing conditions are similar to those currently required for flight in Appendix C icing conditions. The proposals address the three options allowed by proposed CS 25.1420(a). The proposed Appendix O Part II would contain definitions of the ice accretions appropriate to each phase of flight.

The proposed Appendix O Part II(b) would define the ice accretions used to show compliance with the performance and handling qualities requirements for any portion of Appendix O in which the aeroplane is not certified to operate.

The proposed Appendix O Part II(c) would define the ice accretions for any portion of Appendix O in which the aeroplane is certified to operate.

The proposed Appendix O Part II(d) would define the ice accretion in Appendix O conditions before the airframe ice protection system is activated and is performing its intended function to reduce or eliminate ice accretions on protected surfaces. This ice accretion would be used in showing compliance with the controllability and stall warning margin requirements of CS 25.143(j) and CS 25.207(h), respectively, that apply before the airframe ice protection system has been activated and is performing its intended function.

Even if the aeroplane is certified to operate only in a portion of the Appendix O icing conditions, the ice accretion used to show compliance with CS 25.143(j) and CS 25.207(h) must consider all Appendix O icing conditions (indeed, the initial entry into icing conditions may be into Appendix O icing conditions in which the aeroplane is not certified to operate).

To reduce the number of ice accretions needed to show compliance with CS 25.21(g), the proposed Appendix O Part II(e) would allow the option of using an ice accretion defined for one flight phase for any other flight phase if it is shown to be more critical than the ice accretion defined for that other flight phase.

The existing CS 25.21(g)(1) requires that the performance and handling qualities requirements of CS-25 Subpart B, with certain exceptions, be met in Appendix C icing conditions. The proposed CS 25.21(g)(2) would identify the performance and handling qualities requirements that must be met to ensure that an aeroplane certified to either the proposed CS 25.1420(a)(1) or (a)(2) could safely exit icing if the icing conditions of proposed Appendix O, for which certification is not sought, are encountered. Such an aeroplane would not be approved to take off in proposed Appendix O icing conditions and would only need to be able to detect and safely exit those icing conditions encountered en route. Therefore, it is proposed that, in addition to the exceptions identified in the existing CS 25.21(g)(1), such an aeroplane would not need to meet certain requirements for Appendix O icing conditions.

With one exception, for an aeroplane certified under proposed CS 25.1420(a)(1) or (a)(2), the same handling qualities requirements that must currently be met for flight in Appendix C icing conditions are proposed for flight in Appendix O icing conditions for which certification is not sought. That exception is CS 25.143(c)(1), which addresses controllability following engine failure during takeoff at V2. Compliance with that rule would not be necessary since the aeroplane would not be approved for takeoff in Appendix O icing conditions. No justification for a relaxation of other handling qualities requirements could be identified.

The requirements for safe operation in all or any portion of proposed Appendix O icing conditions under proposed CS 25.21(g)(3) are similar to those currently required for Appendix C icing conditions. With one exception, the list of CS-25 Subpart B requirements that currently do not have to be met for flight in Appendix C icing conditions would not have to be met in proposed Appendix O icing conditions. The exception is that compliance with CS 25.121(a), *Climb: One-engine inoperative* would be required for Appendix O icing conditions since, unlike for Appendix C icing conditions, the EASA cannot justify an assumption that the ice accretion in this flight phase can be assumed insignificant. In practice, it is expected that some applicants may use an operating limitation to prohibit takeoff in Appendix O icing conditions. Otherwise, the same rationales behind the requirements are used for both Appendix C and Appendix O icing conditions. For continued operation in Appendix O icing conditions, there should effectively be no degradation in handling qualities, and any degradation in performance should be no greater than that allowed by the rules for Appendix C icing conditions.

B) Consideration about Appendix O, Part II

The Agency is considering an option of moving Part II of Appendix O to CS-25 Book 2. This would then become the AMC material used to show compliance with CS-25 Subpart B using the meteorological data in Part I of Appendix O.

This consideration comes from our assessment of Part II which appears to be relatively detailed and complex. Usually, rules are written at higher level and the possible detailed means of compliance are provided in an AMC. This could also provide more flexibility in the process of showing compliance when interpretation of the requirements is complex and subject to discussions or different views between the parties.

We therefore invite stakeholders to provide their comments about this option. If decided, the same change could be applied to Part I of Appendix C.

g. Component requirements

In certification programmes, both the aeroplane as a whole and its individual components are evaluated for flight in icing conditions. There are several rules in CS-25[5] that contain icing related requirements for specific components. It is proposed to revise those rules to ensure the aeroplane can safely operate in the new icing conditions established in this proposed rule.

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[5] CS 25.773, 25.929, 25.1093, 25.1323, and 25.1325.

CS 25.1419 requires that an aeroplane be able to safely operate in all of the conditions specified in Appendix C, whereas the proposed CS 25.1420 would not require an aeroplane to safely operate in all of the Appendix O icing conditions. Proposed CS 25.1420(a)(1) and (a)(2) only require an aeroplane to be capable of safely exiting icing conditions after encountering an Appendix O icing condition for which that aeroplane will not be certified. The existing rules for pilot compartment view, airspeed indication system, and static pressure system[6] contain requirements for operation in icing conditions.

CS 25.773(b)(1)(ii), for pilot compartment view, would be revised to add requirements for operation in Appendix O icing conditions.

A new paragraph CS 25.1324 *Flight Instrument External Probes Heating Systems* would be created to require each flight instrument external probe system to be heated, or have an equivalent means of preventing malfunction, in the icing conditions specified in Appendix C, Appendix O, in the ice crystals and mixed phase conditions of Appendix P, and the rain conditions that will be provided in an AMC to CS 25.1324.

This table is based on the EASA CRI interpretative material and is provided in advance here below:

Static air temperature	**Altitude range**		**Liquid water content**	**Horizontal extent**		**Droplet MVD (Median Volume Diameter)**
Degrees Celsius	Feet (ft)	Meter (m)	(g/m^3)	Kilometer (km)	Nautical miles (NM)	Microns (µm)
-2 to 0	0 to 10000	0 to 30000	1	100	50	1000
			6	5	3	2000
			15	1	0.5	2000

Flight instrument external probes include but are not limited to Pitot tubes, Pitot-static tubes, static probes, angle of attack sensors, side slip vanes, and temperature probes.

The proposed Appendix P is identical to the FAA proposed Appendix D to Part 33, which originated from the ARAC recommendations. Based on EASA knowledge of service experiences with Pitot probes, the associated convective cloud ice crystal icing envelope (Figure 1 of Appendix P) would cover an important portion but not all of the occurrences. Indeed, EASA is aware of incidents of temporary erroneous airspeed indication which happened at high altitude with static air temperature (SAT) below the current proposed Appendix P limit of -60°C. One of these events happened at (SAT=-70°C, Altitude=45,000ft). Other events occurred at SAT above -60°C but at altitudes outside the proposed Appendix P, figure 1.

For this reason, EASA is envisaging an extension of Appendix P, figure 1 envelope to encompass all the known occurrences, with a minimum temperature of -75°C. This extension should also include the current AMC 25.1419 Ice crystal conditions envelopes. Any comments on this proposal are welcome.

In addition, we propose to revise the existing CS 25.1326 *Pitot heat indication systems*. The objective is to explicitly cover abnormal functioning of the heating system, since incidents evidenced that some failures of the Pitot probe heating resistance may not be detected by the low current detection system. This is considered as a clarification since CS 25.1419(c) already requires that "Caution

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[6] CS 25.773, 25.1323, and 25.1325.

information, such as an amber caution light or equivalent, must be provided to alert the flight crew when the anti-ice or de-ice system is not functioning normally". Consistently with the creation of the new CS 25.1324, paragraph CS 25.1326 would be modified to extend the scope of the requirement to all Flight Instrument External Probes including, but not necessarily limited to Pitot tubes, Pitot-static tubes and static probes, angle of attack sensors, side slip vanes and temperature probes.

In the proposed revision to pilot compartment view requirements and in the proposed new requirements for flight instrument external probes, an aeroplane certified in accordance with CS 25.1420(a)(1) or (a)(2) would not be required to be evaluated for all of Appendix O. For aeroplanes certified in accordance with CS 25.1420(a)(1), the icing conditions that the aeroplane is certified to safely exit following detection must be considered. For aeroplanes certified in accordance with CS 25.1420(a)(2), the icing conditions that the aeroplane is certified to safely operate in, and to safely exit following detection, must be considered. For aeroplanes certified in accordance with CS 25.1420(a)(3), all icing conditions must be considered. Aeroplanes not certified for flight in icing need not consider Appendix O.

The engine air intake system icing paragraph CS 25.1093 and the propeller de-icing paragraph CS 25.929 contain requirements for operation in icing conditions. As a conservative approach to ensure safe operation of an aeroplane in an inadvertent encounter with icing, the existing CS 25.1093 contains requirements for operation in icing conditions, even for an aeroplane that is not approved for flight in icing. Since proposed Appendix O defines icing conditions that also may be inadvertently encountered, CS 25.1093 would be revised to reference Appendix O in its entirety. This would maintain the conservative approach for this paragraph. CS 25.929 (propeller de-icing) would also be revised to reference Appendix O in its entirety. The proposed revision to CS 25.929 also clarifies the meaning of the words ''for aeroplanes intended for use where icing may be expected.'' The intent has been for the rule to be applicable to aeroplanes certified for flight in icing.

CS 25.929 and CS 25.1323 generically reference icing instead of specifically mentioning Appendix C. Historically, the icing conditions specified in Appendix C have been applied to these rules. For clarity, CS 25.929 is revised to specifically reference Appendix C and Appendix O. CS 25.1323 will reference CS 25.1324 which provides the icing conditions to be considered for all flight instrument external probes; similarly, the same reference is added to CS 25.1325 for static probes (and sub-paragraphs to CS 25.1325(b) are created for clarity).

The proposed revisions to icing regulations for pilot compartment view, propellers, engine air intake system icing protection, flight instrument external probe systems would be applicable to all large aeroplanes to ensure safe operation during operations in icing conditions.

The proposed revisions to CS 25.903 would retain the existing regulations and add new sub-paragraphs to be consistent with the proposed CS-E changes in CS-E 780 (please refer to NPA 2011-04). These revisions would allow for approving new aircraft type certification programmes with engines certified to earlier amendment levels. The proposed revisions would make it clear that the proposed CS-E changes would not be retroactively imposed on an already type-certified engine design, unless service history indicated that an unsafe condition was present.

h. Engine and engine installation requirements

The proposed revisions to CS 25.1093 and to CS-E (please refer to NPA 2011-04) would change the icing environmental requirements used to evaluate engine protection and operation in icing conditions. The reason for these changes is that the incident history of some aeroplanes has shown that the current icing environmental requirements are inadequate. The effect of the change would be to require an evaluation of safe operation in the revised icing environment.

The proposed revision to CS 25.1093, applicable to engines air intake systems, restructures Paragraph (b) and adds a new table providing freezing fog conditions to be used for engine ground idle test. In-service events over the recent past years have shown that those conditions may be exceeded in service, as aircraft may remain on the ground for longer than 30 minutes while taxiing or waiting for de-icing procedure. Environmental conditions may also be more severe than the temperature range defined in CS 25.1093(b)(2). Service history has also shown that in flight snow (and mixed phase) conditions have caused power interruptions on some turbine engines and APUs with inlets that incorporate plenum chambers, reverse flow, or particle separating design features. The proposed rules would require engines and engine installations to operate safely throughout the SLD conditions defined in the proposed new Appendix O, the newly defined mixed phase and ice crystal conditions defined in the proposed Appendix P, and in falling and blowing snow.

The proposed Appendix P was developed by the ARAC Engine Harmonization Working Group and the Power Plant Installation Harmonization Working Group, which included meteorologists and icing research specialists from industry, FAA/FAA Tech Center, Meteorological Services of Canada, National Aeronautics and Space Administration (NASA), and Transport Canada/Transport Development Center. It has been recommended as a new Appendix D to FAR Part 33; for more details on the development of this Appendix, refer to FAA report DOT/FAA/AR–09/13 Technical Compendium from Meetings of the Engine Harmonization Working Group, March 2009.

Based on EASA experience, there is at least one engine event which occurred outside the proposed Appendix P, figure 1 envelope (at approximately Altitude=42,000ft and SAT=-65°C). <u>Therefore, as explained above when reviewing Pitot probes incidents, the EASA is considering the extension of Appendix P, figure 1 to encompass all the events.</u>

A new sub-paragraph to CS 25.1521 is proposed to require an additional operating limitation for turbine engine installations during ground operation in icing conditions defined in CS 25.1093(b)(2). That operating limitation would address the maximum time interval between any engine run-ups from idle and the minimum ambient temperature associated with that run-up interval. This limitation is necessary since currently we do not have any specific requirements for run-up procedures for engine ground operation in icing conditions. The engine run-up procedure, including the maximum time interval between run-ups from idle, run-up power setting, duration at power, and the minimum ambient temperature demonstrated for that run-up interval proposed in CS 25.1521, would be included in the Aeroplane Flight Manual in accordance with existing CS 25.1581(a)(1) and CS 25.1583(b)(1). The engine run-up procedure from ground idle to a moderate power or thrust setting is necessary to shed ice build-up on the fan blades before the quantity of ice reaches a level that could adversely affect engine operation if ice is shed into the engine. The proposed revision to CS 25.1521 would not require additional testing. The ice shedding demonstration may be included as part of the CS-E 780 engine icing testing.

i. Additional operating limitations

A new CS 25.1533 sub-paragraph (c) is proposed to establish an operating limitation applicable to aeroplanes that are certified in accordance with proposed CS 25.1420(a)(1) or (a)(2). The flight crews of these aeroplanes would be required to exit all icing conditions if they encounter Appendix O icing conditions that the aeroplane has not been certified to operate in.

15. Differences compared to the FAA NPRM

The proposed CS-25 rules entail several differences compared to the FAA proposal in their NPRM "Airplane and Engine Certification Requirements in Supercooled Large Drop, Mixed Phase, and Ice Crystal Icing Conditions" dated 29 June 2010 (Docket No. FAA-2010-0636; Notice No. 10-10); the main differences are described here below:

a. The applicability of the FAA proposed § 25.21(g) and §25.1420 (Supercooled Large Droplet (SLD) icing conditions) to a certain category of aeroplanes

The FAA proposed the exclusion of aeroplanes with certain attributes (aeroplanes with a maximum takeoff weight (MTOW) less than 60,000 lbs or with reversible flight controls) from the §25.1420 rule requiring the evaluation of the aeroplane in the SLD conditions of the proposed Appendix O. This exclusion is not supported by EASA. Indeed, SLD large drops impinge and freeze farther aft on aeroplane surfaces than the drops defined in the current Appendix C and this may affect the aeroplane's performance, handling qualities on all type of aeroplane.

EASA reviewed the IPHWG Task 2 Report Rev A dated December 2005, which provides explanation on the "minority position" proposition for this exclusion. The main argument put forward by the "minority position" is that safety record of the class of aeroplanes proposed for exclusion support that the current airworthiness requirements of FAR Part 25/CS-25 for flight in icing certification have proven to be sufficient to provide the desired level of safety.

It is agreed that many aeroplanes have been flying safely in SLD conditions for decades.

It is also recognised that existing large aeroplanes designs are less sensitive to lifting surfaces contamination than aeroplanes designs not covered by the proposed exclusion, but we cannot assume that the design will not change on future aeroplanes and that past service experience will remain applicable. The proposed Certification Specifications will be in application for the next decades, and it is difficult today to predict design evolutions.

EASA agrees with the IPHWG "majority position" (ALPA, CAA/UK, FAA/FAA Tech Center, Meterological Services of Canada, NASA, SAAB, Transport Canada/Transport Development Center) in the Appendix F of the IPHWG task 2 report rev A, "Response to exclusion from §25.1420 for aeroplane with certain design features".

Moreover, new on-going large aeroplane projects already tend to use different anti-icing systems compared to previous usual systems: either based on electrical power architectures or they use engine bleed air anti-icing systems in a different way (e.g. running wet instead of fully evaporative). This, combined with different aeroplane aerodynamic characteristics, makes it difficult to anticipate the aeroplane behaviour when flying in the Appendix O environment.

Operational experiences in SLD indicate that CS-25 Appendix C icing conditions standards are no longer sufficient and that the icing conditions standards of CS-25 should be expanded to include SLD, mixed-phase and ice crystal icing envelope without any exclusion of aeroplane class.

EASA therefore proposes a CS 25.1420 rule applicable to all CS-25 large aeroplanes.

b. The mixed phase and ice crystals environment proposed by FAA for Pitot tubes and Angle of Attack sensors (§25.1323 and §25.1324).

The conditions of FAA proposed environment (Table 1 of §25.1323) are already included in the current EASA AMC 25.1419. EASA has been using the proposed conditions for many years and got strong indications, based on recent in-service data, that the proposed Appendix D to FAR Part 33 does better cover the existing environment.

As recognised by FAA on page 37318 of the NPRM, the FAA proposed Table 1 of §25.1323 would not address some known events of airspeed indicating system malfunctions. EASA proposes to use the mixed phase and ice crystal environment provided in FAA Appendix D to FAR Part 33; these conditions are proposed as a new Appendix P to CS-25.

In addition, again based on in-service experience, EASA fully supports the inclusion of a new requirement to cover freezing rain conditions, as suggested by FAA on page 37318 of their NPRM. The EASA proposed rule includes these freezing rain conditions.

c. The applicability of the FAA proposed mixed phase and ice crystals which is limited to Pitot tubes and Angle of Attack sensors (§25.1323 and §25.1324).

As explained above, EASA has been using the FAA proposed conditions for many years and got strong indications that the proposed FAR Part 33 Appendix D does better cover the existing environment, which is applicable to any external probe fitted on an aeroplane. Consistently, EASA has recently issued a generic CRI “Flight Instrument External Probes – Qualification in Icing Conditions” which will be used on all new type certificate applications made after 31 January 2010.

Therefore we propose to have a specific requirement for Flight Instrument External Probes (new CS 25.1324) including, but not necessarily limited to Pitot tubes, Pitot-static tubes and static probes, angle of attack sensors, side slip vanes and temperature probes.

d. Flight instrument external probes heat indication system

Some incidents evidenced that some failures of the Pitot probe heating resistance may not be seen by the low current detection system on aircraft. In some conditions, an out of tolerance resistance, failing to provide a proper Pitot probe de-icing could not be detected. EASA thus proposes to address failures, such as found in Pitot probes that may not be seen by the low current detection system on aircraft, by modifying the existing CS 25.1326 “Pitot heat indication systems” to explicitly cover abnormal functioning of the heating system. This is considered as a clarification since CS 25.1419 (c) already requires that “Caution information, such as an amber caution light or equivalent, must be provided to alert the flight crew when the anti-ice or de-ice system is not functioning normally”. CS 25.1326 is also proposed to be modified to extend the scope of the requirement to all Flight Instrument External Probes including, but not necessarily limited to Pitot tubes, Pitot-static tubes and static probes, angle of attack sensors, side slip vanes and temperature probes.

This change has not been proposed by FAA.

e. Figures 1 and 4 of the proposed Appendix O

FAA proposed curves that are different compared to the IPHWG report.

After discussion with FAA, it seems that these figures should not have been changed (mistake); therefore the EASA keeps the IPHWG report curves.

16. Alternatives to rulemaking

Two alternatives to rulemaking were considered by the IPHWG group. They were not retained for the reasons explained below.

a. Alternative 1: Terminal Area Radar and Sensors

This alternative would be based on the use of terminal area radar and ground-based sensors to identify areas of icing conditions including SLD. Once SLD areas would be detected and characterised, the information could be communicated to flight crews which would be able to avoid these areas. This could be an alternative to requiring certification for safe operation in SLD conditions. Equipment for detecting and characterising icing conditions in holding areas is being developed. However, this equipment would have limited coverage area.

For areas not covered by terminal area radar and ground-based sensors, airborne radars and sensors are being developed that would identify SLD conditions in sufficient time for avoidance. However, these ground-based and airborne systems are not mature enough to provide sufficient protection for all flight operations affected by SLD.

Even if the equipment was mature, rulemaking would still be necessary to establish safety margins for inadvertent flight into such conditions and to provide an option for applicants to substantiate that the aeroplane is capable of safe operation in SLD conditions.

b. Alternative 2: Icing Diagnostic and Predictive Weather Tools

Another alternative would be the use of icing diagnostic and predictive weather tools to avoid SLD rather than certify an aeroplane to operate in SLD conditions. Tools have been developed that can provide information on icing and SLD potential, but may not report all occurrences of SLD. These experimental tools are available on the Internet and can be used to provide flight planning information guidance for avoidance of SLD conditions.

However, rulemaking would still be necessary to establish safety margins for inadvertent flight into such conditions and to provide an option for applicants to substantiate that the aeroplane is capable of safe operation in SLD conditions.

V. Regulatory Impact Assessment

0. Process and consultation

This RIA has been developed based on the recommendations from the ARAC IPHWG to FAA and on the FAA NPRM initial regulatory evaluation dated 16 June 2010 (available in Docket No FAA-2010-0636).

Adaptations were made to take into account the European aeroplanes fleet characteristics and the labour cost in the EU.

1. Issue analysis and risk assessment

1.1 What is the issue?

It has been evidenced that the icing environment used for certification of large aeroplanes and turbine engines needs to be expanded in order to improve the level of safety when operating in icing conditions.

On 31 October 1994, near Roselawn, Indiana-USA, an accident involving an Avions de Transport Régional ATR 72 occurred in icing conditions believed to include freezing drizzle drops. Indeed, the accident investigation led to the conclusion that freezing drizzle conditions created a ridge of ice on the wings' upper surface aft of the de-icing boots and forward of the ailerons. It was further concluded that the ridge of ice resulted in an uncommanded roll of the aeroplane. The atmospheric condition (freezing drizzle) that may have contributed to the accident is outside the existing CS-25 Appendix C icing envelope that is used for certification of large aeroplanes.

Another atmospheric icing condition which aeroplanes may experience and which is outside of the Appendix C icing envelope is freezing rain. These kinds of icing conditions constitute an icing environment known as Supercooled Large Drops (SLDs).

Since 1988 at least six accidents and twenty-five incidents were caused by these kinds of severe icing conditions.

1.2 Who is affected?

This issue mainly concerns CS-25 aeroplanes. Therefore the main affected stakeholders are CS-25 aeroplanes manufacturers, manufacturers of turbine engines installed on CS-25 aeroplanes and operators of those aircraft.

1.3 What are the risks (probability and severity)?

The most severe risk is the loss of control of the aeroplane in SLD icing conditions which can lead to a hull loss of the aeroplane. At least five accidents happened with this scenario, and four of them involved fatalities.

Engine power losses or flameouts are also a safety threat, especially in ice crystal and mixed phase icing conditions. More than one hundred documented cases exist.

Furthermore, service experience indicates that flight crews have experienced temporary loss of or erroneous airspeed indications, malfunctioning and/or damage to temperature probes in severe icing conditions (in areas of deep convection). The main suspected cause is ice crystals in high concentration.

The on-going investigation of an Airbus A330 accident[7] (flight AF447, 01 June 2009, Atlantic Ocean) has established in the interim report No 2 that several (twenty-four) maintenance messages were transmitted by the ACARS system and that these messages show an

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[7] Refer to the Interim Report No 2 dated 17 December 2009 available on the BEA France Website. Please use the following link: http://www.bea.aero/en/enquetes/flight.af.447/flight.af.447.php.

inconsistency in the measured airspeeds. A meteorological analysis shows strong condensation towards AF447's flight level probably associated with convection phenomena. The aircraft Pitot probes potentially may have encountered severe icing conditions including ice crystals and mixed phase. However, as of today the root cause of the accident has not been established, therefore it is not possible to determine whether or not the mentioned airspeed measurements inconsistencies have played a role among the causal factors.

In-flight snow (and mixed phase) conditions have also caused power interruptions on some turbine engines and APUs.

Finally, service experience of different engine types has identified the potential for a multiple engine failure during take-off, after prolonged ground operation in freezing fog.

Table 1: Risk index matrix

Probability of occurrence		**Severity of occurrence**				
		Negligible	**Minor**	**Major**	**Hazardous**	**Catastrophic**
		1	2	3	5	8
Extremely improbable	1	🟩	🟩	🟩	🟩	🟨
Improbable	2	🟩	🟩	🟩	🟨	🟥 **16**
Remote	3	🟩	🟩	🟨	🟧	🟥
Occasional	4	🟩	🟨	🟨	🟥	🟥
Frequent	5	🟩	🟨	🟥	🟥	🟥

2. Objectives

The overall objectives of the Agency are defined in Article 2 of Regulation (EC) No 216/2008 (the Basic Regulation). This proposal will contribute to the overall objectives by addressing the issues outlined in Section 2.

The specific objective of this proposal is to better protect large aeroplanes certificated for flight in icing conditions. The new icing environment would include Supercooled Large Drops, Mixed Phase and Ice Crystals. We also propose to update the requirements for turbine engine air intake system protection (updated freezing fog conditions and new falling and blowing snow conditions).

3. Options identified

Table 2: Selected policy options

Option No	Description
0	Baseline option (No change in rules, risks remain as outlined in issue analysis)
1	Amend CS-25 by updating the atmospheric environment (icing and snow) required for certification of large aeroplanes.

4. Methodology and data requirements

4.1 Applied methodology

The Agency used the analysis performed by the IPHWG and FAA in their NPRM (docket FAA-2010-0636), which has been adapted to the EU case, to evaluate the impacts of the preferred option, which is Option 1.

The Agency also applied a Cost Benefit Analysis (CBA) to analyse the impact of the proposed EASA regulation. While CBA is used in this case, the Agency is not bound to CBA as a methodology to determine the preferred option and in particular reserves the right to consider non-monetised safety benefits.

A CBA is based on the fully monetised values for costs and benefits using a discount rate to make cash-flows comparable that occur at different points in time. The discount rate allows taking into account that the human being, and especially economic actors, have a preference for benefits occurring in the near future rather than in the far future.

4.2 Data requirements

Certification cost impacts were provided by CS-25 aircraft manufacturers to the IPHWG and FAA.

European Central Bank data was used to assess the US dollar/Euro conversion rate. In 2009 this rate was 1.4 US dollars/Euro.

Discount rate: There is a general agreement among economists that discounting is necessary when comparing a stream of benefits and costs accruing over a number of years. Our estimates contain both nominal and present values. We use a discount rate of 4 % as recommended by the European Commission's (2009) Impact Assessment Guidelines

Labour cost assumption: 55 Euros/hour.

Hourly wage rates were based on the salary figures of ERI Economic Research Institute for France, Germany, Italy, Spain and the United Kingdom (these five countries together account for 83.5 % of all employment in the manufacture of aircraft and spacecraft sector in EASA countries). Estimates for ERI salary are derived from employer information, national statistics offices and employee-provided data.

New project certification and deliveries:

We assume that the proposed rule becomes effective on 1 January 2012 and that all new certification projects are approved one year after the rule becomes effective, i.e. on 1 January 2013, and that the deliveries begin one year later, i.e. on 1 January 2014. Indeed not all certification will occur during the first year of implementation, but this approach maximises the cost impacts in order to have a conservative analysis. The number of delivered aeroplanes and the corresponding number of years are determined depending on the category of aeroplanes as explained in the following fleet chapter.

We consider three categories among the CS-25 fleet aircraft: smaller, medium and larger aeroplanes. See explanations in the following chapter.

SLD ice detection system: The industry estimates that roughly 50 % of the smaller and medium aeroplanes might be certified using visual cues and the remaining smaller and medium aeroplanes might be certified with detectors. Therefore 50 % of the smaller and medium aeroplanes deliveries would be affected.

5. Analysis of impacts

5.1 Safety impact

Option 0 would let the current situation unchanged and would have a neutral safety impact.

Option 1 would provide a safety benefit by preventing the occurrences of aircraft loss of control, engine power losses or flameouts and flight instrument external probes malfunctions when operating in icing conditions. New CS-25 aircraft would be demonstrated for safe operation throughout the updated atmospheric icing environment.

Benefit assessment of Option 1

The Agency assessed the aeroplane accidents and incidents for which causal factors involved severe icing conditions including SLD (Supercooled Large Drops) conditions, ice crystals and mixed phase.

Although all accidents occurred outside the EU (European Union), we include an estimation of the corresponding cost which would have been incurred should they have occurred in the EU.

A) <u>Accidents in severe icing conditions including SLD</u>

The following list of accidents is relevant:

Date	Type of aeroplane	Location	Fatalities	Injuries	Hull loss of the aeroplane
29 April 1993	EMB-120	Pine Bluff, USA	0	13 minor	Yes
31 October 1994	ATR-72	Roselawn, USA	68	0	Yes
30 December 1995	Cessna 560	Eagle River, USA	2	0	Yes
09 January 1997	EMB-120	Monroe, USA	29	0	Yes
19 March 2001	EMB-120	Orlando, USA	0	0	Severe damage
21 December 2002	ATR-72	Pengu island, Taïwan	2	0	Yes

Hereafter we add some information about these accidents and a justification why they are relevant.

<u>29 April 1993</u>

An Embraer EMB-120 was substantially damaged when it collided with rough terrain during an overrun following a forced landing. The forced landing was executed following a stall and loss of control at 17,412 feet during climb which resulted in damage to the left engine and propeller. Of the 3 crew members and 27 passengers aboard, **13 individuals received minor injuries**.

The NTSB found that in combination with other factors ice accretion led to an aerodynamic stall, loss of control, and a forced landing.

<u>Justification for applicability:</u>

The meteorological report indicated the possibility of supercooled large droplet icing in the area of this accident. The proposed CS 25.1420 would require the aeroplane be able to operate safely in Appendix O conditions or have a means of detecting Appendix O conditions and be capable of operating safely within those conditions for the purpose of exiting those conditions.

<u>31 October 1994</u>

An ATR-72 struck the ground after the flight crew lost control of the aeroplane during an adverse roll event at 9,200 feet causing a total of **68 fatalities**.

The NTSB found that the probable cause of the accident was the loss of control, attributed to a sudden and unexpected aileron hinge moment reversal that occurred after a ridge of ice accreted beyond the deice boots while the aeroplane was in a holding pattern. It intermittently encountered supercooled cloud and drizzle/rain drops, the size and water content of which exceeded those described in the icing certification envelope.

Justification for applicability:

The aeroplane stalled and lost control after encountering large droplet icing conditions, which may have been consistent with Appendix O. Proposed CS 25.1420 would require the aeroplane to be able to operate safely in Appendix O conditions or have a means of detecting Appendix O conditions and be capable of operating safely within those conditions for the purpose of exiting those conditions.

30 December 1995

Two fatalities occurred as a result of a Cessna 560 colliding with the terrain at the Eagle River Airport, Eagle River, Wisconsin. The National Transportation Safety Board determined that the probable cause of the accident was the failure of the pilot to maintain airspeed while executing the circling approach. Factors were descent below minimum descent altitude, fog, low ceiling and icing conditions.

Although the ice accretion was not described as consistent with large droplet icing, a sheriff's deputy reported freezing rain and sleet were falling at the time of the accident.

Justification for applicability:

Existing aeroplanes have not substantiated that they are capable of operating safely in Appendix O conditions (freezing drizzle and freezing rain). CS 25.1420 would require the aeroplane to be able to operate safely in Appendix O conditions or have a means of detecting Appendix O conditions and be capable of operating safely within those conditions for the purpose of exiting those conditions.

01 September 1997

An Embraer EMB-120RT crashed while being vectored for approach to runway 3R at Detroit Metropolitan Wayne County Airport, which resulted in **29 fatalities**.

The investigation revealed that it was likely that the aeroplane gradually accumulated a thin, rough glaze/mixed ice coverage on the leading edge de-icing boot surfaces, possibly with ice ridge formation on the leading edge upper surface.

The National Transportation Safety Board determined that one of the probable causes was the failure to establish adequate aeroplane certification standards for flight in icing conditions.

Justification for applicability:

Existing aeroplanes have not substantiated that they are capable of operating safely in Appendix O conditions (freezing drizzle and freezing rain). The proposed CS 25.1420 would require the aeroplane to be able to operate safely in Appendix O conditions or have a means of detecting Appendix O conditions and be capable of operating safely within those conditions for the purpose of exiting those conditions.

19 March 2001

An EMB-120 encountered severe icing conditions while in cruise flight at 17,000 feet mean sea level (msl) and departed controlled flight, descending to an altitude of about 10,000 feet. The pilots recovered control of the aeroplane and diverted to West Palm Beach, Florida, where they landed without further incident. 2 flight crew members, 1 flight attendant, and 25 passengers were **uninjured**, and the aeroplane sustained substantial damage to the elevators and the horizontal stabiliser.

Justification for applicability:

The aeroplane encountered severe icing conditions and meteorological data indicated that supercooled large droplet icing conditions were probably present. The flight crew delayed exiting the conditions. The proposed CS 25.1420 would require the aeroplane be able to safely operate in Appendix O conditions or have a means of detecting Appendix O conditions and be capable of operating safely within those conditions for the purpose of exiting those conditions.

21 December 2002

The ATR-72 cargo was flying to Macau and it encountered severe icing condition; when flying at FL180, a stall warning sounded and the stick shaker activated, followed by a large pitch angle and a large left bank angle. The autopilot was disengaged and the pilots tried to maintain control of the aeroplane. However, the aeroplane rapidly lost altitude until it crashed into the sea. **Both crew members were killed**.

Justification for applicability:

The Aviation Safety Council of Taiwan investigation found that the crash was caused by ice accumulation around the aeroplane's major components, resulting in the aircraft's loss of control. The investigation concluded that the icing conditions were beyond the CS-25 Appendix C envelope (in term of liquid water content and maximum droplet size estimations). The investigation identified that flight crew did not respond to the severe icing conditions with the appropriate alert situation awareness and did not take the necessary actions. The proposed CS 25.1420 would require the aeroplane to be able to operate safely in Appendix O conditions or have a means of detecting Appendix O conditions and be capable of operating safely within those conditions for the purpose of exiting those conditions; Appendix O would provide a supercooled large drops icing environment.

B) Accidents cost estimation

No accident occurred in the EU. Meanwhile, we provide as an indication the cost corresponding to the 6 accidents described above, calculated in the EU environment.

Assumptions:

- Avoided cost by preventing one casualty: this is the monetised value that society would be willing to pay to avoid one casualty in the future. This Value for Preventing a Casualty (VPC) is a benefit for the society if the accident is avoided.
- For the purpose of this impact assessment we use the mean value of 2,000,000 euros for preventing a casualty, as recommended by the Impact Assessment Guidelines of the European Commission (15 January 2009, Annex p42).[8]
- For the value of avoided injuries, we use relative value coefficients based on the Abbreviated Injury Scale (AIS), which calculates the benefit of preventing injuries as a fraction of VSL (e.g. a minor injury is AIS level 1, which is 0.2% of the VPC, i.e. 4,000 euros).
- Cost of aeroplane hull loss and accident investigation: we use the value used by the FAA in their regulatory impact assessment. They have estimated that the corresponding average cost is 20 million US dollars (11.46 million US dollars for the aircraft replacement plus 8.6 million US dollars for the accident investigation). This is equivalent to 14.3 million Euros today.
- We calculate the cost as a present value.

Result:

We find a **total cost of 245 million Euros**, and an **average cost per accident of 41 million Euros**, as detailed in the following table.

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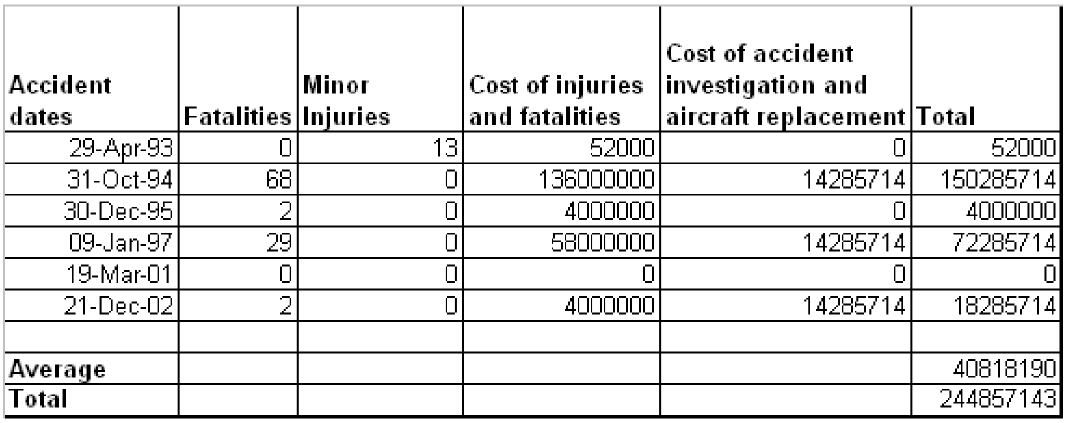
[8] The Agency uses the VPS as a tool to illustrate significant safety benefits. However, the Agency reserves the right to consider also non-monetised safety benefits.



Accident dates	Fatalities	Minor Injuries	Cost of injuries and fatalities	Cost of accident investigation and aircraft replacement	Total
29-Apr-93	0	13	52000	0	52000
31-Oct-94	68	0	136000000	14285714	150285714
30-Dec-95	2	0	4000000	0	4000000
09-Jan-97	29	0	58000000	14285714	72285714
19-Mar-01	0	0	0	0	0
21-Dec-02	2	0	4000000	14285714	18285714
Average					40818190
Total					244857143

We use a projected fleet based on historical data (see part 5.4.1.1. The CS-25 fleet), the historical average annual number of preventable accidents per affected aircraft (3.79×10^{-5}, an FAA estimate based on the number of relevant accidents divided by the sum of the annual number of aeroplanes in the fleet), and the above-mentioned average cost per accident for the calculation of benefits for smaller and medium-sized aircraft.

For larger aircraft we used the same assumptions to calculate the cost of an accident except that we also assume an average of 126 seats (same assumption as FAA in their RIA), therefore 126 averted fatalities. This results in an **average cost per accident of 266.4 million Euros**.

Smaller aeroplane fleet				Annaul Risk per Airplane	Nominal Values (risk × fleet × €40.8mill)	Present Value (EUR)
EASA Estimate						
Year	Deliveries	Retirements	Net Fleet			
2012	0	0	0	3.79E-05	0	0
2013	0	0	0	3.79E-05	0	0
2014	12	0	12	3.79E-05	18,551	15,858
2015	12	0	24	3.79E-05	37,102	30,495
2016	12	0	36	3.79E-05	55,654	43,984
2017	12	0	48	3.79E-05	74,205	56,390
2018	12	0	60	3.79E-05	92,756	67,776
2019	12	0	72	3.79E-05	111,307	78,203
2020	12	0	84	3.79E-05	129,858	87,728
2021	12	0	96	3.79E-05	148,410	96,404
2022	12	0	108	3.79E-05	166,961	104,283
2023	12	0	120	3.79E-05	185,512	111,414
2024	12	0	132	3.79E-05	204,063	117,841
2025	12	0	144	3.79E-05	222,614	123,610
2026	12	0	156	3.79E-05	241,166	128,760
2027	12	0	168	3.79E-05	259,717	133,332
2028	12	0	180	3.79E-05	278,268	137,361
2029	12	0	192	3.79E-05	296,819	140,883
2030	12	0	204	3.79E-05	315,370	143,931
2031	12	0	216	3.79E-05	333,921	146,536
2032	12	0	228	3.79E-05	352,473	148,728
2033	12	0	240	3.79E-05	371,024	150,534
2034	12	0	252	3.79E-05	389,575	151,982
2035	0	0	252	3.79E-05	389,575	146,136
2036	0	0	252	3.79E-05	389,575	140,516
2037	0	0	252	3.79E-05	389,575	135,111
2038	0	0	252	3.79E-05	389,575	129,915
2039	0	0	252	3.79E-05	389,575	124,918
2040	0	0	252	3.79E-05	389,575	120,113
2041	0	0	252	3.79E-05	389,575	115,494
2042	0	0	252	3.79E-05	389,575	111,051
2043	0	12	240	3.79E-05	371,024	101,695
2044	0	12	228	3.79E-05	352,473	92,895
2045	0	12	216	3.79E-05	333,921	84,621
2046	0	12	204	3.79E-05	315,370	76,846
2047	0	12	192	3.79E-05	296,819	69,544
2048	0	12	180	3.79E-05	278,268	62,690
2049	0	12	168	3.79E-05	259,717	56,260
2050	0	12	156	3.79E-05	241,166	50,232
2051	0	12	144	3.79E-05	222,614	44,585
2052	0	12	132	3.79E-05	204,063	39,297
2053	0	12	120	3.79E-05	185,512	34,351
2054	0	12	108	3.79E-05	166,961	29,727
2055	0	12	96	3.79E-05	148,410	25,407
2056	0	12	84	3.79E-05	129,858	21,376
2057	0	12	72	3.79E-05	111,307	17,618
2058	0	12	60	3.79E-05	92,756	14,117
2059	0	12	48	3.79E-05	74,205	10,859
2060	0	12	36	3.79E-05	55,654	7,831
2061	0	12	24	3.79E-05	37,102	5,020
2062	0	12	12	3.79E-05	18,551	2,413
2063	0	12	0	3.79E-05	0	0
					11,297,677	4,086,669

Medium aeroplane fleet				Annaul Risk per Airplane	Nominal Values (risk × fleet × €40.8mill)	Present Value (EUR)
EASA Estimate						
Year	Deliveries	Retirements	Net Fleet			
2012	0	0	0	3.79E-05	0	0
2013	0	0	0	3.79E-05	0	0
2014	8	0	8	3.79E-05	12,367	10,572
2015	8	0	16	3.79E-05	24,735	20,330
2016	8	0	24	3.79E-05	37,102	29,323
2017	8	0	32	3.79E-05	49,470	37,593
2018	8	0	40	3.79E-05	61,837	45,184
2019	8	0	48	3.79E-05	74,205	52,135
2020	8	0	56	3.79E-05	86,572	58,485
2021	8	0	64	3.79E-05	98,940	64,269
2022	8	0	72	3.79E-05	111,307	69,522
2023	8	0	80	3.79E-05	123,675	74,276
2024	8	0	88	3.79E-05	136,042	78,561
2025	8	0	96	3.79E-05	148,410	82,407
2026	8	0	104	3.79E-05	160,777	85,840
2027	8	0	112	3.79E-05	173,144	88,888
2028	8	0	120	3.79E-05	185,512	91,574
2029	8	0	128	3.79E-05	197,879	93,922
2030	8	0	136	3.79E-05	210,247	95,954
2031	8	0	144	3.79E-05	222,614	97,691
2032	8	0	152	3.79E-05	234,982	99,152
2033	8	0	160	3.79E-05	247,349	100,356
2034	8	0	168	3.79E-05	259,717	101,321
2035	8	0	176	3.79E-05	272,084	102,063
2036	8	0	184	3.79E-05	284,452	102,599
2037	8	0	192	3.79E-05	296,819	102,942
2038	8	0	200	3.79E-05	309,187	103,107
2039	8	0	208	3.79E-05	321,554	103,107
2040	8	0	216	3.79E-05	333,921	102,954
2041	8	0	224	3.79E-05	346,289	102,661
2042	8	0	232	3.79E-05	358,656	102,238
2043	0	8	224	3.79E-05	346,289	94,916
2044	0	8	216	3.79E-05	333,921	88,006
2045	0	8	208	3.79E-05	321,554	81,487
2046	0	8	200	3.79E-05	309,187	75,339
2047	0	8	192	3.79E-05	296,819	69,544
2048	0	8	184	3.79E-05	284,452	64,083
2049	0	8	176	3.79E-05	272,084	58,939
2050	0	8	168	3.79E-05	259,717	54,096
2051	0	8	160	3.79E-05	247,349	49,539
2052	0	8	152	3.79E-05	234,982	45,252
2053	0	8	144	3.79E-05	222,614	41,221
2054	0	8	136	3.79E-05	210,247	37,434
2055	0	8	128	3.79E-05	197,879	33,877
2056	0	8	120	3.79E-05	185,512	30,538
2057	0	8	112	3.79E-05	173,144	27,406
2058	0	8	104	3.79E-05	160,777	24,469
2059	0	8	96	3.79E-05	148,410	21,718
2060	0	8	88	3.79E-05	136,042	19,143
2061	0	8	80	3.79E-05	123,675	16,733
2062	0	8	72	3.79E-05	111,307	14,481
2063	0	8	64	3.79E-05	98,940	12,377
2064	0	8	56	3.79E-05	86,572	10,413
2065	0	8	48	3.79E-05	74,205	8,582
2066	0	8	40	3.79E-05	61,837	6,877
2067	0	8	32	3.79E-05	49,470	5,290
2068	0	8	24	3.79E-05	37,102	3,815
2069	0	8	16	3.79E-05	24,735	2,445
2070	0	8	8	3.79E-05	12,367	1,176
2071	0	8	0	3.79E-05	0	0
					10,401,036	3,298,217

Large aeroplane fleet				Annaul Risk per Airplane	Nominal Values (risk × fleet × €266.4mill)	Present Value (EUR)
EASA Estimate						
Year	Deliveries	Retirements	Net Fleet			
2012				3.79E-05	0	0
2013				3.79E-05	0	0
2014	40		40	3.79E-05	403,581	344,983
2015	40		80	3.79E-05	807,163	663,429
2016	40		120	3.79E-05	1,210,744	956,869
2017	40		160	3.79E-05	1,614,325	1,226,755
2018	40		200	3.79E-05	2,017,907	1,474,465
2019	40		240	3.79E-05	2,421,488	1,701,305
2020	40		280	3.79E-05	2,825,069	1,908,516
2021	40		320	3.79E-05	3,228,651	2,097,270
2022	40		360	3.79E-05	3,632,232	2,268,681
2023	40		400	3.79E-05	4,035,813	2,423,805
2024	40		440	3.79E-05	4,439,395	2,563,640
2025	40		480	3.79E-05	4,842,976	2,689,133
2026	40		520	3.79E-05	5,246,557	2,801,180
2027	40		560	3.79E-05	5,650,139	2,900,630
2028	40		600	3.79E-05	6,053,720	2,988,286
2029	40		640	3.79E-05	6,457,301	3,064,909
2030	40		680	3.79E-05	6,860,883	3,131,217
2031	40		720	3.79E-05	7,264,464	3,187,891
2032	40		760	3.79E-05	7,668,045	3,235,573
2033	40		800	3.79E-05	8,071,627	3,274,871
2034		40	760	3.79E-05	7,668,045	2,991,469
2035		40	720	3.79E-05	7,264,464	2,725,022
2036		40	680	3.79E-05	6,860,883	2,474,646
2037		40	640	3.79E-05	6,457,301	2,239,499
2038		40	600	3.79E-05	6,053,720	2,018,779
2039		40	560	3.79E-05	5,650,139	1,811,725
2040		40	520	3.79E-05	5,246,557	1,617,612
2041		40	480	3.79E-05	4,842,976	1,435,750
2042		40	440	3.79E-05	4,439,395	1,265,485
2043		40	400	3.79E-05	4,035,813	1,106,193
2044		40	360	3.79E-05	3,632,232	957,282
2045		40	320	3.79E-05	3,228,651	818,190
2046		40	280	3.79E-05	2,825,069	688,381
2047		40	240	3.79E-05	2,421,488	567,347
2048		40	200	3.79E-05	2,017,907	454,605
2049		40	160	3.79E-05	1,614,325	349,696
2050		40	120	3.79E-05	1,210,744	252,185
2051		40	80	3.79E-05	807,163	161,657
2052		40	40	3.79E-05	403,581	77,720
2053		40	0	3.79E-05	0	0
					161,432,532	68,916,650

Incidents in severe icing conditions

In addition to accidents, the IPHWG identified, between 1988 and 2002, **25 incidents** in which severe icing conditions were identified among the causal factors. The following descriptors were used: severe ice, freezing rain, freezing drizzle, side window icing, heavy icing, large droplets, SLD, and, for mixed ice conditions, descriptors sleet, snow, snow grains, and ice were used for these events.

The Agency was also informed by manufacturers that malfunctioning of flight instrument external probes such as Pitot tubes is reported by operators in icing conditions that include ice crystals or mixed phase and which are beyond the existing CS-25 specifications. The number of these events is not known precisely but they happen regularly. Despite the corrective actions that have been taken by manufacturers to improve the robustness of these probes in ice crystals or mixed phase icing conditions, it appears necessary to update the certification icing environment to avoid these incidents. The proposed CS-25 rule and its Appendix P would provide such updated environment, which would avert the majority of these events.

5.2 Environmental impact

The method we use to calculate the environmental impact of the proposed amendment is based on the approach recommended by the European Commission financed HEATCO research project (Harmonised European Approach for Transport Costing). One of the main objectives of HEATCO is to create a consistent framework for monetary valuation and contribute to consistency with transport costing.

We calculate the costs due to the emission of greenhouse gases by multiplying the amount of CO_2 equivalents emitted by a cost factor. The cost factor is based on the work of Watkiss et al (2005), which assumes that emissions in future years will have greater total impacts than emissions today.

Shadow prices per tonne of CO_2 equivalent emitted (EUR)

Year of emission	Central guidance	For sensitivity analysis	
		Lower central estimate	Upper central estimate
2000-2009	22	14	51
2010-2019	26	16	63
2020-2029	32	20	81
2030-2039	40	26	103
2040-2049	55	36	131
2050-	83	51	166

In high altitudes other emissions from aircraft than CO_2 (water vapour, sulphate and soot aerosols, as well as nitrogen oxides) have a considerable climatic effect. To take into account the warming effect of other emissions than CO_2, we multiply high altitude CO_2 emissions by a factor of 2, as recommended by the HEATCO report based on recent research results.

For the amount of extra fuel burn caused by the proposed amendment, see section 5.4.1.5. on Operating costs. We assumed that burning 1 kg of fuel creates 3.16 kg of CO_2 emission.

The monetary value of the additional greenhouse gas emission caused by the additional fuel burn is €177,296, which is 0.3 % of the total costs caused by the proposed amendment.

Present value of shadow prices of emissions with climatic effect (EUR)

		For sensitivity analysis	
Fleet	**Central guidance**	**Lower estimate**	**Upper estimate**
Smaller aeroplane	94,186	60,217	228,248
Medium aeroplane	83,110	52,967	196,335
Larger aeroplane	0	0	0
Total	177,296	113,184	424,582
Share of total costs	0.3%	0.2%	0.8%

5.3 Social impact

None identified.

5.4 Economic impact

5.4.1 Cost impact

The following costs have been calculated: certification costs, hardware costs and operating costs.

5.4.1.1 The CS-25 fleet

We have assessed the European CS-25 aeroplanes fleet based on statistical data from 1950 to 2010. The source of these data is the Ascend CASE aviation database.

Three categories of CS-25 aeroplanes are used in our assessment: smaller aeroplanes, medium aeroplanes, larger aeroplanes.

For each category, we have determined:

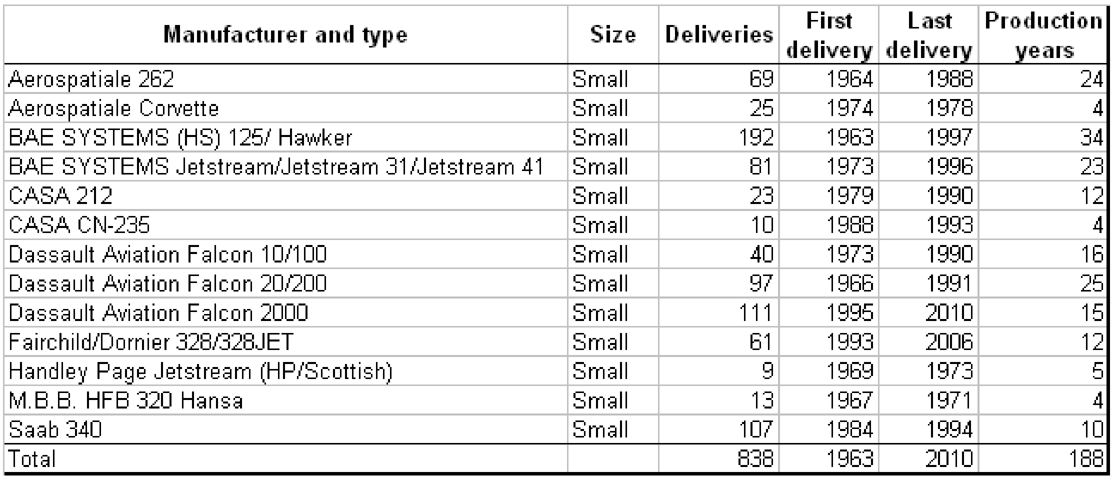
- the average number of new CS-25 large aeroplane certification projects which will be impacted by the new rule; we only consider aeroplanes designed, manufactured and operated in the EASA countries,
- the average life of each aeroplane until retirement,
- the average number of aeroplanes manufactured and delivered per year until their retirement.

1) Smaller CS-25 aeroplanes

This category comprises the light to mid-size business aeroplanes and light regional transport aeroplanes with Maximum Takeoff Weight (MTOW) in the range 5700=<MTOW<16700Kg.

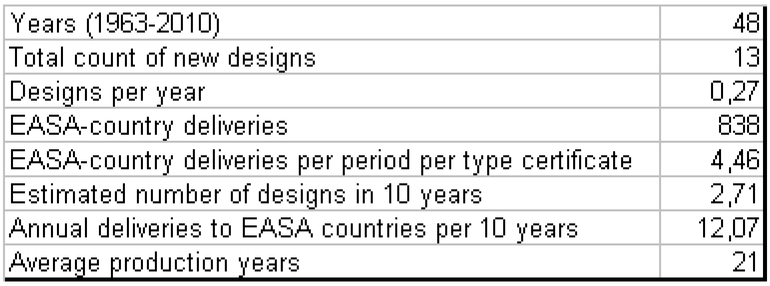
We have estimated that there are 2.71 new type certificates per 10-years period (13 new designs between 1963 and 2010) and we calculate an average 12 deliveries per year to EASA countries for all new types (=838/188*2.71).

Each type is produced for 21 years on the average, and the average retirement age is 29 years.



Manufacturer and type	Size	Deliveries	First delivery	Last delivery	Production years
Aerospatiale 262	Small	69	1964	1988	24
Aerospatiale Corvette	Small	25	1974	1978	4
BAE SYSTEMS (HS) 125/ Hawker	Small	192	1963	1997	34
BAE SYSTEMS Jetstream/Jetstream 31/Jetstream 41	Small	81	1973	1996	23
CASA 212	Small	23	1979	1990	12
CASA CN-235	Small	10	1988	1993	4
Dassault Aviation Falcon 10/100	Small	40	1973	1990	16
Dassault Aviation Falcon 20/200	Small	97	1966	1991	25
Dassault Aviation Falcon 2000	Small	111	1995	2010	15
Fairchild/Dornier 328/328JET	Small	61	1993	2006	12
Handley Page Jetstream (HP/Scottish)	Small	9	1969	1973	5
M.B.B. HFB 320 Hansa	Small	13	1967	1971	4
Saab 340	Small	107	1984	1994	10
Total		838	1963	2010	188

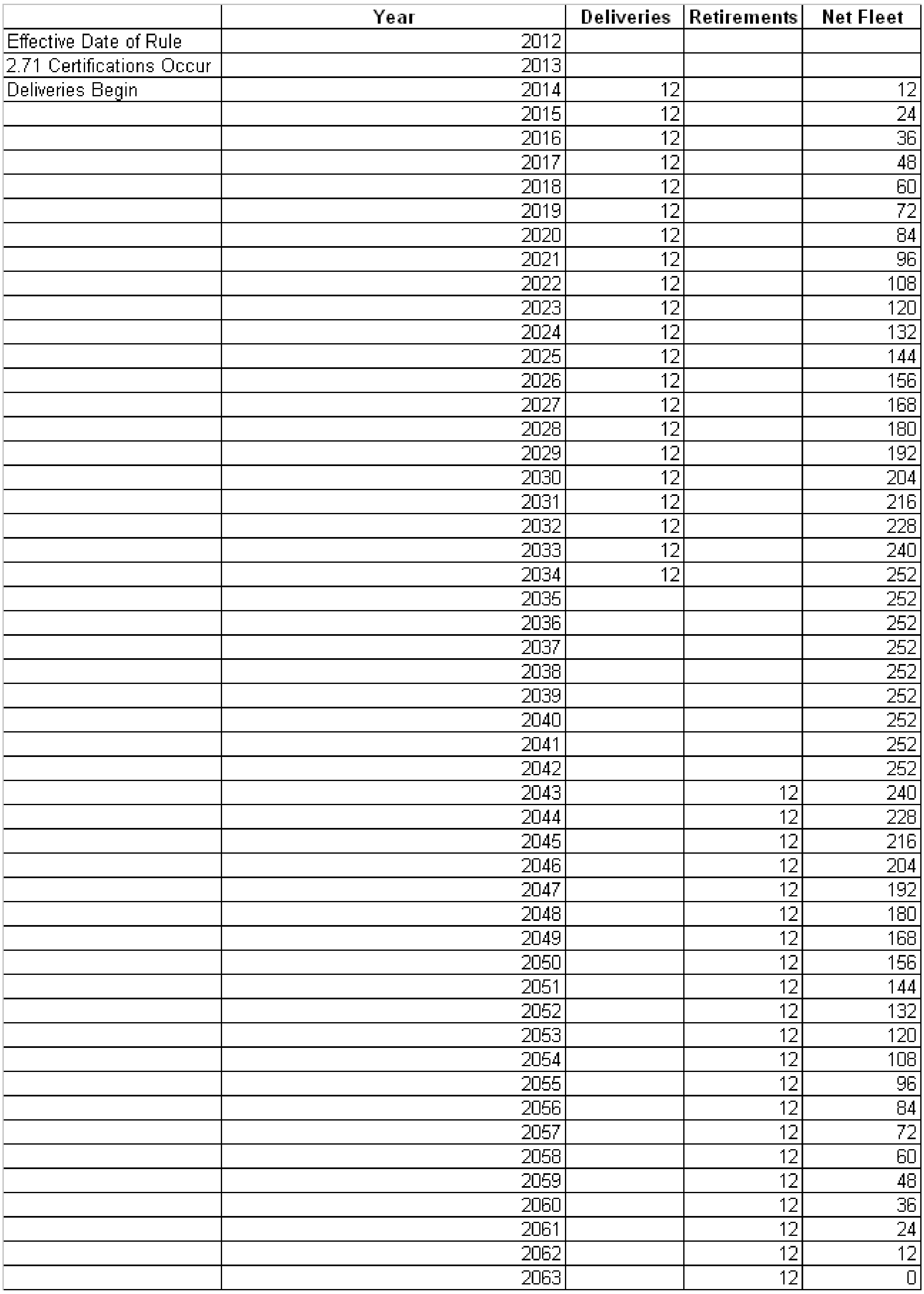
Table 1: Smaller CS-25 deliveries (history)



Years (1963-2010)	48
Total count of new designs	13
Designs per year	0,27
EASA-country deliveries	838
EASA-country deliveries per period per type certificate	4,46
Estimated number of designs in 10 years	2,71
Annual deliveries to EASA countries per 10 years	12,07
Average production years	21

Table 2: Certification summary for smaller CS-25 aeroplanes

The following table provides our European fleet forecast. We have assumed that there will be 2.71 new type certificates in 10 years and that these certifications will all occur in 2013 (conservatively).



	Year	Deliveries	Retirements	Net Fleet
Effective Date of Rule	2012			
2.71 Certifications Occur	2013			
Deliveries Begin	2014	12		12
	2015	12		24
	2016	12		36
	2017	12		48
	2018	12		60
	2019	12		72
	2020	12		84
	2021	12		96
	2022	12		108
	2023	12		120
	2024	12		132
	2025	12		144
	2026	12		156
	2027	12		168
	2028	12		180
	2029	12		192
	2030	12		204
	2031	12		216
	2032	12		228
	2033	12		240
	2034	12		252
	2035			252
	2036			252
	2037			252
	2038			252
	2039			252
	2040			252
	2041			252
	2042			252
	2043		12	240
	2044		12	228
	2045		12	216
	2046		12	204
	2047		12	192
	2048		12	180
	2049		12	168
	2050		12	156
	2051		12	144
	2052		12	132
	2053		12	120
	2054		12	108
	2055		12	96
	2056		12	84
	2057		12	72
	2058		12	60
	2059		12	48
	2060		12	36
	2061		12	24
	2062		12	12
	2063		12	0

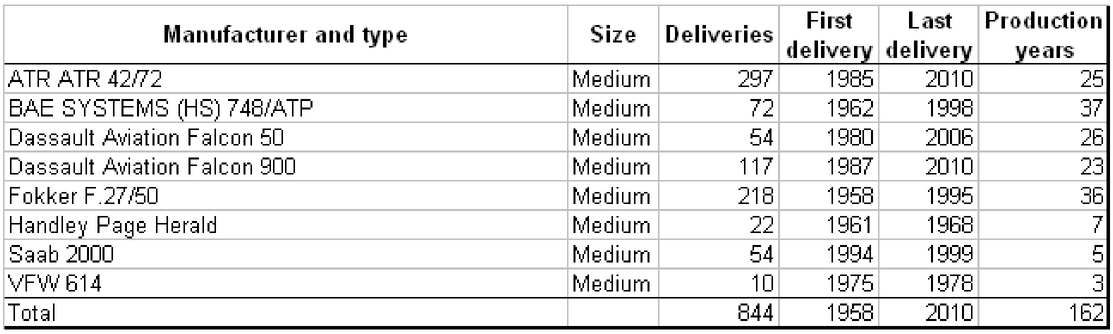
Table 3: Smaller CS-25 aeroplanes fleet

2) Medium CS-25 aeroplanes

This category comprises the larger business aeroplanes and the mid-size regional transport aeroplanes with MTOW in the range 16700=<MTOW<27215Kg.

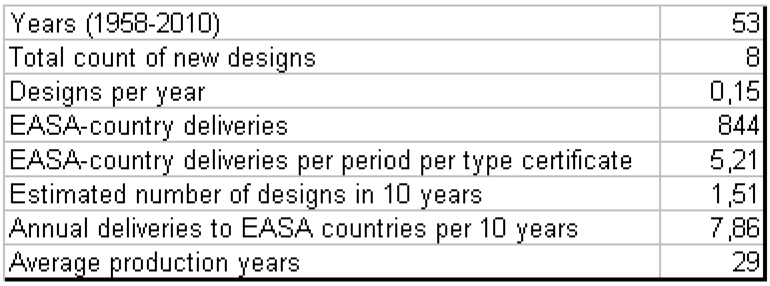
We have estimated that there are 1.51 new type certificates per 10-years period (8 new designs between 1958 and 2010) and we calculate an average 8 deliveries per year to EASA countries for all new types (=844/162*1.51).

Each type is produced for 29 years on the average, and the average retirement age is 29 years.



Manufacturer and type	Size	Deliveries	First delivery	Last delivery	Production years
ATR ATR 42/72	Medium	297	1985	2010	25
BAE SYSTEMS (HS) 748/ATP	Medium	72	1962	1998	37
Dassault Aviation Falcon 50	Medium	54	1980	2006	26
Dassault Aviation Falcon 900	Medium	117	1987	2010	23
Fokker F.27/50	Medium	218	1958	1995	36
Handley Page Herald	Medium	22	1961	1968	7
Saab 2000	Medium	54	1994	1999	5
VFW 614	Medium	10	1975	1978	3
Total		844	1958	2010	162

Table 4: Medium CS-25 deliveries (history)



Years (1958-2010)	53
Total count of new designs	8
Designs per year	0,15
EASA-country deliveries	844
EASA-country deliveries per period per type certificate	5,21
Estimated number of designs in 10 years	1,51
Annual deliveries to EASA countries per 10 years	7,86
Average production years	29

Table 5: Certification summary for medium CS-25 aeroplanes

The following table provides our European fleet forecast. We have assumed that there will be 1.51 new type certificates in 10 years and that these certifications will all occur in 2013 (conservatively).

	Year	Deliveries	Retirements	Net Fleet
Effective Date of Rule	2012			
1.51 Certifications Occur	2013			
Deliveries Begin	2014	8		8
	2015	8		16
	2016	8		24
	2017	8		32
	2018	8		40
	2019	8		48
	2020	8		56
	2021	8		64
	2022	8		72
	2023	8		80
	2024	8		88
	2025	8		96
	2026	8		104
	2027	8		112
	2028	8		120
	2029	8		128
	2030	8		136
	2031	8		144
	2032	8		152
	2033	8		160
	2034	8		168
	2035	8		176
	2036	8		184
	2037	8		192
	2038	8		200
	2039	8		208
	2040	8		216
	2041	8		224
	2042	8		232
	2043		8	224
	2044		8	216
	2045		8	208
	2046		8	200
	2047		8	192
	2048		8	184
	2049		8	176
	2050		8	168
	2051		8	160
	2052		8	152
	2053		8	144
	2054		8	136
	2055		8	128
	2056		8	120
	2057		8	112
	2058		8	104
	2059		8	96
	2060		8	88
	2061		8	80
	2062		8	72
	2063		8	64
	2064		8	56
	2065		8	48
	2066		8	40
	2067		8	32
	2068		8	24
	2069		8	16
	2070		8	8
	2071		8	0

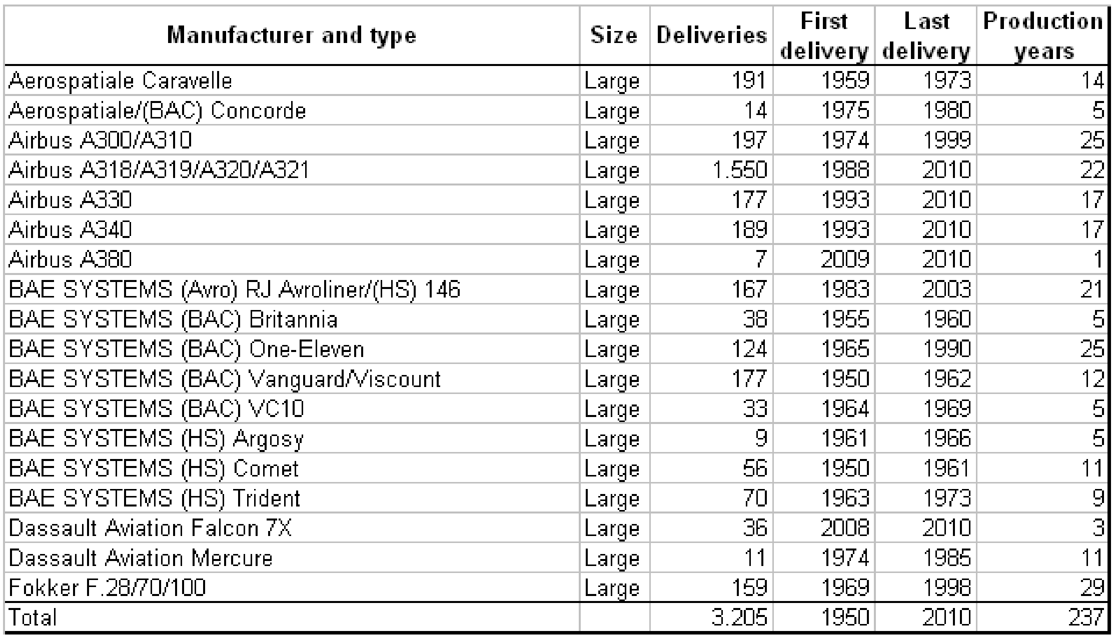
Table 6: Medium CS-25 aeroplanes fleet

3) <u>Larger CS-25 aeroplanes</u>

This category comprises the larger regional transport aeroplanes and the large transport aeroplanes with MTOW=>27215Kg.

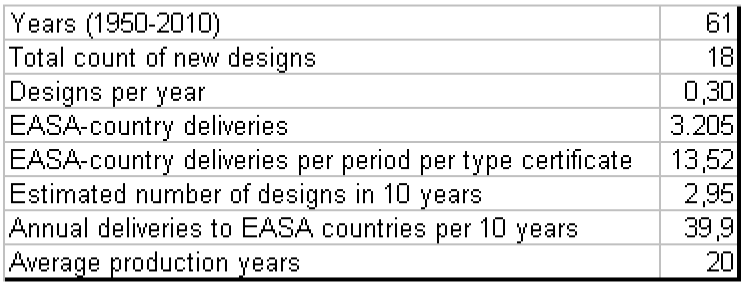
We have estimated that there are 2.95 new type certificates per 10-years period (18 new designs between 1950 and 2010) and we calculate an average 40 deliveries per year to EASA countries for all new types (=3205/237*2.95).

Each type is produced for 20 years on the average, and the average retirement age is 20 years.



Manufacturer and type	Size	Deliveries	First delivery	Last delivery	Production years
Aerospatiale Caravelle	Large	191	1959	1973	14
Aerospatiale/(BAC) Concorde	Large	14	1975	1980	5
Airbus A300/A310	Large	197	1974	1999	25
Airbus A318/A319/A320/A321	Large	1.550	1988	2010	22
Airbus A330	Large	177	1993	2010	17
Airbus A340	Large	189	1993	2010	17
Airbus A380	Large	7	2009	2010	1
BAE SYSTEMS (Avro) RJ Avroliner/(HS) 146	Large	167	1983	2003	21
BAE SYSTEMS (BAC) Britannia	Large	38	1955	1960	5
BAE SYSTEMS (BAC) One-Eleven	Large	124	1965	1990	25
BAE SYSTEMS (BAC) Vanguard/Viscount	Large	177	1950	1962	12
BAE SYSTEMS (BAC) VC10	Large	33	1964	1969	5
BAE SYSTEMS (HS) Argosy	Large	9	1961	1966	5
BAE SYSTEMS (HS) Comet	Large	56	1950	1961	11
BAE SYSTEMS (HS) Trident	Large	70	1963	1973	9
Dassault Aviation Falcon 7X	Large	36	2008	2010	3
Dassault Aviation Mercure	Large	11	1974	1985	11
Fokker F.28/70/100	Large	159	1969	1998	29
Total		3.205	1950	2010	237

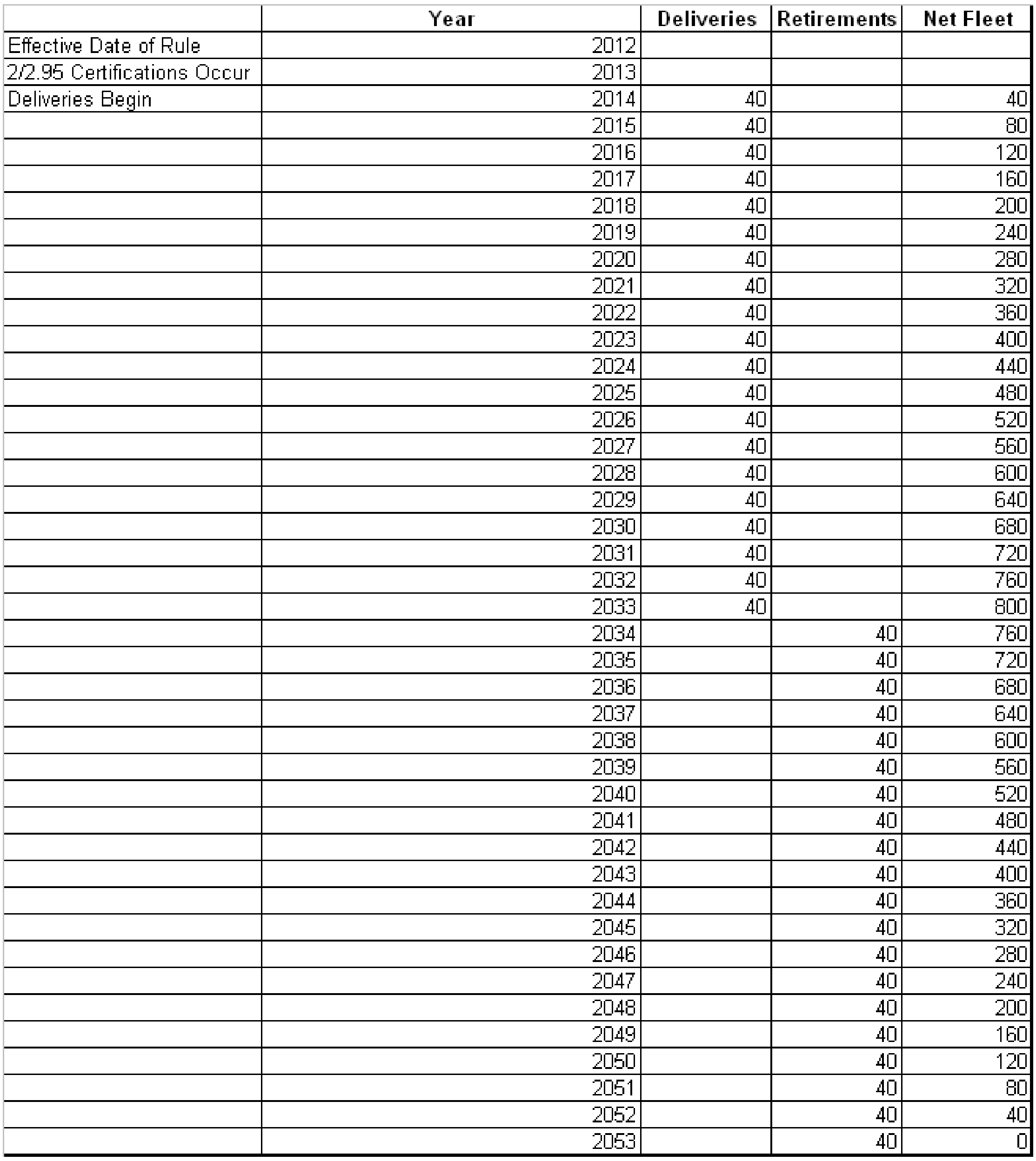
Table 7: Larger CS-25 deliveries (history)



Years (1950-2010)	61
Total count of new designs	18
Designs per year	0,30
EASA-country deliveries	3.205
EASA-country deliveries per period per type certificate	13,52
Estimated number of designs in 10 years	2,95
Annual deliveries to EASA countries per 10 years	39,9
Average production years	20

Table 8: Certification summary for larger CS-25 aeroplanes

The following table provides our European fleet forecast. We have assumed that there will be 2.95 new type certificates in 10 years and that these certifications will all occur in 2013 (conservatively).



	Year	Deliveries	Retirements	Net Fleet
Effective Date of Rule	2012			
2/2.95 Certifications Occur	2013			
Deliveries Begin	2014	40		40
	2015	40		80
	2016	40		120
	2017	40		160
	2018	40		200
	2019	40		240
	2020	40		280
	2021	40		320
	2022	40		360
	2023	40		400
	2024	40		440
	2025	40		480
	2026	40		520
	2027	40		560
	2028	40		600
	2029	40		640
	2030	40		680
	2031	40		720
	2032	40		760
	2033	40		800
	2034		40	760
	2035		40	720
	2036		40	680
	2037		40	640
	2038		40	600
	2039		40	560
	2040		40	520
	2041		40	480
	2042		40	440
	2043		40	400
	2044		40	360
	2045		40	320
	2046		40	280
	2047		40	240
	2048		40	200
	2049		40	160
	2050		40	120
	2051		40	80
	2052		40	40
	2053		40	0

Table 9: Larger CS-25 aeroplanes fleet

5.4.1.2 Certification costs for new projects

Certification costs are based on manufacturers cost estimates detailing design, qualification and certification costs. Manufacturers assessed the labour hours, equipment and materials that would be required to comply with the proposed rules. When conversions are made between US dollars and Euros, we use European Central Bank published values for the corresponding year; for instance in 2009, an average rate of 1.4 US dollar/Euro is used.

The costs are distributed in the following categories:

- SLD ice detection system design, qualification and certification

These are the costs estimates provided by manufacturers for SLD detection system design, qualification and certification to show compliance with the proposed rule.

The larger aeroplanes would not need to include this system as we assume that they will be certified for operation in the full Appendix O.

Moreover, the industry estimates that roughly 50 % of the smaller and medium aeroplanes might be certified using visual cues and the remaining ones might be certified using detectors. Therefore 50 % of the smaller and medium aeroplanes deliveries would be affected.

<u>- Aerodynamic wind and icing tunnel tests</u>

Wind and icing tunnel tests would be used by manufacturers to verify compliance of the aeroplane systems and performance; they would also limit the amount of natural icing flight test hours (for cost reason).

<u>- Analysis</u>

Additional costs need to be considered for the analysis and showing compliance with the rule. The methods used are variable and depend on the manufacturer. This may include using icing codes or CFD (Computational fluid dynamics).

<u>- Flight tests</u>

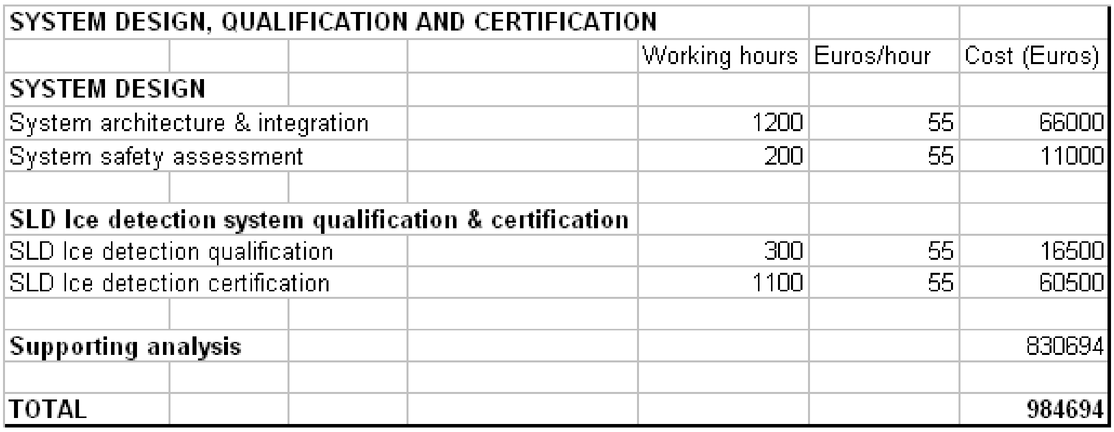
Manufacturers would perform flight tests campaigns in order to verify a number of items that are required for certification, including verifying that their system design is effective and meets the expected performances, evaluating the degradation of the aeroplane performance and flying qualities, verifying the adequacy of the operational procedures and limitations, verifying that powerplant systems perform satisfactorily.

<u>- Additional costs for flight instrument external probes, pilot compartment view, engines installation requirements</u>

These are additional costs induced by the new certification requirements provided for protection of flight instrument external probes (CS 25.1324) (including Pitot tubes, Pitot-static tubes, static probes, angle of attack sensors, side slip vanes and temperature probes), pilot compartment view (CS 25.773) engines installation (CS 25.903 and 25.1093).

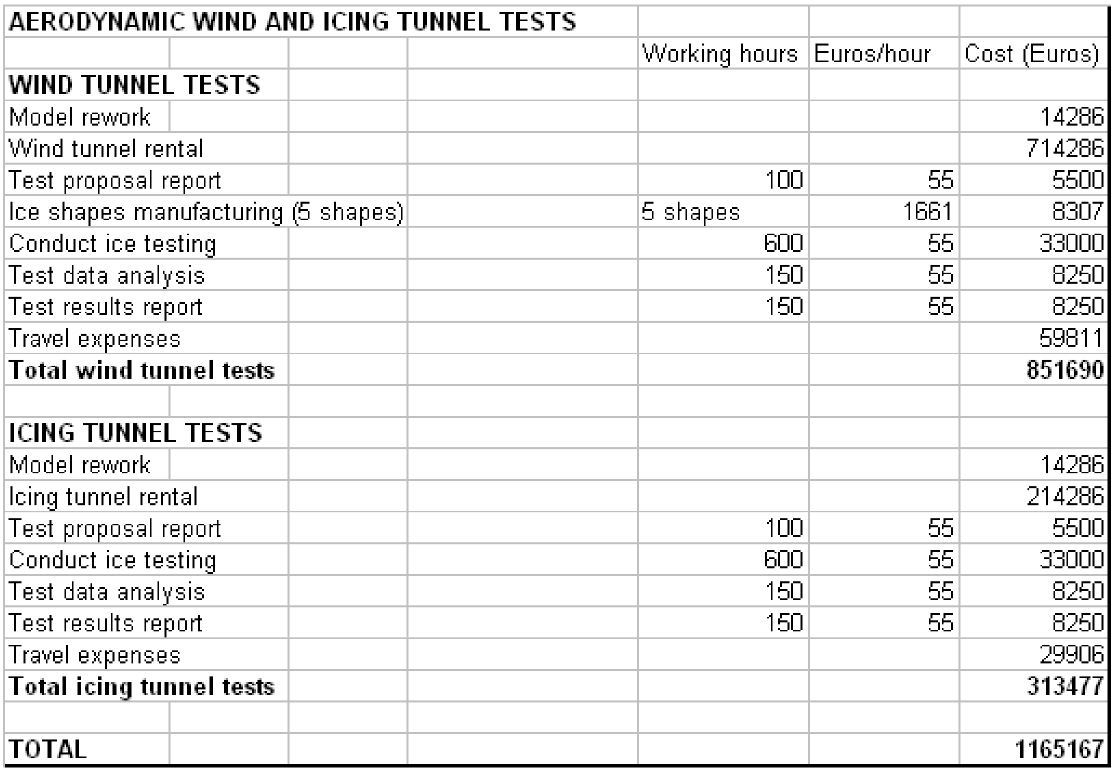
1) <u>Smaller CS-25 aeroplanes</u>

- SLD ice detection system design, qualification and certification:



SYSTEM DESIGN, QUALIFICATION AND CERTIFICATION			
	Working hours	Euros/hour	Cost (Euros)
SYSTEM DESIGN			
System architecture & integration	1200	55	66000
System safety assessment	200	55	11000
SLD Ice detection system qualification & certification			
SLD Ice detection qualification	300	55	16500
SLD Ice detection certification	1100	55	60500
Supporting analysis			830694
TOTAL			**984694**

- Aerodynamic wind and icing tunnel tests:

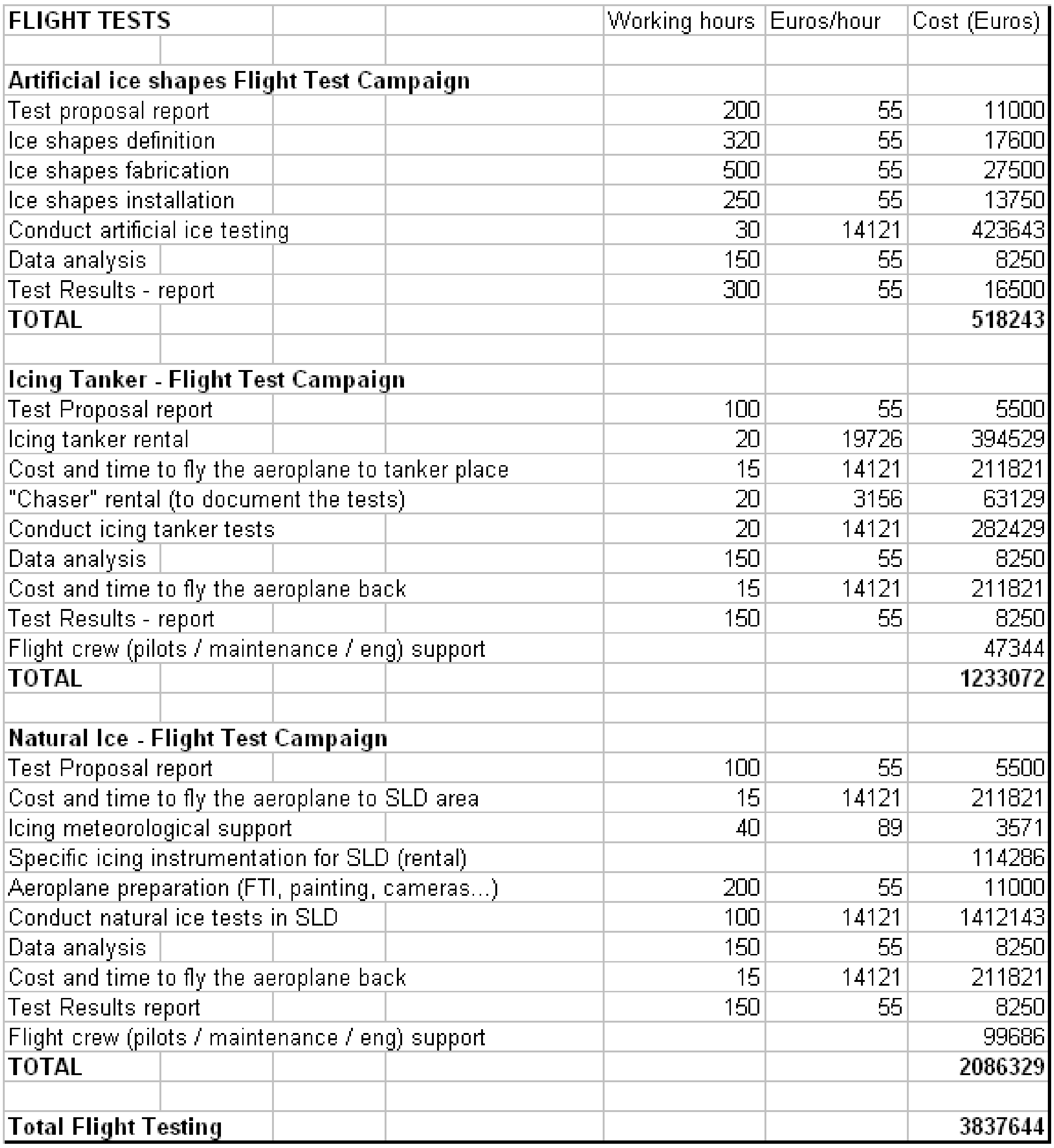


AERODYNAMIC WIND AND ICING TUNNEL TESTS			
	Working hours	Euros/hour	Cost (Euros)
WIND TUNNEL TESTS			
Model rework			14286
Wind tunnel rental			714286
Test proposal report	100	55	5500
Ice shapes manufacturing (5 shapes)	5 shapes	1661	8307
Conduct ice testing	600	55	33000
Test data analysis	150	55	8250
Test results report	150	55	8250
Travel expenses			59811
Total wind tunnel tests			**851690**
ICING TUNNEL TESTS			
Model rework			14286
Icing tunnel rental			214286
Test proposal report	100	55	5500
Conduct ice testing	600	55	33000
Test data analysis	150	55	8250
Test results report	150	55	8250
Travel expenses			29906
Total icing tunnel tests			**313477**
TOTAL			**1165167**

- Analysis:

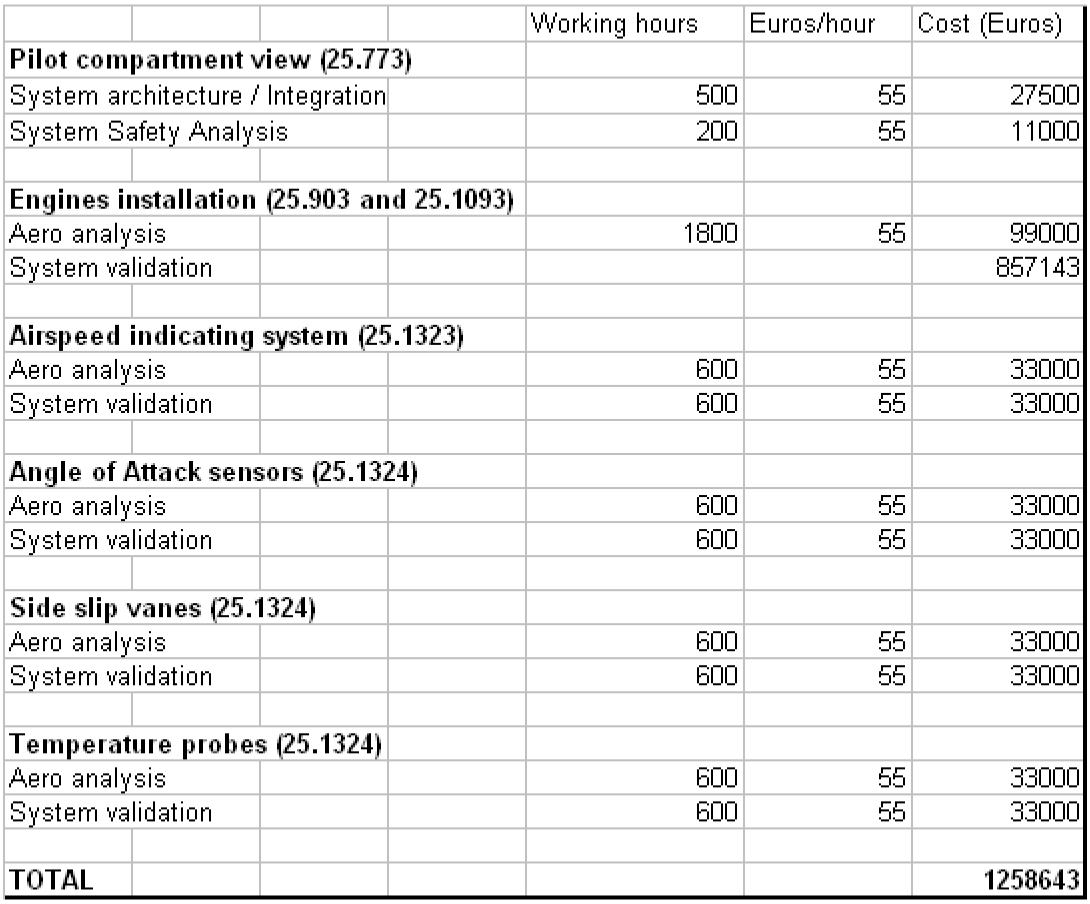
ANALYSIS	
Additional analysis for compliance with the proposed rule requirements	
Cost in Euros:	**857143**

- Flight tests:



FLIGHT TESTS	Working hours	Euros/hour	Cost (Euros)
Artificial ice shapes Flight Test Campaign			
Test proposal report	200	55	11000
Ice shapes definition	320	55	17600
Ice shapes fabrication	500	55	27500
Ice shapes installation	250	55	13750
Conduct artificial ice testing	30	14121	423643
Data analysis	150	55	8250
Test Results - report	300	55	16500
TOTAL			**518243**
Icing Tanker - Flight Test Campaign			
Test Proposal report	100	55	5500
Icing tanker rental	20	19726	394529
Cost and time to fly the aeroplane to tanker place	15	14121	211821
"Chaser" rental (to document the tests)	20	3156	63129
Conduct icing tanker tests	20	14121	282429
Data analysis	150	55	8250
Cost and time to fly the aeroplane back	15	14121	211821
Test Results - report	150	55	8250
Flight crew (pilots / maintenance / eng) support			47344
TOTAL			**1233072**
Natural Ice - Flight Test Campaign			
Test Proposal report	100	55	5500
Cost and time to fly the aeroplane to SLD area	15	14121	211821
Icing meteorological support	40	89	3571
Specific icing instrumentation for SLD (rental)			114286
Aeroplane preparation (FTI, painting, cameras...)	200	55	11000
Conduct natural ice tests in SLD	100	14121	1412143
Data analysis	150	55	8250
Cost and time to fly the aeroplane back	15	14121	211821
Test Results report	150	55	8250
Flight crew (pilots / maintenance / eng) support			99686
TOTAL			**2086329**
Total Flight Testing			**3837644**

- Additional costs for flight instrument external probes, pilot compartment view, engines installation requirements:



	Working hours	Euros/hour	Cost (Euros)
Pilot compartment view (25.773)			
System architecture / Integration	500	55	27500
System Safety Analysis	200	55	11000
Engines installation (25.903 and 25.1093)			
Aero analysis	1800	55	99000
System validation			857143
Airspeed indicating system (25.1323)			
Aero analysis	600	55	33000
System validation	600	55	33000
Angle of Attack sensors (25.1324)			
Aero analysis	600	55	33000
System validation	600	55	33000
Side slip vanes (25.1324)			
Aero analysis	600	55	33000
System validation	600	55	33000
Temperature probes (25.1324)			
Aero analysis	600	55	33000
System validation	600	55	33000
TOTAL			**1258643**

Therefore:

The total cost for a new smaller CS-25 aeroplane certification is 8.103.290 Euros with an SLD ice detection system and 7.118.596 Euros without an SLD ice detection system.

We have estimated that there will be 2.71 new certification projects in the next 10 years, and 50 % of the projects would include an SLD ice detection system.

The total certification cost would be **20.625.656 Euros (Present value: 19.069.579 Euros)**.

2) <u>Medium CS-25 aeroplanes</u>

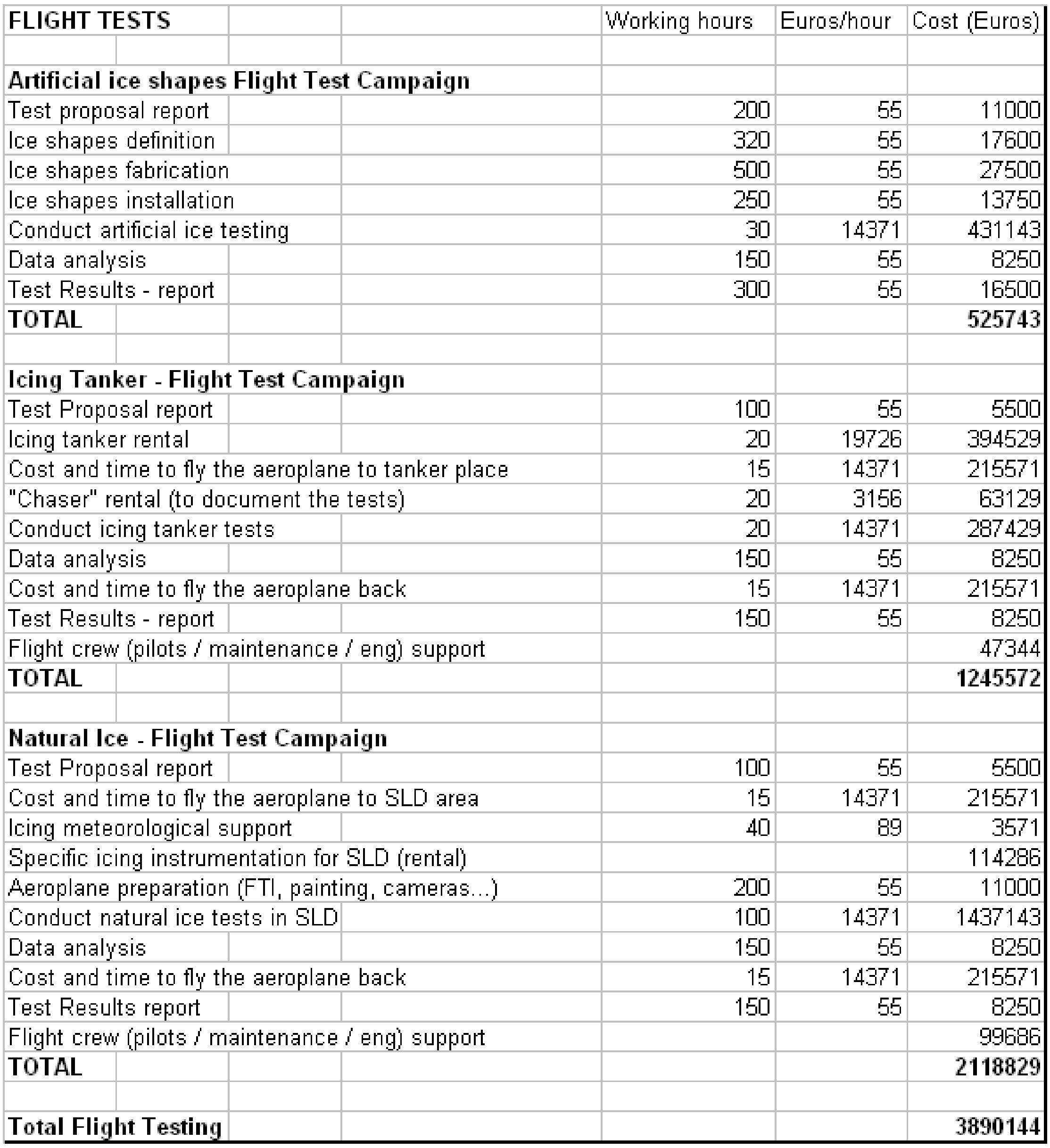
System design, qualification and certification costs are identical to the smaller aeroplanes.

Aerodynamic wind and icing tunnel tests costs are identical to the smaller aeroplanes.

Analysis costs are identical to the smaller aeroplanes.

Additional costs for flight instrument external probes, pilot compartment view, engines installation requirements are identical to the smaller aeroplanes.

Flight tests costs would be higher, as follows:



FLIGHT TESTS	Working hours	Euros/hour	Cost (Euros)
Artificial ice shapes Flight Test Campaign			
Test proposal report	200	55	11000
Ice shapes definition	320	55	17600
Ice shapes fabrication	500	55	27500
Ice shapes installation	250	55	13750
Conduct artificial ice testing	30	14371	431143
Data analysis	150	55	8250
Test Results - report	300	55	16500
TOTAL			**525743**
Icing Tanker - Flight Test Campaign			
Test Proposal report	100	55	5500
Icing tanker rental	20	19726	394529
Cost and time to fly the aeroplane to tanker place	15	14371	215571
"Chaser" rental (to document the tests)	20	3156	63129
Conduct icing tanker tests	20	14371	287429
Data analysis	150	55	8250
Cost and time to fly the aeroplane back	15	14371	215571
Test Results - report	150	55	8250
Flight crew (pilots / maintenance / eng) support			47344
TOTAL			**1245572**
Natural Ice - Flight Test Campaign			
Test Proposal report	100	55	5500
Cost and time to fly the aeroplane to SLD area	15	14371	215571
Icing meteorological support	40	89	3571
Specific icing instrumentation for SLD (rental)			114286
Aeroplane preparation (FTI, painting, cameras...)	200	55	11000
Conduct natural ice tests in SLD	100	14371	1437143
Data analysis	150	55	8250
Cost and time to fly the aeroplane back	15	14371	215571
Test Results report	150	55	8250
Flight crew (pilots / maintenance / eng) support			99686
TOTAL			**2118829**
Total Flight Testing			**3890144**

Therefore:

The total cost for a new medium CS-25 aeroplane certification is 8.155.790 Euros with an SLD ice detection system and 7.171.096 Euros without an SLD ice detection system.

We have estimated that there will be 1.51 new certification projects in the next 10 years, and 50 % of the projects would include an SLD ice detection system.

The total certification cost would be **11.571.799 Euros (Present value: 10.698.779 Euros)**.

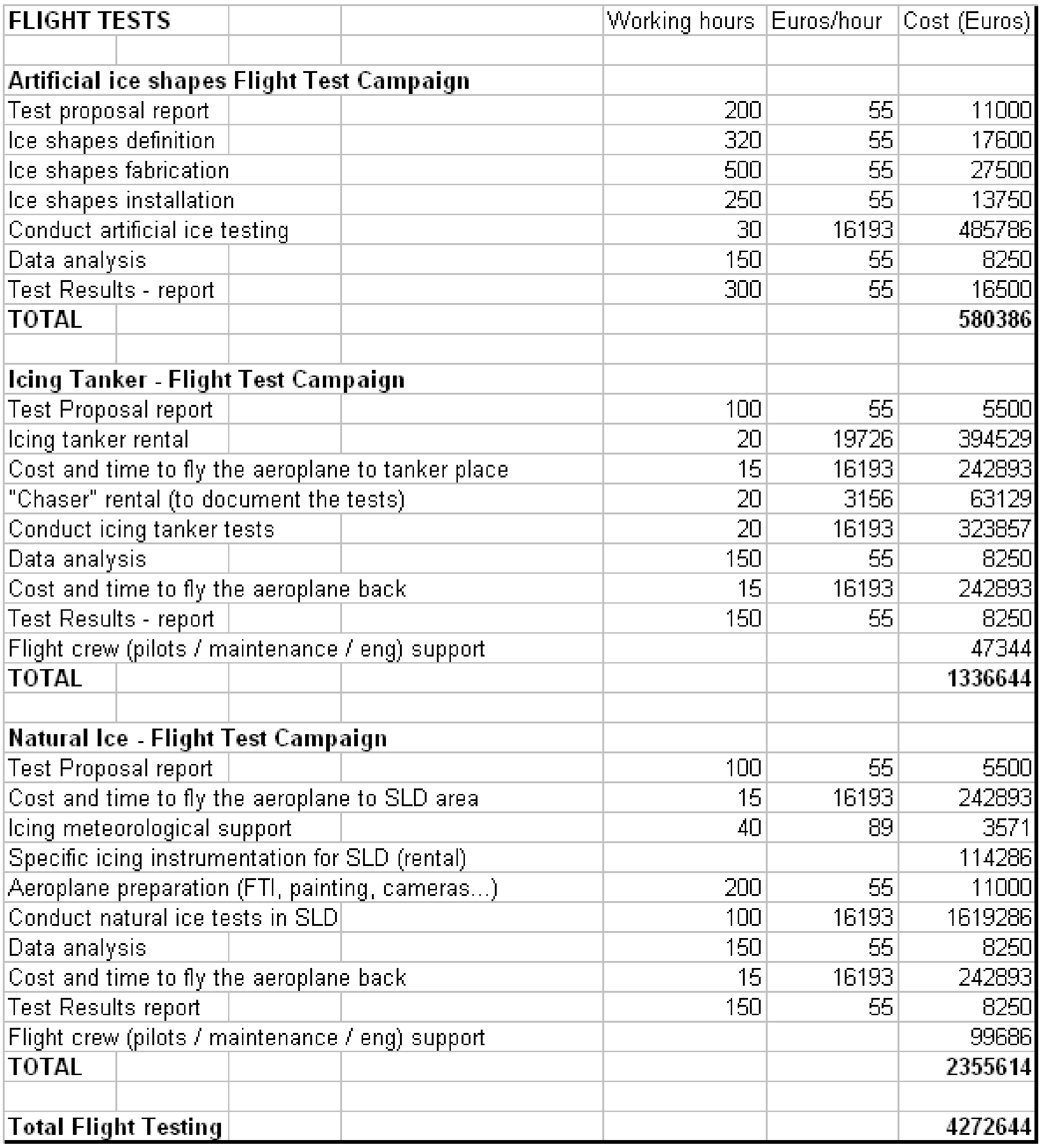
3) <u>Larger CS-25 aeroplanes</u>

Aerodynamic wind and icing tunnel tests costs are identical to the smaller aeroplanes.

Analysis costs are identical to the smaller aeroplanes.

Additional costs for flight instrument external probes, pilot compartment view, engines installation requirements are identical to the smaller aeroplanes.

Flight tests costs would be higher, as follows:



FLIGHT TESTS	Working hours	Euros/hour	Cost (Euros)
Artificial ice shapes Flight Test Campaign			
Test proposal report	200	55	11000
Ice shapes definition	320	55	17600
Ice shapes fabrication	500	55	27500
Ice shapes installation	250	55	13750
Conduct artificial ice testing	30	16193	485786
Data analysis	150	55	8250
Test Results - report	300	55	16500
TOTAL			**580386**
Icing Tanker - Flight Test Campaign			
Test Proposal report	100	55	5500
Icing tanker rental	20	19726	394529
Cost and time to fly the aeroplane to tanker place	15	16193	242893
"Chaser" rental (to document the tests)	20	3156	63129
Conduct icing tanker tests	20	16193	323857
Data analysis	150	55	8250
Cost and time to fly the aeroplane back	15	16193	242893
Test Results - report	150	55	8250
Flight crew (pilots / maintenance / eng) support			47344
TOTAL			**1336644**
Natural Ice - Flight Test Campaign			
Test Proposal report	100	55	5500
Cost and time to fly the aeroplane to SLD area	15	16193	242893
Icing meteorological support	40	89	3571
Specific icing instrumentation for SLD (rental)			114286
Aeroplane preparation (FTI, painting, cameras...)	200	55	11000
Conduct natural ice tests in SLD	100	16193	1619286
Data analysis	150	55	8250
Cost and time to fly the aeroplane back	15	16193	242893
Test Results report	150	55	8250
Flight crew (pilots / maintenance / eng) support			99686
TOTAL			**2355614**
Total Flight Testing			**4272644**

Therefore:

The total cost for a new larger CS-25 aeroplane certification is 7.553.596 Euros.

As we have estimated that there will be 2.95 new certification projects in the next 10 years, the total certification cost would be **22.283.109 Euros (Present value: 20.601.987 Euros)**.

The total cost for new aeroplane type certification in the 10-years period of the analyses (smaller/medium/larger): **54.480.565 Euros (Present value: 50.370.345 Euros).**

5.4.1.3 Certification costs for derivatives

We have evaluated the impact of the proposed new CS-25 rules on the certification of aeroplanes which are derivatives of already certificated types.

Two scenarios can be envisaged:

1) Derivative project involving changes which are not significant under Part 21, 21.101.

This would be the case as long as the general configuration or the principles of construction are retained and the assumptions used for certification of the “father aeroplane” remain valid.

In those cases, the applicant can elect to comply with the existing type certification basis of the aeroplane from which the new product is derivate. Therefore, no cost impact would be induced by the proposed rules and the applicant is free to elect complying with the last CS-25 amendment.

2) Derivative project involving changes which are significant under Part 21, 21.101.

Examples:

- Modification of the ice protection system involving significant change in the performance of the system or in the architecture of the system (e.g. adding new ice detectors, new ice protection devices),
- Significant changes which would require a complete analysis of the existing ice protection, such as a significant change of the wing profile or wing span.
- Installation of new engines with substantial performance change (typically more than 10 % thrust increase) and/or requiring a complete analysis of the engine anti-ice system.

In such cases, the Agency would require compliance with the last requirements for ice protection as provided in the proposed CS-25 rule.

Based on our experience, we believe that the majority of the applications would fall in Option 1.

The cases which would correspond to Option 2 are very rare, and nowadays manufacturers prefer to propose a completely new aircraft projects instead of proposing expensive modifications of old types. Therefore we consider that the corresponding costs impacts are included in our assessment for new project certification (see previous paragraph).

5.4.1.4 Hardware costs

The industry provided an estimate for the additional SLD ice detectors at 10000 US dollars, which is equivalent to 7143 Euros (in 2010).

Moreover, the industry estimates that roughly 50 % of the smaller and medium aeroplanes might be certified using visual cues and the remaining ones might be certified using detectors. Therefore 50 % of the smaller and medium aeroplanes deliveries would be affected.

For the larger aeroplanes, we assume that all aeroplanes will be certificated to the full Appendix O, therefore there is no obligation of installing an SLD ice detector, and no additional hardware cost is to be considered.

Using our previous European fleet assessment, we find the following costs:

- Smaller aeroplanes (126 aircraft): 900.000 Euros
- Medium aeroplanes (116 aircraft): 828.571 Euros
- Larger aeroplanes: 0 Euro

Total cost: **1.728.571 Euros (Present value: 965.893 Euros).**

5.4.1.5 Operating costs

<u>- Fuel costs</u>

The SLD ice detectors hardware would add weight and thus induce a fuel burn penalty.

The estimated additional hardware weight is 19 pounds or 8.6 kilograms.

50 % of the smaller and medium aeroplanes and none of the larger aeroplanes would be concerned.

For fuel consumption estimates, we use data from the "FAA Aerospace Forecast 2009-2025", along with the fuel consumption methodology in "FAA's guidance, Economic values for FAA investment and regulatory decisions".

We assume an average 0.005 gallons per flight hour per pound of additional weight for the smaller CS-25 aeroplanes, 0.004 for medium CS-25 aeroplanes and 0.003 for larger CS-25 aeroplanes.

The estimated average incremental fuel cost is 1.92 US dollar per gallon.

1) Smaller CS-25 aeroplanes

The additional weight is first multiplied by the fuel burn factor per aeroplane. The product is then multiplied by the annual flight hours and by the cost of fuel. This provides the additional annual cost per aeroplane.

The average annual number of flight hours for the smaller CS-25 aeroplanes is 900 hours (source: Ascend CASE aviation database).

Therefore the first year annual estimated additional cost of fuel for each smaller aeroplane is 164 US dollars (=19*0.005*900*1.92) or 117 Euros (2010).

We multiply by the number of affected aeroplanes (50 % of the net fleet) over the years until the last retirement.

The total cost over the period of analysis is 428.458 Euros.

2) Medium CS-25 aeroplanes

Similarly, we make the same calculation using an average annual number of flight hours for the medium CS-25 aeroplanes of 1316 hours (source: Ascend CASE aviation database).

Therefore the first year annual estimated additional cost of fuel for each medium aeroplane is 192 US dollars (=19*0.004*1316*1.92) or 137 Euros (2010).

We multiply by the number of affected aeroplanes (50 % of the net fleet) over the years until the last retirement.

The total cost over the period of analysis is 461.422 Euros.

3) Larger CS-25 aeroplanes

For the larger aeroplanes, we assume that all aeroplanes will be certificated to the full Appendix O, therefore there is no obligation of installing an SLD ice detector, and no additional fuel cost.

Total fuel cost (smaller/medium/larger): **889.880 Euros (Present value: 301.304 Euros).**

- Other operating costs

Smaller and medium aeroplanes: as recommended by the IPHWG, other operating costs could be added for aeroplanes not certified for operation in severe icing conditions like the SLD environment. These costs come from the requirement to make diversions when exiting from SLD conditions, diverting the aeroplane to an alternate airport or from cancellations of flights.

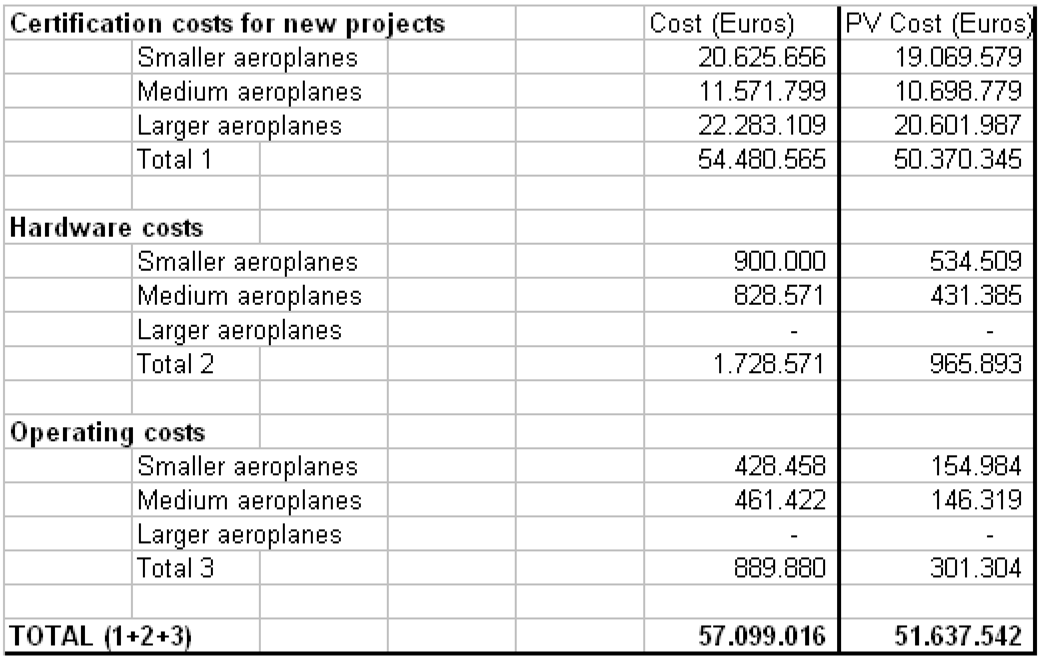
Meanwhile, today operators already follow procedures to avoid flying in or exit from severe icing conditions as required in Aeroplane Flight Manuals (using visual cues); Airworthiness Directives were published in the past years to address this subject.

Therefore operators already bear the cost of diversions or flight cancellations and this NPA does not need to consider this cost in its impact assessment.

Larger aeroplanes: assuming that these aircraft will be certified to the full Appendix O, there will not be any additional cost from diversions or cancellations.

5.4.1.6 Cost summary

The total estimated cost for the period of analysis is **57.1 millions Euros (Present value: 51.6 millions Euros)**; the following table summarises the different cost categories.



Certification costs for new projects		Cost (Euros)	PV Cost (Euros)
	Smaller aeroplanes	20.625.656	19.069.579
	Medium aeroplanes	11.571.799	10.698.779
	Larger aeroplanes	22.283.109	20.601.987
	Total 1	54.480.565	50.370.345
Hardware costs			
	Smaller aeroplanes	900.000	534.509
	Medium aeroplanes	828.571	431.385
	Larger aeroplanes	-	-
	Total 2	1.728.571	965.893
Operating costs			
	Smaller aeroplanes	428.458	154.984
	Medium aeroplanes	461.422	146.319
	Larger aeroplanes	-	-
	Total 3	889.880	301.304
TOTAL (1+2+3)		**57.099.016**	**51.637.542**

5.5 Proportionality issues

None identified.

5.6 Impact on regulatory coordination and harmonisation

Some differences are identified compared to the draft rule proposed by the FAA in their NPRM (docket FAA-2010-0636). Refer to chapter IV.15 for detailed explanations.

6. Conclusion and preferred option

6.1 Comparing the options

The Agency prefers Option 1, rulemaking action.

The associated total cost of 51.8 million Euros (Nominal value: 57.7 million Euros) brought by the proposed rule is considered balanced by the safety benefit of 76.3 million Euros (Nominal value: 183.1 million) of preventing accidents. The net benefit of option 1 is 24.5 million Euros.

Although there are no documented fatal accidents in the EU caused by the specific severe icing environment, we consider that the safety threat is present with an equivalent probability as established by the FAA and that Certification Specifications must be updated to better protect new aeroplane types.

Summary of benefits and costs (including environmental impacts)

Costs (EUR)	Nominal Value	Present Value	Benefits (EUR)	Nominal Value	Present Value
Certification costs	54,480,565	50,370,345	Smaller aeroplanes	11,297,677	4,086,669
Hardware costs	1,728,571	965,893	Medium aeroplanes	10,401,036	3,298,217
Operating costs	889,880	301,304	Larger aeroplanes	161,432,532	68,916,650
Environmental impacts	600,750	117,296			
Total costs	57,699,766	51,754,838	Total benefits	183,131,244	76,301,537

Annex A: Risk assessment

ICAO defines safety as the state in which the risk of harm to persons or property damage is reduced to, and maintained at or below, an acceptable level through a continuous process of hazard identification and risk management.

Thus, risk assessment is a key element for managing safety. Risk is expressed in terms of predicted probability and severity of the consequences of a hazard taking as a reference to the worst foreseeable situation.

In order to define the elements 'probability' and 'severity', the following tables were developed based on the ICAO framework.

Table 3: Probability of occurrence[9]

Definition	Value	Description
Frequent	5	Likely to occur many times (has occurred frequently). Failure conditions are anticipated to occur one or more times during the entire operational life to each aircraft within a category.
Occasional	4	Likely to occur sometimes (has occurred infrequently). Failure conditions are anticipated to occur one or more times during the entire operational life to many different aircraft types within a category.
Remote	3	Unlikely, but possible to occur (has occurred rarely). Those failure conditions that are unlikely to occur to each aircraft within a category during its total life but that may occur several times when considering a specific type of operation.
Improbable	2	Very unlikely to occur. Those failure conditions not anticipated to occur to each aircraft during its total life but which may occur a few times when considering the total operational life of all aircraft within a category.
Extremely improbable	1	Almost inconceivable that the event will occur. For rulemaking proposals aimed at CS-25, CS-29 or CS-23 (commuter) aircraft, the failure conditions are so unlikely to occur that they are not anticipated to occur during the entire operational life of the entire fleet. For other categories of aircraft, the likelihood of occurrence may be greater.[10]

---

[9] These categories need to be applicable to a wide range of safety issues and are taken from the ICAO Safety Management Manual. The description is harmonised with CS-25. Note that these descriptions are indicative only and may have to be adjusted to different rulemaking tasks depending on subsector of aviation.

[10] The category 'extremely improbable' here can also include cases where the probability cannot be quantified as 10^{-9}.

Table 4: Severity of occurrences

Definition	**Value**	**Description**
Catastrophic[11]	8	Multiple deaths (three and more) and equipment destroyed (hull loss).
Hazardous	5	A large reduction of safety margins. Maximum two fatalities. Serious injury. Major equipment damage.
Major	3	A significant reduction of safety margins. Serious incident. Injury of persons.
Minor	2	Nuisance. Operating limitations. Use of emergency procedures. Minor incident.
Negligible	1	Little consequences.

---

[11] Note that severity category 'Catastrophic' was attributed the value of 8. This has been done in order to distinguish a 'Catastrophic/Extremely improbable' case from a 'Negligible/Frequent' case and give a higher weight to catastrophic events. The former is considered to be of medium significance whereas the latter is of low significance as the potential outcome is limited.

Table 5: Risk index matrix

Probability of occurrence		**Severity of occurrence**				
		Negligible	**Minor**	**Major**	**Hazardous**	**Catastrophic**
		1	2	3	5	8
Extremely improbable	1	**1**	**2**	**3**	**5**	**8**
Improbable	2	**2**	**4**	**6**	**10**	**16**
Remote	3	**3**	**6**	**9**	**15**	**24**
Occasional	4	**4**	**8**	**12**	**20**	**32**
Frequent	5	**5**	**10**	**15**	**25**	**40**

Table 6: Description of the different risk indices

Risk index		Description[12]
15-40	High significance	Unacceptable under the existing circumstances.
15	Medium or High significance	For non-complex aircraft this would result in a medium significance issue. For CAT with complex motor-powered aircraft this would result in a high significance issue.
7-14	Medium significance	Tolerable based on risk mitigation by the stakeholders and/or rulemaking action.
1-6	Low significance	Acceptable, but monitoring or non-rulemaking action required.

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[12] The descriptions are based on the ICAO Safety Management Systems Handbook. However, as the SMS system is geared towards operators and not regulators, the descriptions were adjusted to better reflect EASA's needs.

B. Draft Decision

The text of the amendment is arranged to show deleted text, new text or new paragraph as shown below:

1. deleted text is shown with a strike through: ~~deleted~~
2. new text is highlighted with grey shading: new
3. ….

   indicates that remaining text is unchanged in front of or following the reflected amendment.

I Draft Decision amending CS-25

Book 1

Amend CS 25.21 as follows:

CS 25.21 Proof of compliance

…

(g) …

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

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

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

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

Amend CS 25.105 as follows:

CS 25.105 Take-off

(a) …

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

…

Amend CS 25.111 as follows:

CS 25.111 Take-off path

…

(c) …

(5) …

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

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

…

Amend CS 25.119 as follows:

CS 25.119 Landing climb: all-engines-operating

…

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

Amend CS 25.121 as follows:

CS 25.121 Climb: one-engine-inoperative

…

(b) …

(2) …

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

…

(c) …

(2) …

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

…

(d) …

(2) …

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

…

Amend CS 25.123 as follows:

CS 25.123 En-route flight paths

(b) …

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

…

Amend CS 25.125 as follows:

CS 25.125 Landing

(a) …

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

(b) …

(2) …

(ii) …

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

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

…

Amend CS 25.143 as follows:

CS 25.143 Controllability and manoeuvrability - General

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

…

(i) …

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

…

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

…

Amend CS 25.207 *Stall warning* as follows:

CS 25.207 Stall warning

…

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

…

(e) …

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

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

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

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

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

…

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

…

Amend CS 25.237 as follows:

CS 25.237 Wind velocities

(a) …

(3) …

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

Amend CS 25.253 as follows:

CS 25.253 High-speed characteristics

…

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

…

Amend CS 25.773 as follows:

CS 25.773 Pilot compartment view

…

(b) …

(1) …

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

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

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

(C) For aeroplanes certificated in accordance with CS 25.1420(a)(3) and for aeroplanes not subject to CS 25.1420, all icing conditions.

Amend CS 25.903 as follows:

CS 25.903 Engines

(a) …

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

…

Amend CS 25.929 as follows:

CS 25.929 Propeller de-icing

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

…

Amend CS 25.1093 as follows:

CS 25.1093 Air intake system de-icing and anti-icing provisions

…

(b) Turbine engines

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

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

~~(ii) Reserved~~

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

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

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

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

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

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

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

Table 1- ICING CONDITIONS FOR GROUND TESTS

Condition	Total air temperature	Water concentration (minimum)	Mean effective particle diameter	Demonstration
(i) Rime ice condition	-18 to -9°C (0 to 15°F)	Liquid—0.3 g/m^3	15–25 microns	By test, analysis or combination of the two.
(ii) Glaze ice condition	-7 to -1°C (20 to 30°F)	Liquid—0.3 g/m^3	15–25 microns	By test, analysis or combination of the two.
(iii) Large drop condition	-9 to -1°C (15 to 30°F)	Liquid—0.3 g/m^3	100 microns (minimum)	By test, analysis or combination of the two.

Amend CS 25.1323 as follows:

CS 25.1323 Airspeed indicating system

…

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

…

Create a new CS 25.1324 as follows:

CS 25.1324 Flight instrument external probes heating systems

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

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

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

(c) For aeroplanes certificated in accordance with CS 25.1420(a)(3) and for aeroplanes not subject to CS 25.1420, all icing conditions.

Each flight instrument external probes systems must be designed and installed to operate normally without any malfunction in presence of heavy rain conditions (refer to AMC 25.1324).

Amend CS 25.1325 as follows:

CS 25.1325 Static pressure systems

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

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

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

Amend CS 25.1326 as follows:

CS 25.1326 Flight instrument external probes heat indication systems ~~Pitot~~ heat indication systems

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

(a) The indication provided must incorporate an amber light that is in clear view of a flight-crew member.

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

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

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

Create a new CS 25.1420 as follows:

CS 25.1420 Supercooled large drop icing conditions

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

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

(i) There must be a means provided to detect that the aeroplane is operating in Appendix O icing conditions; and

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

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

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

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

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

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

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

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

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

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

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

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

Amend CS 25.1521 as follows:

CS 25.1521 Powerplant limitations

…

(c)…

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

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

Amend CS 25.1533 as follows:

CS 25.1533 Additional operating limitations

…

(c) For aeroplanes certified in accordance with CS 25.1420(a)(1) or (a)(2), an operating limitation must be established to require exiting all icing conditions if icing conditions defined in Appendix O are encountered for which the aeroplane has not been certified to safely operate.

Create a new Appendix O as follows:

Appendix O

Supercooled Large Drop icing conditions

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

Part I—Meteorology

Appendix O icing conditions are defined by the parameters of altitude, vertical and horizontal extent, temperature, liquid water content, and water mass distribution as a function of drop diameter distribution.

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

(1) Pressure altitude range: 0 to 6706 m (22000 feet) MSL.

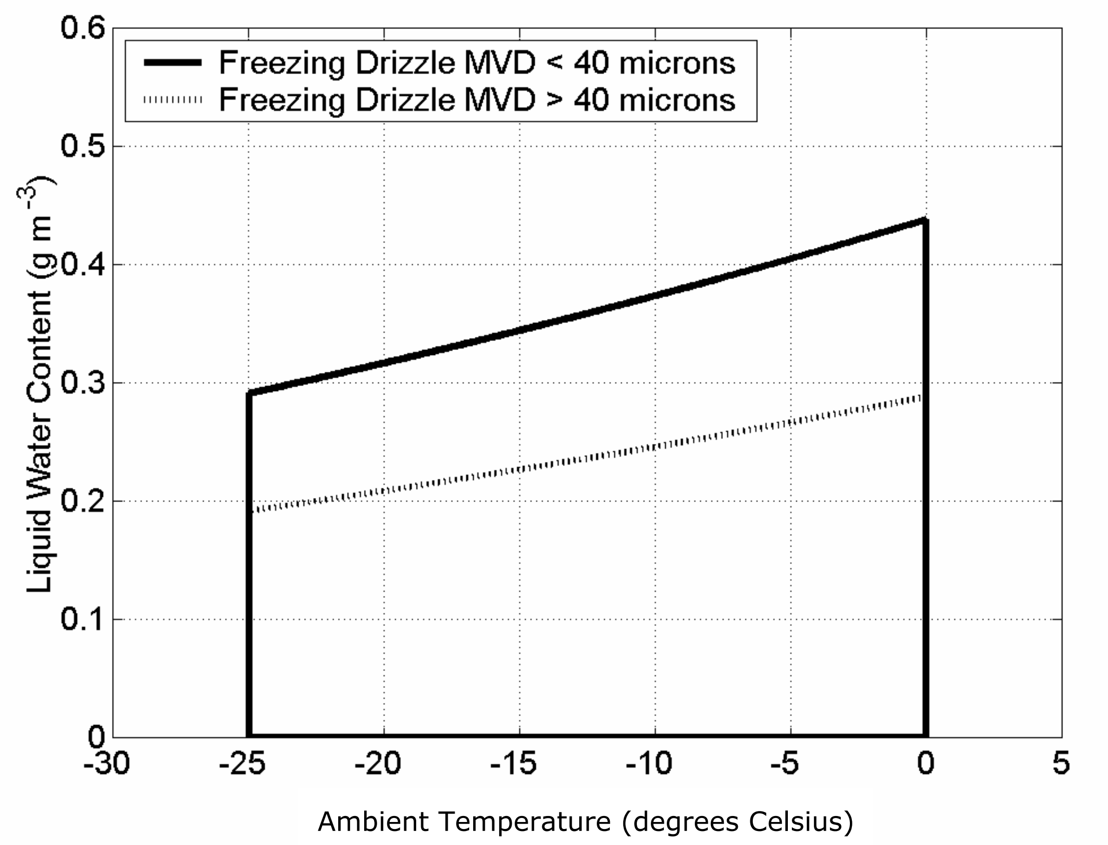
(2) Maximum vertical extent: 3656 m (12000 feet).

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

(4) Total liquid water content:

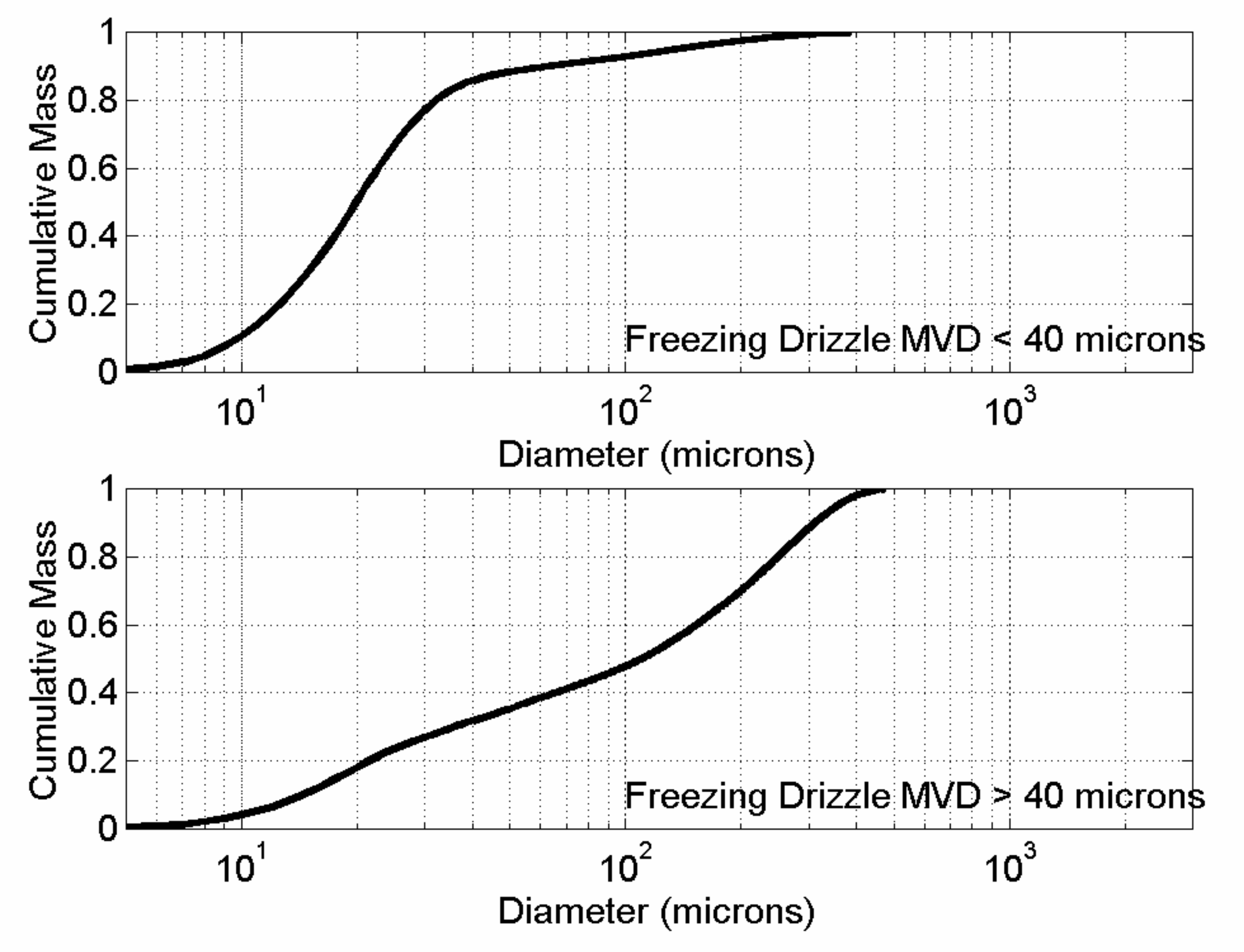
Note: Liquid water content (LWC) in grams per cubic meter (g/m3) based on horizontal extent standard distance of 32.2 km (17.4 nautical miles).

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



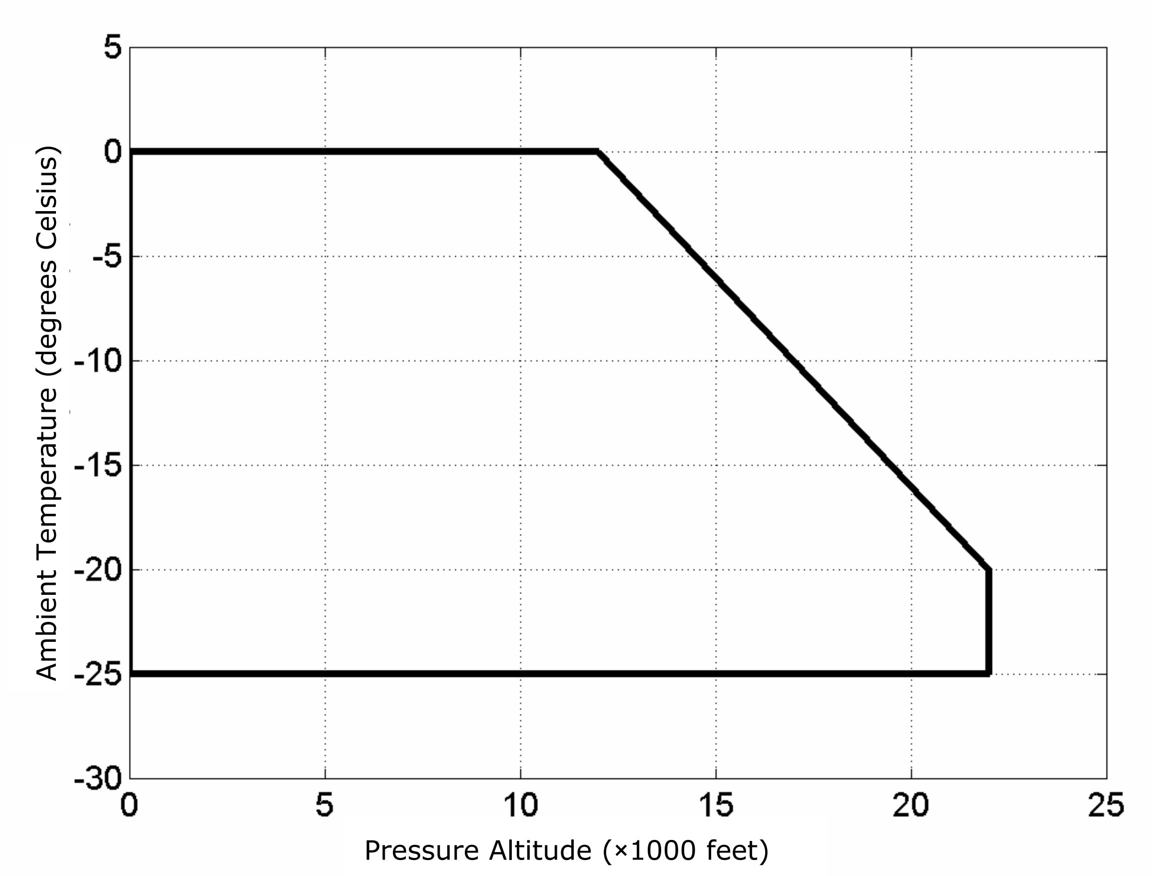
(5) Drop diameter distribution:

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



(6) Altitude and temperature envelope:

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



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

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

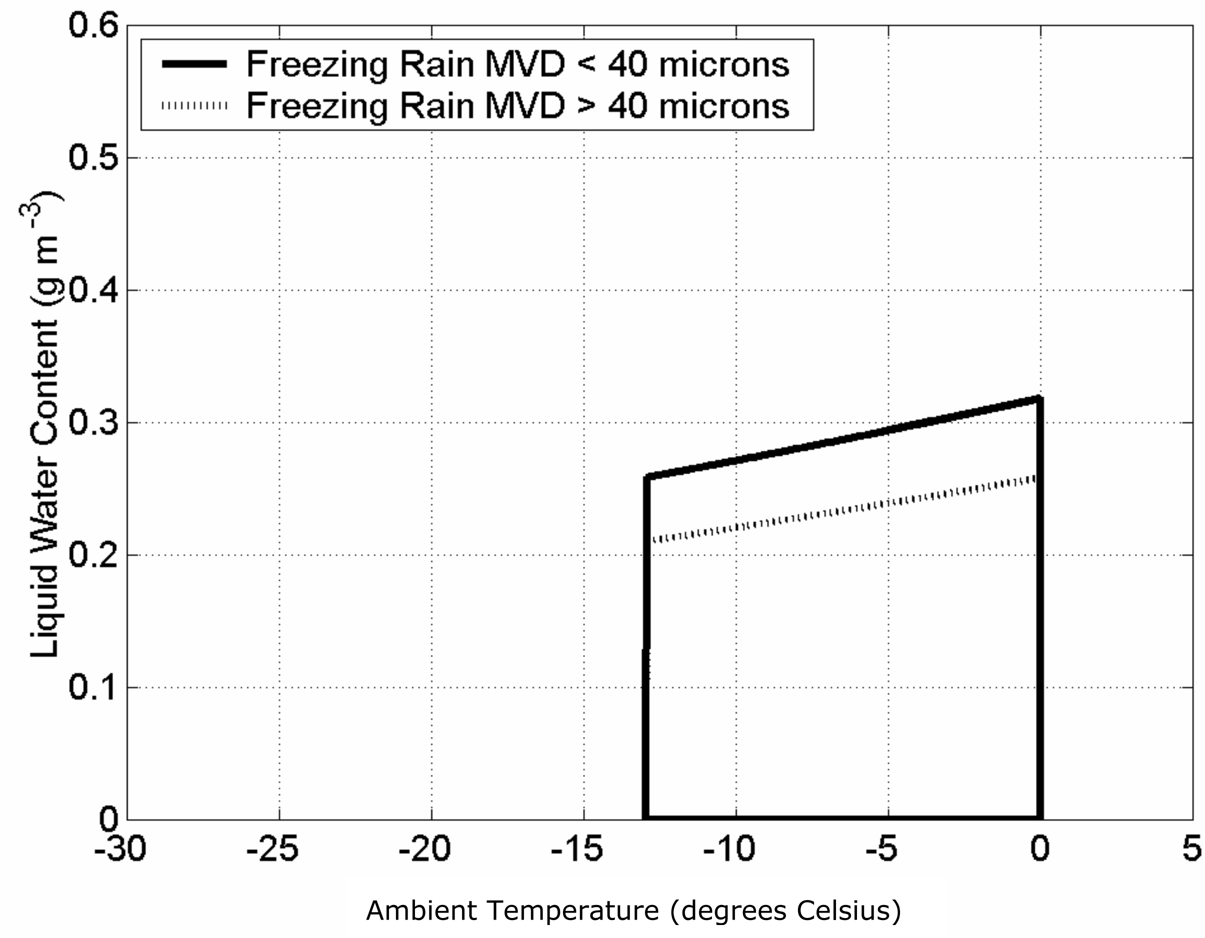
(2) Maximum vertical extent: 2134 m (7000 ft).

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

(4) Total liquid water content:

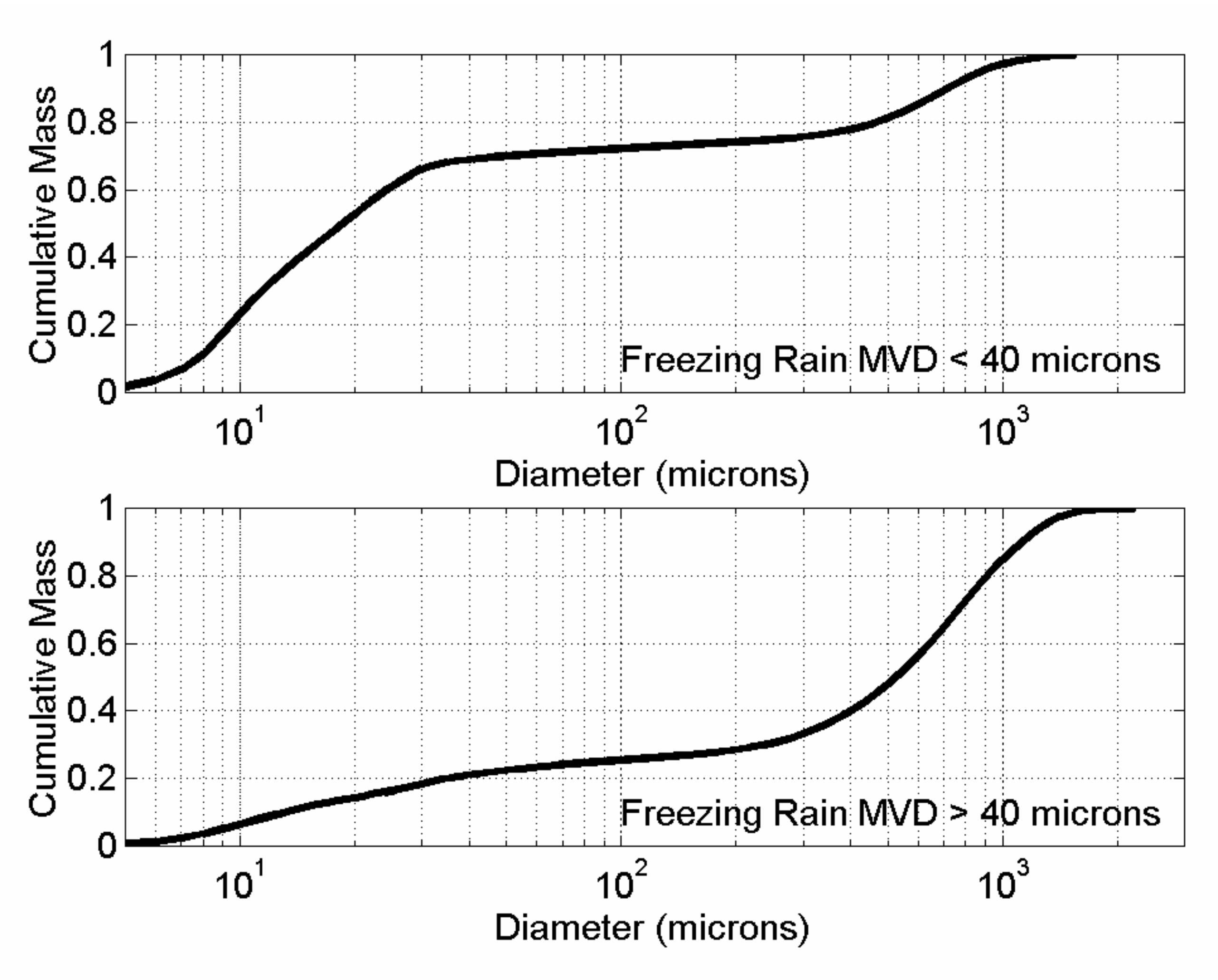
Note: LWC in grams per cubic meter (g/m3) based on horizontal extent standard distance of 32.2 km (17.4 nautical miles).

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



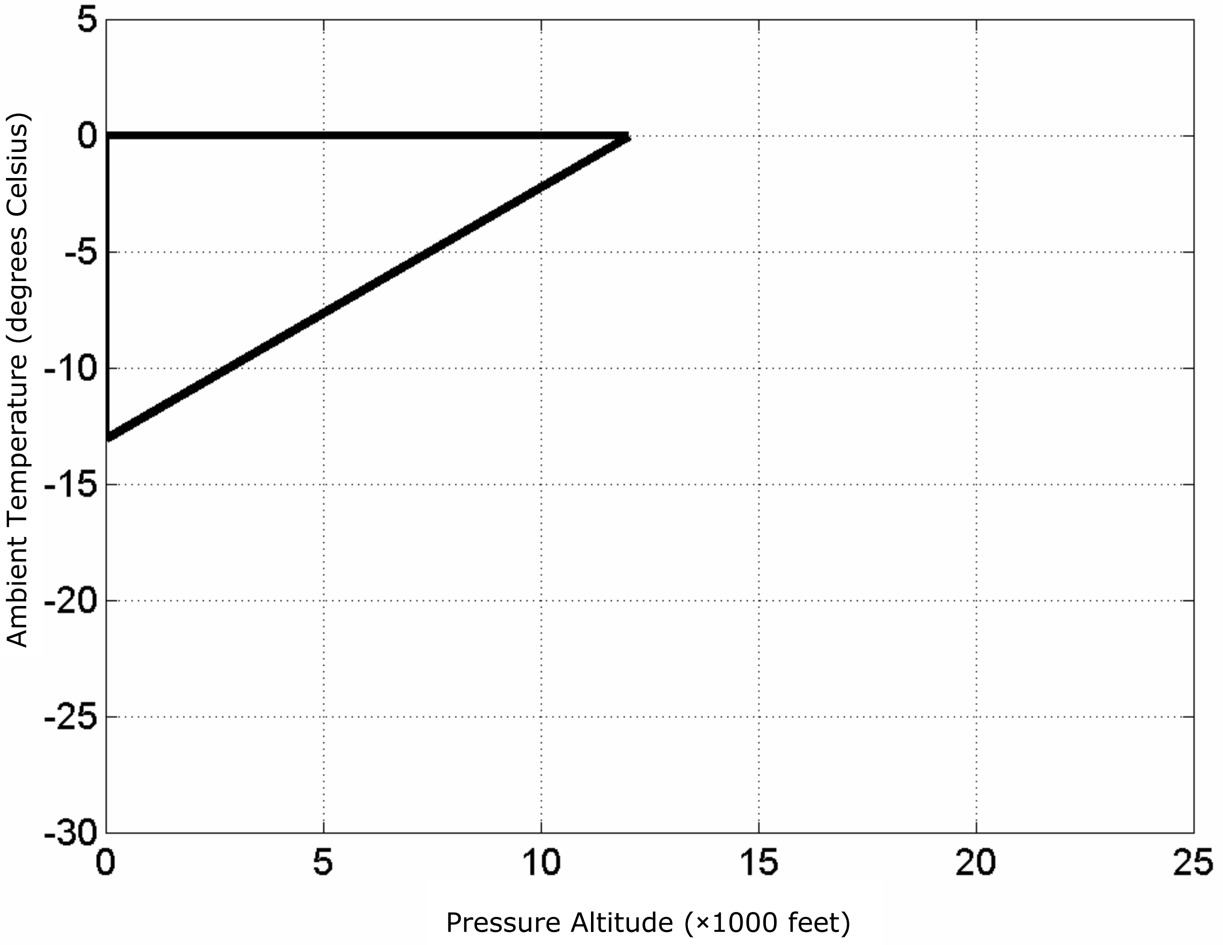
(5) Drop diameter distribution:

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



(6) Altitude and temperature envelope:

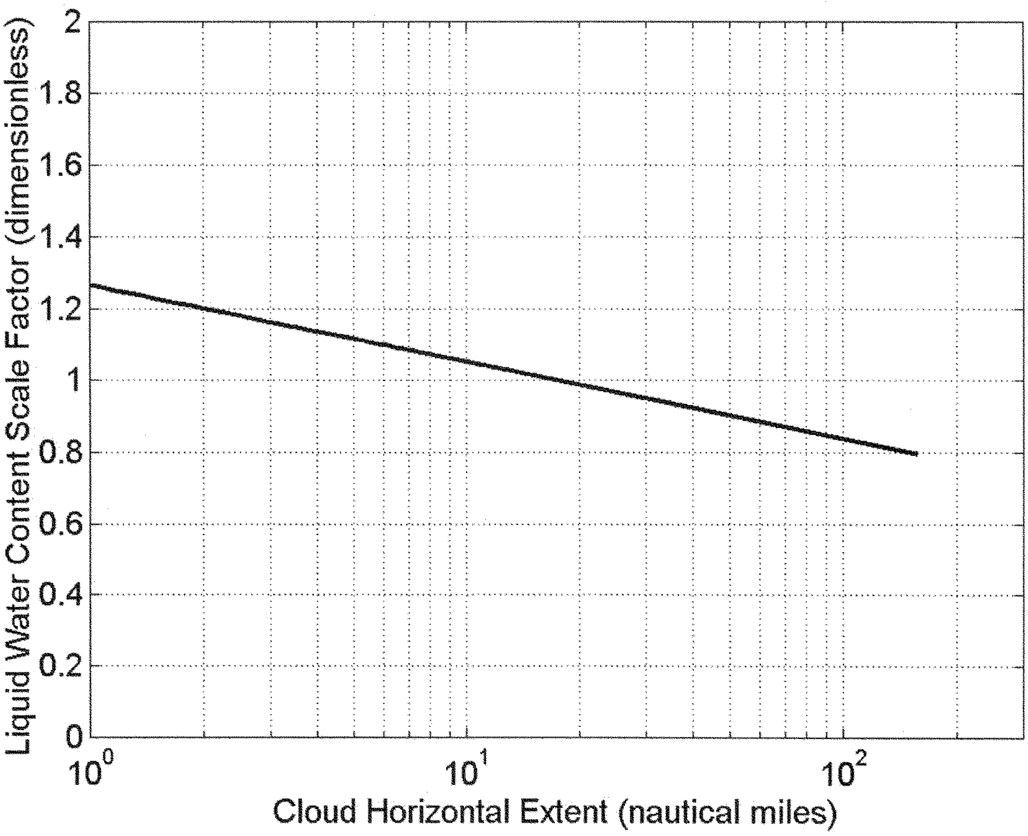
Figure 6 – Appendix O, Freezing Rain, Altitude and Temperature



(c) Horizontal extent

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

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



Part II—Airframe ice accretions for showing compliance with Subpart B

(a) General.

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

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

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

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

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

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

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

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

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

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

(ii) The ice accumulated during the transit of one cloud with a 32.2 km (17.4 nautical miles) horizontal extent in the most critical of the icing conditions defined in part I of this appendix and one cloud with a horizontal extent of 32.2 km (17.4 nautical miles) in the continuous maximum icing conditions defined in Appendix C. The total exposure to the icing conditions need not exceed 45 minutes.

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

(i) For an aeroplane certified in accordance with CS 25.1420(a)(2), the ice accumulated during descent from the maximum vertical extent of the icing conditions defined in part I of this appendix to 610 m (2000 feet) above the landing surface in the cruise configuration, plus transition to the approach configuration, plus:

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

(B) The ice accumulated during the transit at 610 m (2000 feet) above the landing surface of one cloud with a horizontal extent of 32.2 km (17.4 nautical miles) in the most critical of the icing conditions defined in part I of this appendix and one cloud with a horizontal extent of 32.2 km (17.4 nautical miles) in the continuous maximum icing conditions defined in Appendix C.

(ii) For an aeroplane certified in accordance with CS 25.1420(a)(1), the ice accumulated during descent from the maximum vertical extent of the maximum continuous icing conditions defined in part I of Appendix C to 610 m (2000 feet) above the landing surface in the cruise configuration, plus transition to the approach configuration, plus:

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

(B) The ice accumulated during the transit at 610 m (2000 feet) above the landing surface of one cloud with a horizontal extent of 32.2 km (17.4 nautical miles) in the most critical of the icing conditions defined in part I of this appendix and one cloud with a horizontal extent of 32.2 km (17.4 nautical miles) in the continuous maximum icing conditions defined in Appendix C.

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

(i) For an aeroplane certified in accordance with CS 25.1420(a)(2), the ice accretion defined by part II, paragraph (c)(5)(i) of this appendix, plus a descent from 610 m (2000 feet) above the landing surface to a height of 61 m (200 feet) above the landing surface with a transition to the landing configuration in the icing conditions defined in part I of this appendix, plus:

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

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

(ii) For an aeroplane certified in accordance with CS 25.1420(a)(1), the ice accumulated in the maximum continuous icing conditions defined in Appendix C, during a descent from the maximum vertical extent of the icing conditions defined in Appendix C, to 610 m (2000 feet) above the landing surface in the cruise configuration, plus transition to the approach configuration and flying for 15 minutes at 610 m (2000 feet) above the landing surface, plus a descent from 610 m (2000 feet) above the landing surface to a height of 61 m (200 feet) above the landing surface with a transition to the landing configuration, plus:

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

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

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

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

(ii) For an aeroplane certified in accordance with CS 25.1420(a)(2), the pre-existing ice accretion must be based on the more critical of the icing conditions defined in Appendix C, or the icing conditions defined in part I of this appendix in which the aeroplane is capable of safely operating. The pre-detection ice accretion applies in showing compliance with CS 25.143(j) and CS 25.207(h), and as part of the ice accretion definitions of part II, paragraph (b)(1) through (b)(4) of this appendix.

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

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

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

(2) Final take-off ice is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, between 122 m (400 feet) and either 457 m (1500 feet) above the take-off surface, or the height at which the transition from the take-off to the en-route configuration is completed and V_{FTO} is reached, whichever is higher. Ice accretion is assumed to start at lift-off in the icing conditions defined in part I of this appendix.

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

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

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

(i) Ice accumulated in the icing conditions defined in part I of this appendix during a descent from the maximum vertical extent of the icing conditions defined in part I of this appendix, to 610 m (2000 feet) above the landing surface in the cruise configuration, plus transition to the approach configuration and flying for 15 minutes at 610 m (2000 feet) above the landing surface; or

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

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

(i) Ice accretion defined by part II, paragraph (c)(5)(i), of this appendix, plus ice accumulated in the icing conditions defined in part I of this appendix during a descent from 610 m (2000 feet) above the landing surface to a height of 61 m (200 feet) above the landing surface with a transition to the landing configuration, followed by a go-around at the minimum climb gradient required by CS 25.119, from a height of 61 m (200 feet) above the landing surface to 610 m (2000 feet) above the landing surface, flying for 15 minutes at 610 m (2000 feet) above the landing surface in the approach configuration, and a descent to the landing surface (touchdown) in the landing configuration; or

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

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

(i) The airfoils, control surfaces, and, if applicable, propellers are free from frost, snow, or ice at the start of takeoff;

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

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

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

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

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

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

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

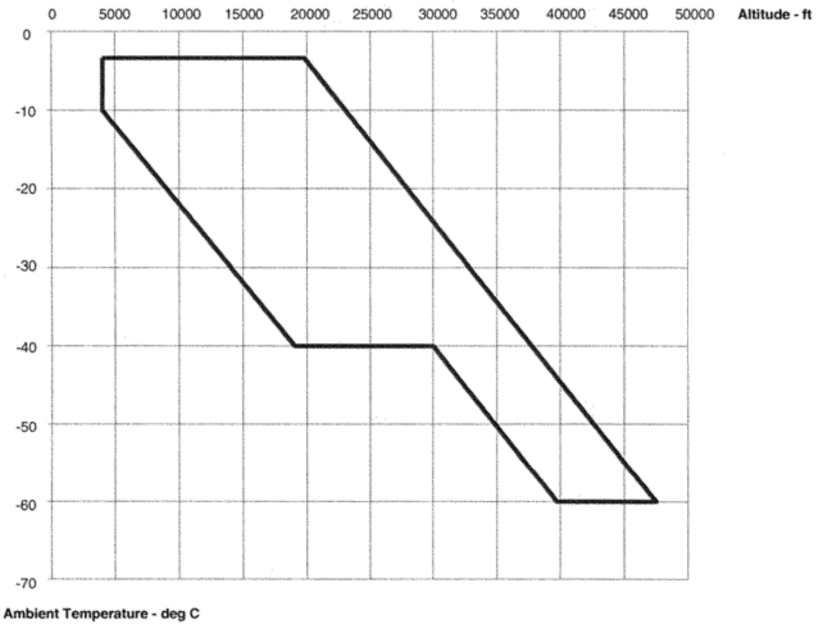
Create a new Appendix P as follows:

Appendix P

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

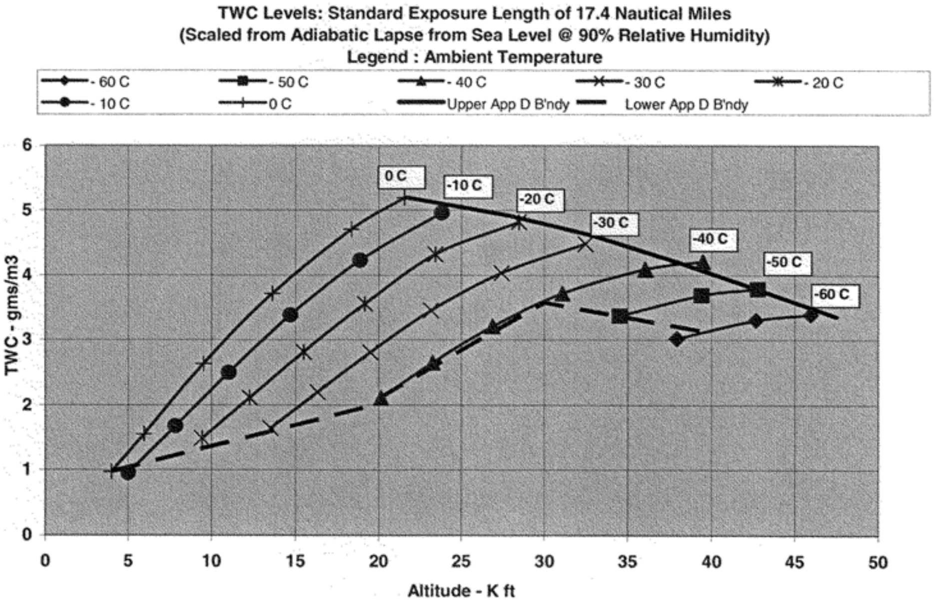
Ice crystal conditions associated with convective storm cloud formations exist within the CS-25 Appendix C, Intermittent Maximum Icing envelope (including the extension to -40 deg C) and the Mil Standard 210 Hot Day envelope. This ice crystal icing envelope is depicted in Figure 1 below.

Figure 1 – Convective cloud ice crystal envelope



Within the envelope, total water content (TWC) in g/m^3 has been determined based upon the adiabatic lapse defined by the convective rise of 90 % relative humidity air from sea level to higher altitudes and scaled by a factor of 0.65 to a standard cloud length of 32.2 km (17.4 nautical miles). Figure 2 displays TWC for this distance over a range of ambient temperature within the boundaries of the ice crystal envelope specified in Figure 1.

Figure 2 – Total water content



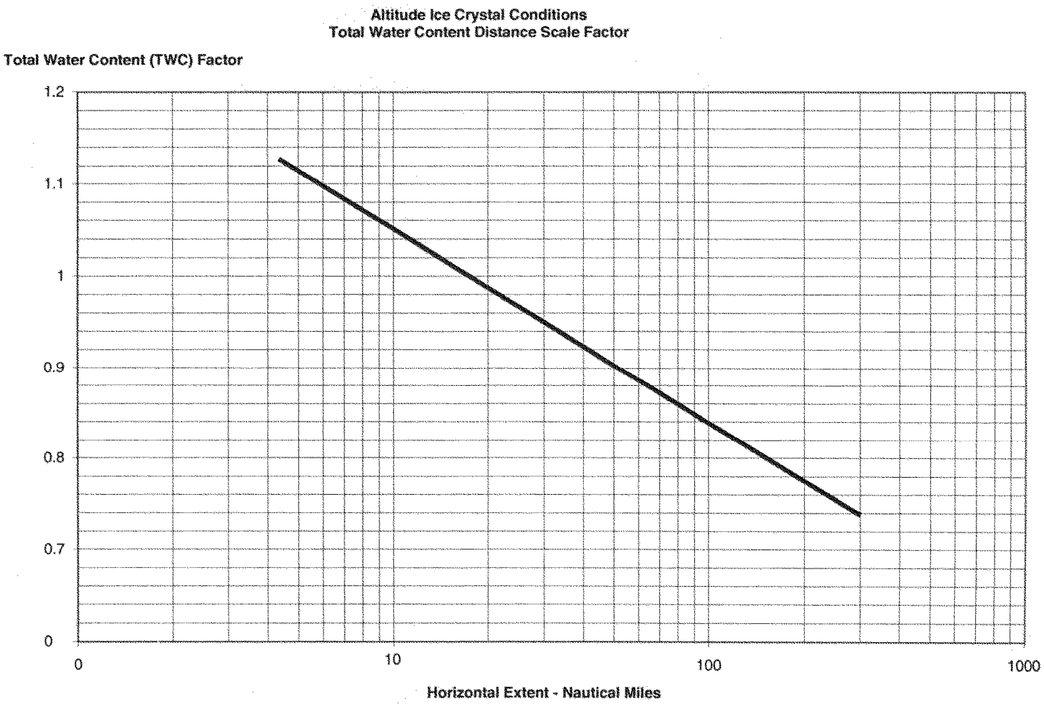
Ice crystal size median mass dimension (MMD) range is 50–200 microns (equivalent spherical size) based upon measurements near convective storm cores. The TWC can be treated as completely glaciated (ice crystal) except as noted in the Table 1.

Table 1 – Supercooled Liquid Portion of TWC

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

The TWC levels displayed in Figure 2 represent TWC values for a standard exposure distance (horizontal cloud length) of 32.2 km (17.4 nautical miles) that must be adjusted with length of icing exposure. The assessment from data measurements[13] supports the reduction factor with exposure length shown in Figure 3.

Figure 3 – Exposure Length Influence on TWC



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[13] *The analysis of measurements of free ice and ice/water concentrations in the atmosphere of the equatorial zone, Ian I. McNaughton, B.Sc., Dip. R.T.C., Royal Aircraft Establishment (Farnborough) Technical Note No: MECH. ENG. 283, 1959*