Comment-Response Document (CRD) to Notice of Proposed Amendment (NPA) 2011-04

for amending the Executive Director Decision 2003/9/RM of 24 October 2003 on certification specifications, including airworthiness codes and acceptable means of compliance, for engines ('CS-E')

'Turbine Engine Certification Specifications in Icing Conditions'

EXECUTIVE SUMMARY

This CRD provides the responses to comments received on NPA 2011-04, which proposed amending turbine engine certification specifications for operation in icing conditions.
According to some of the comments received, the explanatory note of NPA 2011-04 and its proposed amendment of CS-E 780 have been revised and are provided as appendices to this CRD. These are technical improvements and no major changes were made.

In parallel to the publication of this CRD, the Agency is also publishing a second NPA proposing an amendment of the corresponding advisory material AMC E 780.

A. Explanatory Note

I. General

1. The purpose of the Notice of Proposed Amendment (NPA) 2011-04 dated 22 March 2011 was to propose an amendment to Decision 2003/9/RM of the Executive Director of the European Aviation Safety Agency of 24 October 2003 on certification specifications, including airworthiness codes and acceptable means of compliance, for engines ('CS-E')[1].

II. Consultation

2. The draft Executive Director Decision amending Decision 2003/9/RM was published on the web site (http://www.easa.europa.eu) on 22 March 2011.

   By the closing date of 5 August 2011, the European Aviation Safety Agency (hereafter the 'Agency') had received 32 comments from 15 national aviation authorities, professional organisations and private companies.

III. Publication of the CRD

3. All comments received have been acknowledged and incorporated into this Comment-Response Document (CRD) with the responses of the Agency.

4. In responding to comments, a standard terminology has been applied to attest the Agency's acceptance of the comment. This terminology is as follows:

   - **Accepted** — The comment is agreed by the Agency and any proposed amendment is wholly transferred to the revised text.
   - **Partially accepted** — Either the comment is only agreed in part by the Agency, or he comment is agreed by the Agency but any proposed amendment is partially transferred to the revised text.
   - **Noted** — The comment is acknowledged by the Agency but no change to the existing text is considered necessary.
   - **Not accepted** — The comment or proposed amendment is not shared by the Agency

   The resulting text highlights the changes as compared to the current rule.

5. The Executive Director Decision on amending Decision 2003/9/RM will be issued at least two months after the publication of this CRD to allow for any possible reactions of stakeholders regarding possible misunderstandings of the comments received and answers provided.

6. Such reactions should be received by the Agency not later than **6 February 2013** and should be submitted using the Comment-Response Tool at http://hub.easa.europa.eu/crt.

[1] Decision as last amended by Executive Director Decision 2010/015/R dated 16 December 2010 (CS-E Amendment 3).

VI. CRD table of comments, responses and resulting text

(General Comments)	-

comment	*7* comment by: *Luftfahrt-Bundesamt* The LBA has no comments on NPA 2011-04.
response	*Noted*

comment	*8* comment by: *UK CAA* Please be advised that the UK CAA have no comments to make on NPA 2011-04.
response	*Noted*

comment	*15* comment by: *Swedish Transport Agency, Civil Aviation Department (Transportstyrelsen, Luftfartsavdelningen)* **The Swedish Transport Agency, Civil Aviation Department is supporting Option 1 (*Amend CS-E to require turbine engines be certified for safe operation throughout updated icing conditions that are defined in the Certification Specifications applicable to the aircraft on which the engine is to be installed*.) of the NPA 2011-03.**
response	*Noted*

comment	*16* comment by: *Pratt Whitney Canada* Attachment #1 Please find in attachment the comments to the NPA 2011-04 document.
response	*Partially accepted* Comment#1: Not accepted. Independently from the detailed failure mode which led to the dual engine flameout, this event was triggered when flying at high altitude in presence of ice crystal icing conditions. Therefore it is pertinent to quote it as an example illustrating the threat which justifies upgrading CS-E specifications. Comment#2: Noted. Comment#3: Partially accepted. The text of the explanatory note is modified as following: "During the same period there were 54 aircraft level events of SLD icing engine damage where 56 % occurred on multiple engines on an aircraft and two events resulted in air-turnback. **Those events resulted from exposure to freezing fog during taxi operation."** Comment#4: Accepted. The sentence is modified to read: "[…]must be set at the level assumed to be the most critical, or their effect must be simulated by other acceptable means."

comment	*17* comment by: *AIRBUS*

	The rule has been published without the associated guidance material. The Airbus comments on the rule may change when the AMC is issued as the rule is difficult to interpret and comment upon without the guidance contained within the AMC. The rule now contains very little detail upon which to comment. The details will be included in the Acceptable Means of Compliance. Airbus requests that EASA reopen the public comment period once the AMC is available. Reopening the comment period will help ensure consistency between the rule and the means of compliance thus aiding the consistent application of the rule. Considering the importance of the AMC and the likely complexity of the new guidance Airbus would be willing to aid the agency in drafting the new AMC in co-operation with other important stakeholders such as engine manufacturers, other aircraft manufacturers, airworthiness authorities and others. In Airbus view the key areas to be address by the AMC include: — Definition of pass/fail criteria especially related to engine aerodynamic and combustion stability/engine operability and "acceptable" engine damage criteria taking into consideration the effect of cumulative damage with successive icing encounters. — Quantity of test conditions to be performed. — Ice crystal compliance guidance. — Ice ingestion test and analysis requirements. — Test procedure guidance. — Guidance on acceptable critical point analysis methods and tools.
response	*Noted*

comment	*31* comment by: *FAA* The FAA has reviewed the subject NPA and has not comments.
response	*Noted*

comment	*33* comment by: *Cessna Aircraft Company* Cessna has no comments at this time.
response	*Noted*

NOTICE OF PROPOSED AMENDMENT (NPA) No 2011-04 – General comments p. 1-2

comment	*12* comment by: *Pratt & Whitney* NO Advisory material – can't comply **JUSTIFICATION:** The current state of the art relative to understanding the impact of ice crystal icing conditions on turbine engines is very immature. As a result, there is a critical and sensitive relationship between the newly proposed engine regulations and the corresponding guidance material. Without adequate time to review the revised AC contents and the proposed means of compliance along with the draft regulations, it is extremely difficult to formulate comments on the proposed engine rules. Furthermore, the ARAC committee recognized that there

	are technology needs not yet addressed in order for an applicant to comply with the mixed phase and ice crystal environment. In order to allow for near term certification to Appendix P, a process of certification by similarity must be provided, as the FAA has done in AC 20-147. The upcoming revisions to advisory material must provide a similar process in order that the industry can reasonably show compliance until the technology gaps are closed.
response	*Noted*

comment	*29* comment by: *Swiss International Airlines / Bruno Pfister*
	SWISS Intl Air Lines accetps the NPA 2011-04 without further comments.
response	*Noted*

NOTICE OF PROPOSED AMENDMENT (NPA) No 2011-04 – A. Explanatory Note – II. Consultation p. 3-4

comment	*2* comment by: *Turbomeca*
	NPA related to AMC E 780 is not yet known. It would be appreciated to get this AMC part at the same time as the “rule part”. The review of the future NPA related to this AMC (when issued) could lead to additional comments on NPA 2011-04. Therefore,further comment on NPA 2011-04 should be allowed post 22 june 2011
response	*Noted*

NOTICE OF PROPOSED AMENDMENT (NPA) No 2011-04 – A. Explanatory Note – IV. Content of the draft opinion/decision p. 4

comment	*4* comment by: *Turbomeca*
	<u>1) Comment 1 on last sentence of 1st subparagraph:</u> We fully support the used principle consisting in applying the same environmental conditions for the engine and for the aircraft on which it is installed. This ensure consistency between the aircraft and its engine(s). <u>2) Comment 2 on 3rd subparagraph:</u> NPA related to AMC E 780 is not yet known. It would be appreciated to get this "AMC" part at the same time as the “rule" part. The review of the future NPA related to this AMC (when issued) could lead to additional comments on NPA 2011-04. Therefore, further comment on NPA 2011-04 should be allowed post 22 june 2011.
response	*Noted*

NOTICE OF PROPOSED AMENDMENT (NPA) No 2011-04 – A. Explanatory Note – IV. Content of the draft opinion/decision – Background p. 4-5

comment	*9* comment by: *Boeing*
	Page: 4

	Paragraph: IV.10. Background Revise the text as follows: "Other incidents involved turbine engine power losses or flameouts in ice crystal and mixed phase icing conditions. From 1988–2003, there were over 100 documented cases of ice crystal and mixed phase engine power loss events. Some of these events (11) resulted in total power loss from engine flameouts. During the same period there were 54 aircraft level events of SLD icing engine damage where 56 % occurred on multiple engines on an aircraft and two events resulted in air-turnback. ***All the SLD icing engine events were concluded to be the result of SLD conditions encountered on the ground during aircraft taxi operations. As a result, a new CS 25.1093, Table 1 -- Large Drop Condition, was added.*** **…"** **JUSTIFICATION:** Clarification is needed that all these database events of SLD were from ground taxi operations.
response	*Partially accepted* The text of the explanatory note is modified as following: 'During the same period there were 54 aircraft level events of SLD icing engine damage where 56 % occurred on multiple engines on an aircraft and two events resulted in air-turnback. **Those events resulted from exposure to freezing fog during taxi operation.'**

comment	*13* comment by: *Pratt & Whitney* Other incidents involved turbine engine power losses or flameouts in ice crystal and mixed phase icing conditions. From 1988–2003, there were over 100 documented cases of ice crystal and mixed phase engine power loss events. Some of these events (11) resulted in total power loss from engine flameouts. During the same period there were 54 aircraft level events of SLD icing engine damage where 56 % occurred on multiple engines on an aircraft and two events resulted in air-turnback. **All the SLD icing engine events were concluded to be as a result of SLD conditions encountered on the ground during aircraft taxi operations. As a result, a new CS25.1093 Table 1 Large drop condition was added.** **JUSTIFICATION:** Clarification is needed that all the database events in SLD were from ground taxi operations.
response	*Partially accepted* The text of the explanatory note modified as following: 'During the same period there were 54 aircraft level events of SLD icing engine damage where 56 % occurred on multiple engines on an aircraft and two events resulted in air-turnback. **Those events resulted from exposure to freezing fog during taxi operation.'**

comment	*20* comment by: *AIRBUS* The paragraph 10 reads: *"Other incidents involved turbine engine power losses or flameouts in ice crystal and mixed phase icing conditions. From 1988–2003, there were over 100 documented cases of ice crystal and mixed phase engine power loss events.*

	Some of these events (11) resulted in total power loss from engine flameouts. During the same period there were 54 aircraft level events of SLD icing engine damage where 56 % occurred on multiple engines on an aircraft and two events resulted in air-turnback." All the SLD icing engine events were concluded to be the result of SLD conditions encountered on the ground during aircraft taxi operations. As a result, a new CS25.1093 Table 1 Large drop condition was added. It should be clearly stated that all the database events in SLD are related to taxi operations.
response	*Accepted* The text of the explanatory note modified as following: 'During the same period there were 54 aircraft level events of SLD icing engine damage where 56 % occurred on multiple engines on an aircraft and two events resulted in air-turnback. **Those events resulted from exposure to freezing fog during taxi operation.'**

NOTICE OF PROPOSED AMENDMENT (NPA) No 2011-04 – A. Explanatory Note – IV. Content of the draft opinion/decision – Discussion of the CS-E rule change proposal – a. General	p. 6

comment	*28* comment by: *FAA Aircraft Certification* The proposed CS-E rule update requires the engine to function satisfactorily throughout the conditions of atmospheric icing, including freezing fog, and in falling and blowing snow which are defined in the Certification Specifications applicable to the aircraft on which the engine is to be installed. This appears to be a significant departure from both the ARAC recommendations that were quoted in the NPA, and from the FAA part 33 NPRM proposal. The FAA believes that engines should demonstrate capability to operate in icing conditions, even if the aircraft that they are installed in is not fully or may be partially approved for operating in icing conditions. This is because the airplane may inadvertently encounter periodic intermittent icing encounters, and engine power to depart the inadvertent encounter is considered essential. Also, EASA does not provide guidance as to an acceptable short duration compliance engine test that may be necessary to allow for detect and exit. As evidence of this on-going philosophy, the FAA has historically required turboshaft engines to demonstrate compliance to appendix C icing conditions, even if the rotorcraft that they are installed in is not approved for operations in icing. This is also true for part 23 aircraft installations where operations in icing are not approved. EASA's proposed approach could result in a potential shift in safety for those operations where icing is inadvertently encountered. This difference in philosophy and approach to engine icing compliance requirements could result in significant regulatory difference which would need to be reconciled for all engine validations. Therefore the FAA recommends that EASA specify the engine types (e.g. turbofan, turboprop, turboshaft) that the proposed icing requirements are applicable to, irrespective of the installation.
response	*Noted* The intent was not changing the existing philosophy. The intent is to have consistency between the requirements applied to the engine air intake, the nacelle, the engine and the propeller (if applicable).

	The atmospheric icing and snow conditions used in CS-E 780 must therefore be the same as the ones required in the sub-paragraphs CS 2X.1093(b) provided in the certification specifications of the aircraft on which the engine is to be installed. CS-E 780 text is updated to clarify this point and make the link with CS 2X.1093(b).

NOTICE OF PROPOSED AMENDMENT (NPA) No 2011-04 – A. Explanatory Note – IV. Content of the draft opinion/decision – Discussion of the CS-E rule change proposal – b. The new icing environment for CS-25 aircraft p. 6-7

comment	*27* comment by: *FAA Aircraft Certification*
	Proposed appendix P to CS-25 is identical to the FAA proposed appendix D to part 33, which originated from ARAC recommendations. EASA noted that there has been at least one engine occurrence which occurred outside the proposed CS-25 Appendix P, figure 1 envelope (at 42,000 feet and SAT = -65deg C). EASA also stated that they are 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. For the reasons discussed in the preamble, EASA is envisaging an extension of the proposed appendix P ice crystal environment, figure 1 envelope to encompass all the known occurrences, with a minimum temperature of -75°C. FAA comments on the subject are provided as follows. Appendix P proposed by EASA describes ambient environmental data and is based on a theoretical atmospheric model. Temperature and altitude are only two of the parameters described in figure appendix P. Figure 2 of appendix P describes total water content as a function of altitude and EASA did not describe how figure 2 would be revised. During the loss of airspeed events, it is unknown what the total water content actually was because it was not measured. If appendix P were to be expanded, it should be equally important to expand or otherwise revise the total water content depicted in appendix P figure 2, as well as the horizontal extent depicted in figure 3 accordingly. The FAA is continuing to support the research necessary to validate the ice crystal environment with flight test data. We believe it would be premature for EASA to expand the environmental conditions in appendix P until (1) additional environmental data can be collected to substantiate the conditions, (2) an international working group of engine icing experts convene to discuss and agree on the technical details and the relevance of any in-service event data. Therefore we recommend that EASA does not expand appendix P at this time. We invite EASA to join the anticipated 2015 ARAC to review the engine icing rules, appendices and guidance, following the Darwin, Australia flight in ice crystal campaign.
response	*Accepted* Appendix P is unchanged. However, for flight instrument probes the proposed AMC 25.1324 recommends using more severe conditions, i.e. peak TWC values for glaciated conditions and 2.6NM cloud TWC values for mixed phase conditions. This was recommended by the EUROCAE WG-89 in which the Agency is participating.

NOTICE OF PROPOSED AMENDMENT (NPA) No 2011-04 – A. Explanatory Note – IV. Content of the draft opinion/decision – Discussion of the CS-E rule change proposal – c. Ice ingestion p. 7

comment	1 comment by: *Francis Fagegaltier Services*

Ice slab ingestion has been dealt with for years in engine certification when complying with FAR 33.77 (e). Both JAR-E / CS-E and FAR 33 address ice coming from accumulation on the engine inlet due to delay in activation of aircraft anti-icing system or from functioning of inlet de-icing systems (including ice coming from the propeller when applicable). But only FAR 33 focused on the ice slab.

Indeed, many years of certification testing to both JAR-E / CS-E and FAR 33 have shown that the most severe test is the one requested by JAR-E / CS-E (2 minute delay suggested in AMC E 780, paragraph 4) : generally the FAA ice slab was not damaging. Furthermore, in some cases the effect of the ice slab can be considered to be covered by the hailstone testing of CS-E 790 (a)(1). In the "European" way of testing, the ice is most of the time sliding along the wall of the inlet, hitting the top of the blades where they are the most sensitive, contrary to the ice slab which hits the blades where they are stronger (because of bird requirements for example).

The explanatory part of the NPA is focused on Ice crystal and mixed phase environment. Nowhere in this NPA we can find a justification for changing the existing rules with regard to ice ingestion.

Because ingestion of ice coming from the aircraft engine inlet is already addressed in engine certification specifications, if EASA intends to introduce new requirements into CS-E 780, this would mean that ice accumulation on other aircraft parts would be considered. There are indeed many in-service examples of blue ice, coming out of a faulty toilet system, destroying the engine : the engine cannot be designed to swallow any quantity of ice ! Of course, blue ice is not likely to be addressed under the new rule but this illustrates the fact that engines have limits. The proposal is a significant change compared to current situation where CS-25 requires to limit the amount of ice to be released into the engine to the capability of this engine.
See in particular :
CS 25.929 Propeller de-icing
((a) For aeroplanes intended for use where icing may be expected, there must be a means to prevent or remove hazardous ice accumulation on propellers or on accessories where ice accumulation would jeopardise engine performance.
and
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

The new goal being "to require a demonstration that the engine will not be adversely affected by the ingestion of ice which may be encountered when operated in the icing conditions for which the aircraft is certified", is moving the responsibility from the aircraft designer (to limit the ice amount potentially ingested by the engine to the capability of the engine) to the engine designer (to be capable of swallowing anything coming out of the aircraft).

Furthermore, this new CS-E 780 (h) concept is not consistent with the possibility of granting a type certificate to an engine (see Part 21) separately

	from an aircraft type certificate, especially when the aircraft installation is not known at time of engine certification. To require comments on a new text when all material useful for understanding the intent would be proposed in a separate NPA is not adequate. The ice slab subject should be dealt with in an unique, complete package, with due justification of the change. It is then suggested to remove the proposed CS-E 780 (h) from this NPA.
response	*Noted* As explained in paragraph 12.c of the NPA, the objective is to ensure that the engine ingestion capability is consistent with the characteristics of the ice fragments that can be released from the aircraft to the engine air intake; in other words ensure coordination between the engine manufacturer and the aircraft manufacturer. Therefore, the engine manufacturer and the aircraft manufacturer must cooperate and conduct a joint analysis to demonstrate that the engine will not be adversely affected by ice fragments ingestion. In the case of installation of an already type certificated engine, the engine manufacturer has to communicate to the aircraft manufacturer what is the engine ingestion capability (in the manuals containing instructions for installing and operating the engine). In that case, the installation of the engine on the aircraft should be performed so that such limits will not be exceeded in operation. Further guidance on this aspect is provided in the proposed AMC E 780.

NOTICE OF PROPOSED AMENDMENT (NPA) No 2011-04 – A. Explanatory Note – V. Regulatory Impact Assessment – 1. Issue analysis and risk assessment – 1.1 What is the issue? p. 8

comment	25 comment by: *Rolls-Royce plc* **Section 1.1 'What is the issue'** We have a general concern over the description of the issue. While we accept that ground operation in freezing fog can lead to ice build-up and ice release on take-off, we understand that there are no recorded events of multiple (or even single) engine failure events during take-off from this cause. This suggests that the current rules are sufficient to mitigate a multiple engine failure from this cause. So, to suggest that there is a 'potential for a multiple engine failure during take-off' ignores the fact that experience suggests that the probability of such an event is Extremely Improbable.
response	*Not accepted* As explained in this paragraph, 56 % of the events involved multiple engine damages and there were at least two air turnbacks. These cases did not result in complete failure of the engine(s), however, multiple engine damages occurring during take-off or early in the climb is considered as potentially hazardous, and the scenario of multiple engine failures must be considered.

NOTICE OF PROPOSED AMENDMENT (NPA) No 2011-04 – A. Explanatory Note – V. Regulatory Impact Assessment – 5. Analysis of impacts – 5.1 Safety impact p. 11-14

comment	*10* comment by: *Boeing* Page: 11 Paragraph: 5.1. Safety Impact Revise the text as follows: ***Option 1 benefit assessment**:* *From 1988–2003, there were over 100 documented cases of ice crystal and mixed phase engine power loss events. These events are directly related to the proposed CS-E requirements. From these events, eleven related to total power loss5 from flameouts. ~~One of the events occurred when a Beechjet 400 with PWC JT15D engines had a total power loss at top-of-descent and could not relight the engines. That event resulted in a dead-stick forced landing at Jacksonville airport (USA).~~* **JUSTIFICATION:** This event was not one of the events the Working Group used to determine the need for changes to the rules to include ice crystals. Furthermore, the root cause of this event has not been connected to the ingestion of ice crystals.
response	*Not accepted* Independently from the detailed failure mode which led to the dual engine flameout, this event was triggered when flying at high altitude in presence of ice crystal icing conditions. Therefore, it is pertinent to quote it as an example illustrating the threat which justifies upgrading CS-E specifications.

comment	*11* comment by: *Pratt & Whitney* From 1988–2003, there were over 100 documented cases of ice crystal and mixed phase engine power loss events. These events are directly related to the proposed CS-E requirements. From these events, eleven related to total power loss5 from flameouts. **~~One of the events occurred when a Beechjet 400 with PWC JT15D engines had a total power loss at top-of-descent and could not relight the engines. That event resulted in a dead-stick forced landing at Jacksonville airport (USA).~~** **JUSTIFICATION:** This event was not one of the events the working group used to determine the need for changes to the rules to include ice crystals. Subsequent investigation determined that the flame-out was not due to high compressor surging because of ingesting ice shed from the low pressure stage stators. The root cause was much more subtle and was determined as being a fuel control issue. The combustor case pressure sensing system was determined to be subject to icing due to the compressor discharge air being moist (due to the ice crystal content of the atmosphere) and the fuel control surfaces being cooled to the freezing point of water by the progressive drop in aircraft fuel delivery temperature under conditions of extended high altitude cruise. P&WC presented these findings to the NTSB, and implemented a design improvement that precluded ice forming within the HMUs pneumatic sensing system. This improvement has been incorporated into the fleet - reference TCCA AD CF 2008-23 and FAA AD 2008-24-10

response	*Not accepted* Independently from the detailed failure mode which led to the dual engine flameout, this event was triggered when flying at high altitude in presence of ice crystal icing conditions. Therefore, it is pertinent to quote it as an example illustrating the threat which justifies upgrading CS-E specifications.

comment	*21* comment by: *AIRBUS* The paragraph 5.1, Option 1 reads: *"From 1988–2003, there were over 100 documented cases of ice crystal and mixed phase engine power loss events. These events are directly related to the proposed CS-E requirements. From these events, eleven related to total power loss5 from flameouts. One of the events occurred when a Beechjet 400 with PWC JT15D engines had a total power loss at top-of-descent and could not relight the engines. That event resulted in a dead-stick forced landing at Jacksonville airport (USA)."* This event reported was not one of the events the working group used to determine the need for changes to the rules to include ice crystals.
response	*Not accepted* Independently from the detailed failure mode which led to the dual engine flameout, this event was triggered when flying at high altitude in presence of ice crystal icing conditions. Therefore, it is pertinent to quote it as an example illustrating the threat which justifies upgrading CS-E specifications.

NOTICE OF PROPOSED AMENDMENT (NPA) No 2011-04 – A. Explanatory Note – V. Regulatory Impact Assessment – 5. Analysis of impacts – 5.6 Impact on regulatory coordination and harmonisation p. 15

comment	*26* comment by: *FAA Aircraft Certification* The FAA recognizes the hard work and effort by EASA in preparing this NPA and we appreciate the opportunity to provide comments. We agree with EASA that this rulemaking is necessary and also believe that it will improve the level of safety for airplanes flying in icing conditions. As EASA noted, we initiated a similar rulemaking action, Notice of Proposed Rulemaking (NPRM), notice 10-10 contained in United States Federal Docket FAA-2011-0636. Our NPRM was published for public comment on June 29, 2010 and we are in the process of preparing a final rule which is currently scheduled for publication in the first quarter of 2012. We are intending to make changes to our regulations as a result of comments received during the NPRM process. The comments we are providing are intended to add clarity or identify areas that EASA may want to consider revising for harmonization purposes.
response	*Noted*

NOTICE OF PROPOSED AMENDMENT (NPA) No 2011-04 – B. Draft Decision – I Draft Decision amending CS-E – paragraph CS-E 780 a) p. 20

comment	*5* comment by: *Turbomeca*

	<u>1) Comment 1 related to the complete CS-E 780:</u> As this paragraph CS-E 780 is significantly modified, it should be better to remove the two « reserved » subparagraphs namely CS-E 780(b) and CS-E 780(d) and then re-numbering all the subparagraphs of CS-E 780 from CS-E 780(a) to (f). **<u>2) Comment 2 on CS-E 780(a):</u>** « and falling and blowing snow defined in the certification specification applicable to the aircraft » : The demonstration required for engine certification is not very clear. It is expected that planned future AMC –E 780 (not yet known today) shall provide adequate clarification on demonstration/justification to be provided at engine certification level regarding falling and blowing snow.
response	*Accepted* 1) Accepted 2) Accepted. This sentence is clarified by adding reference to the sub-paragraphs 2X.1093(b) of the certification specifications for the aircraft on which the engine is to be installed. Additionally, the proposed AMC provides more explanations.

comment	*18* comment by: *AIRBUS* Attachment #2 It is proposed to amend CS-E 780 to read as follows: (a) It must be established by tests, unless alternative appropriate evidence is available, that the Engine will function satisfactorily when operated in the atmospheric icing conditions <u>defined in CS 25 Appendix C, Appendix O, Appendix P,</u> falling and blowing snow <u>and freezing fog. The tests defined in Tables 1 and 2 below must be performed and complemented by additional tests determined by the critical point analysis.</u> ~~defined in the Certification Specifications applicable to the aircraft on which the Engine is to be installed, as specified in CS-E 20(b),~~ <u>The engine must operate satisfactorily during and after exposure to icing conditions</u> without unacceptable: (1) Immediate or ultimate reduction of Engine performance, (2) Increase of Engine operating temperatures, (3) Deterioration of Engine handling characteristics, (4) Mechanical damage <u>and</u> <u>(5) Vibration</u> Table 1 - ICING CONDITIONS FOR GROUND OPERATIONS TESTS Refer to attached document Table 2 – CONDITIONS THAT MUST BE DEMONSTRATED BY ENGINE TEST Refer to attached document Justification: Regarding the addition of references to CS 25 icing conditions, it is necessary to define explicitly in the regulation the icing conditions for which the engine must be certified and hence a specific reference to the icing conditions is required. Referring explicitly to CS 25 Appendices C, O and P will avoid

potential misunderstandings or confusion. It would be preferable to reproduce the CS 25 Appendices in the engine regulation but a cross reference would be sufficient. It is important to guide the engine manufacturer, who may not know the aircraft icing conditions regulations, to the relevant specific icing conditions definitions.

It is understood that CS-E is applicable to engines that could be installed on CS 23, 27 or 29 aircraft for which full compliance with CS 25 Appendices C, O and P may not be required. For example many helicopters are not certified for flight in icing conditions. However for such engines the compliance demonstration would be appropriately tailored to the limitations of the category of aircraft in which it will be installed. Appropriate limitations could be included in the engine installation manual in these specific cases.

Regarding the addition of Table 1 test points. For the above reasons it is necessary to include in CS E the specific freezing fog icing conditions to which the engine must be tested. This will aid the engine manufacturer to identify the correct conditions without searching through the aircraft certification specifications of which he may not be fully cognizant.

Regarding the addition of Table 2 test points. As explained in Appendix O of the Ice Protection Harmonisation Working Group Task 2 report the TAEIG Engine Harmonisation Working Group (EHWG) found no engine inservice events caused by inflight SLD (Appendix O) engine icing. The only events linked to SLD icing were due to icing of the engine on ground. It was concluded that this in-service experience was due to the current methods used to certify engines in Appendix C icing conditions. Therefore it was decided to move the test points that had previously been included in the guidance material to the regulation. In addition the critical point analysis recommended by the guidance material was seen as a key factor contributing to this adequate in-service experience in SLD conditions and hence a requirement to perform a CPA was added to the regulation. (refer to comment 3)

There would seem no rationale for EASA not to follow the same logic and include the Part 33 and/or AMC E 780 test points in the regulation as a minimum set of test conditions which must be augmented by test conditions coming from a critical point analysis.

After completion of the engine certification there should be no unacceptable engine related icing issues discovered during the aircraft certification icing tests or after entry into service. The engine certification shall ensure that the engine achieves the adequate level of engine robustness and safety when operating in icing conditions without the need for engine modifications due to problems discovered during aircraft certification tests or after EIS.

Airbus experience shows that to achieve this basic objective of the engine certification program it is important to perform a minimum number of tests. With too few tests the adequate level of engine robustness and safety in icing conditions may not be achieved because the uncertainties associated with icing tests cannot be adequately addressed with only a handful of tests. In addition if too few engine icing tests are performed the cumulative effects of engine damage due to engine ice accretion and shedding may not be adequately addressed.

In determining the adequate number of tests Airbus believes that the AC 20-147 guidance on engine icing testing and certification provides a good baseline

	upon which to build the future engine certification rules and that the table points and the requirement to perform a CPA should be included in the regulation. Airbus believes that the CPA should augment the table points rather than replace them thus ensuring that the engine certification achieves the minimum level of testing required to achieve adequate engine robustness and safety in icing conditions. By performing a sufficient number of tests over a sufficient range of conditions, any underlying design weaknesses can be identified and appropriately mitigated during the engine test campaign. Too few tests may lead to unacceptable weaknesses remaining undiscovered until late in the aircraft certification process or after entry into service.
response	*Partially accepted* The first sentence is clarified by adding reference to the sub-paragraphs 2X.1093(b) of the certification specifications for the aircraft on which the engine is to be installed. The proposed AMC E 780 addresses guidance on establishment of test points (ground and flight conditions). This includes standard test points and guidance to perform the analysis, including a Critical Point Analysis

comment	*22* comment by: *Rolls-Royce plc* (See AMC E 780) It is unfortunate that the proposed changes to CS-E 780 cannot be read in conjunction with the proposed changes to AMC E 780 since there is nothing in NPA 2011-04 to describe what testing/evidence is envisaged. A complete package of proposed CS and AMC changes would be highly desirable to facilitate a complete understanding of the implications and intent of the proposed changes. It is important that the agreed changes to AMC E 780 are issued simultaneously with the changes to CS-E 780.
response	*Noted*

comment	*23* comment by: *Rolls-Royce plc* Having removed all mention of **CS-Definitions - Icing design envelopes,** there is, equally, no point in retaining mention of any specific icing threats that are already covered by the reference to '...the conditions of atmospheric icing defined in the Certification Specifications applicable to the aircraft on which the engine is to be installed...' We therefore propose that the paragraph is changed as follows: It must be established by tests, unless alternative appropriate evidence is available, that the Engine will function satisfactorily throughout the conditions of atmospheric icing ~~(including freezing fog on ground) and in falling and blowing snow~~ defined in the Certification Specifications applicable to the aircraft on which the Engine is to be installed, as specified in CS-E 20(b), without unacceptable:…..
response	*Not accepted* The engine must be treated consistently with the engine air intake and propeller, if applicable. The first sentence is clarified by adding reference to the

	sub-paragraphs 2X.1093(b) of the certification specifications for the aircraft on which the engine is to be installed.

comment	*30* comment by: *FAA Aircraft Certification* The proposed CS-E rule is written differently then the FAA 14 CFR part 33 icing requirements in that EASA has not included any of the detailed test conditions or the slab requirements within the rule. Therefore, until the applicable AMC is issued for comment, it is difficult for the FAA to provide a comprehensive set of comments to the proposed CS-E icing requirements. We will provide additional comments at that time.
response	*Noted*

comment	*32* comment by: *Snecma* Attachment #3 Please see in letter letter 2764-RC : comments 1 and 2 on page 11 and 12.
response	*Not accepted* The engine must be treated consistently with the engine air intake and propeller, if applicable. The first sentence is clarified by adding reference to the sub-paragraphs 2X.1093(b) of the certification specifications for the aircraft on which the engine is to be installed.

NOTICE OF PROPOSED AMENDMENT (NPA) No 2011-04 – B. Draft Decision – I Draft Decision amending CS-E – paragraph CS-E 780 (b) and (c)	p. 20

comment	*14* comment by: *Pratt & Whitney* (c) ~~During the tests of~~ In showing compliance with the specifications of CS-E 780(a), all optional Engine bleeds and mechanical power offtakes permitted during icing conditions must be **simulated in the test or** ~~in the position~~ set at the level assumed to be the most critical. It must be established, however, that other likely use of bleed or mechanical power offtake will not lead to Engine malfunctioning. **JUSTIFICATION:** In icing certification tests, the equipments for running power offtake and ECS bleeds are often not available in many icing test facilities. The applicants should be allowed to simulate those effects in certification tests. For example, the effects of mechanical power offtake and engine bleeds on engine operating lines can be easily simulated by other means, e.g. turbine area change, an increased transient operating line or actual power extraction, etc.
response	*Accepted* The sentence is modified to read: ‘[…]must be set at the level assumed to be the most critical, or their effect must be simulated by other acceptable means.’

NOTICE OF PROPOSED AMENDMENT (NPA) No 2011-04 – B. Draft Decision – I Draft Decision amending CS-E – paragraph CS-E 780 (d)	p. 20

comment	19 comment by: AIRBUS
	It is proposed to amend CS-E 780 by revising paragraph (d) to read as follows: <u>(d) It must be shown through Critical Point Analysis (CPA) in the icing conditions defined by CS25 Appendix C that the complete ice envelope has been analyzed, and that the engine will operate acceptably at the most critical points as demonstrated by engine test, validated analysis or a combination of the two. The applicant must account for in-flight effects in any critical point analysis.</u> <u>Extended flight in icing conditions such as hold, descent, approach, climb, and cruise, must be addressed, for the ice conditions defined.</u> Justification: As explained in comment 18, the use of critical point analysis was identified by EHWG as one of the key factors that has led to the in-service experience in SLD conditions. It is therefore strongly recommended to include in the regulation a requirement to perform a CPA and the need to ensure that the engine icing tests, when combined with adequate validated analysis, cover the full range of critical conditions identified by the CPA.
response	*Not accepted* The proposed AMC E 780 provides more detailed guidance on how to show compliance, this also includes performance of a Critical Points Analysis.

NOTICE OF PROPOSED AMENDMENT (NPA) No 2011-04 – B. Draft Decision – I Draft Decision amending CS-E – paragraph CS-E 780 (h) p. 20-21

comment	6 comment by: Turbomeca
	<u>**1) Comment 1 on CS-E 780(h)(1) :**</u> The concept of « soft body damage tolerance » is not understood. This concept does not appear currently anywhere in CS-E. Therefore it is expected that the future AMC-E 780 shall clarify this new concept of « soft body damage tolerance » <u>**2) Comment 2 on CS-E 780(h)(2):**</u> CS-E 780(h)(2) says : « *Following the ingestion of ice under the conditions of this paragraph the engine shall comply with CS-E 540(b)* ». Instead of referring to CS-E 540(b), it is proposed to refer to CS-E 780(a). Reference to CS-E 780(a) is deemed more appropriate as the origin of such ice comes from the icing atmospheric conditions defined in CS-E 780(a) and therefore, for consistency, should comply with the same criteria i.e. CS-E 780(a). In addition, reference to CS-E 780(a) would imply applicability of CS-E 780(f) which is directly linked to CS-E 780(a)(4), whereas current reference to CS-E 540 could mean CS-E 780(f) being not applicable for ice ingestion. See also comment 3 below related to CS-E 780(h)(3)(iii). <u>**3) Comment 3 on CS-E 780(h)(3)(iii):**</u> CS-E 780(h)(3)(iii) says: *" The engine complies with CS-E 540(b) …."* Instead of referring to CS-E 540(b), it is proposed to refer to CS-E 780(a).

Reference to CS-E 780(a) is deemed more appropriate as the origin of such ice comes from the icing atmospheric conditions defined in CS-E 780(a) and therefore, for consistency, should comply with the same criteria i.e. CS-E 780(a). In addition, reference to CS-E 780(a) would imply applicability of CS-E 780 (f) which is directly link to CS-E 780(a)(4), whereas current reference to CS-E 540 could mean CS-E 780(f) being not applicable for ice ingestion.

See also comment 2 above related to CS-E 780(h)(2).It is quite understood that E 780(h)(2) and 780(h)(3)(iii) should refer to the same paragraph.

4) Comment 4 on CS-E 780(h)(3)(iii):

CS-E 780(h)(3)iii) says: « *The engine complies with CS-540(b) following the blockage of the protection device by ice »*

As a reminder, CS-E 790(d)(3) says: " *The subject rain or hail constituents stopped by the protection device will not obstruct the flow of induction air into the Engine resulting in damage, power or thrust loss, or other adverse Engine anomalies in excess of what would be accepted in CS-E 790 (a), (b) and (c)."*

And Part 33.77 (from nprm "notice 10-10") says: "*the ice stopped by the protective device will not obstruct the flow of induction air inlet into the engine with a resultant sustained reduction in power or thrust greater than those values defined by paragraph (c) of this section"*

The word "blockage" is not accurate enough and would lead to very different interpretations. It may be interpreted as 100% obstructed or any other type of obstruction. The case to be covered here is obstruction by ice formed forward the protection device and then detached. Therefore (at least for some installations as rotorcrafts), this can only lead to partial/ limited obstruction of the protection device.
Therefore E790 (d)(3) wording is deemed more appropriate. Note that PART 33 wording in nprm "notice 10-10" is similar to CS-E 790(d)(3) wording.
In addition, using wording similar to CS-E 790 would improve consistency within CS-E.

Therefore it is proposed to modify CS-E 780 (h)(3)(iii) as follows (note that this proposal incorporates comment 3 above):
Replace "~~*(iii) The Engine complies with CS-E 540(b) following the blockage of the protection device by the ice*."~~
-by
"(iii) The ice stopped by the protective device will not obstruct the flow of induction air into the engine resulting in damage, power or thrust loss, or other adverse Engine anomalies in excess of what would be accepted in CS-E 780 (a)."

5) Comment 5 on CS-E 780(h)(3):

CS-E 780(h)(3) says: "*For an Engine that incorporates a protection device, compliance with this paragraph need not be demonstrated with respect to ice formed forward of the protection device if it is shown that*: "

This addresses the case where the protection device is part of the engine design.
The case where the protection device is part of the A/C type design (as required by the engine installation requirement (E 20(d)), should also be addressed similarly as done in CS- E 790(d) for hail. Consistency should be maintained between hail and ice sheets within CS-E.

In fact, CS-E 790(d) says *"For an Engine that incorporates **or requires** the use of a protection device, demonstration of the rain and hail ingestion capabilities of the Engine, as required in CS-E 790 (a), (b) and (c), may be waived wholly or in part by the Agency if it is shown that:…"*
and AMC E 790 (5) says: *" If the Engine is certified under the assumption that the protection device considered under CS-E 790 (d) is **provided by the aircraft installation** and if the compliance with CS-E 790 (a) to (c) is waived, then the Engine approval would be endorsed accordingly and the Engine instructions for installation would need to impose the conditions of CS-E 790 (d)(1) to (3) to the installation."*

Therefore CS-E 780(h)(3) should be modified in the same way: see proposals herafter.

Proposals for E 780(h)(3) (note that these two proposals incorporate comments 3 and 4 above):

1st proposal (this is the preferred one as both cases are clearly addressed in the rule and not part in the rule with other part in the AMC):

*"(3) For an Engine that incorporates **or requires the use of** a protection device, compliance with this paragraph need not be demonstrated with respect to ice formed forward of the protection device if it is shown that:*

(i) Such ice is of a size that will not pass through the protection device;

(ii) The protection device will withstand the impact of the ice; and

(iii) ~~The Engine complies with CS-E 540(b) following the blockage of the protection device by the ice."~~

*(iii) **The ice stopped by the protective device will not obstruct the flow of induction air into the engine resulting in damage, power or thrust loss, or other adverse Engine anomalies in excess of what would be accepted in CS-E 780 (a).***

***If the Engine is certified under the assumption that the protection device is provided by the aircraft installation and if (with respect to ice formed forward of the protection device) the compliance with CS-E 780 (h)(1) to (h)(2) is waived, then the Engine approval would be endorsed accordingly and the Engine instructions for installation would need to impose the conditions of CS-E 780 (h)(3)(i) to (iii) to the installation**."*

2nd proposal:

*"(3) For an Engine that incorporates **or requires the use of** a protection device, compliance with this paragraph need not be demonstrated with respect to ice formed forward of the protection device if it is shown that **(See AMC E 780 (h)(3)):***

(i) Such ice is of a size that will not pass through the protection device;

(ii) The protection device will withstand the impact of the ice; and

(iii) ~~The Engine complies with CS-E 540(b) following the blockage of the protection device by the ice."~~

*(iii) **The ice stopped by the protective device will not obstruct the flow of induction air into the engine resulting in damage, power or thrust loss, or other adverse Engine anomalies in excess of what would be accepted in CS-E 780 (a).***

AMC E 780 (h)(3) Icing Conditions – Ice ingestion - Protection device.

If the Engine is certified under the assumption that the protection device considered under CS-E 780 (h)(3) is provided by the aircraft installation and if (with respect to ice formed forward of the protection

	device) the compliance with CS-E 780 (h)(1) to (h)(2) is waived, then the Engine approval would be endorsed accordingly and the Engine instructions for installation would need to impose the conditions of CS-E 780 (h)(3)(i) to (iii) to the installation."
response	*Partially accepted* Comment 1: Noted. The proposed AMC E 780 provides guidance on this item. Comment 2: Proposal to replace the reference to CS E 540(b) by CS E 780(a): Accepted. We have revised the rule to specify that the engine must comply to CS-E 780(a). This would also ensure compliance with CS-E 540. The objective of the 'Ice ingestion' paragraph has also been clarified in its first sub-paragraph (now CS-E 780(f)(1)). Comment 3: Accepted. Comment 4: Rewording of CS E 780(h)(3)(iii) for consistency with CS E 790 (d)(3): Partially accepted. The text is updated as following: 'The ice stopped by the protective device will not obstruct the flow of air into the engine resulting in unacceptable effects under CS-E 780 (a).' Comment 5: Proposal to update CS E 780(h)(3) to include the case where the protective device is part of the aircraft design: Partially accepted. We have mentioned this item as part of the minimum list of items to be included in the manuals containing instructions for installing and operating the Engine in the proposed AMC E 780.

comment	*24* comment by: *Rolls-Royce plc* We are concerned that the proposed ice ingestion requirement is intended, in part, to replace the current delayed anti-icing selection demonstration. While no damage is normally allowable for the delayed selection of anti-icing requirement, reference to CS-E 540(b) in the proposed requirement would allow damage as long as the 540(b) criteria are met. This would not seem appropriate in certain cases such as for runback-ice shed from the engine intake (although it may be appropriate for some aircraft-sourced ice, such as that released from the radome). Since the expected advisory material might help in this regard, it is important that consultation on this subject is completed with the proposed advisory material in order that the full intention and implications of the NPA can be properly addressed.
response	*Noted* We have revised the rule to specify that the engine must comply to CS-E 780(a). This would also ensure compliance with CS-E 540. The objective of the 'Ice ingestion' paragraph has also been clarified in its first sub-paragraph (now CS-E 780(f)(1)).

Appendix A — Resulting text

The updated CS-E Book 1 text change is provided below.

CS-E Book 1

SUBPART E — TURBINE ENGINES TYPE SUBSTANTIATION

Amend paragraph CS-E 780 as follows:

CS-E 780 ~~Tests In Ice Forming Conditions~~ Icing Conditions
(See AMC E 780)

(a) It must be established by tests, unless alternative appropriate evidence is available, that the Engine will function satisfactorily when operated ~~in the atmospheric icing conditions of CS-Definitions~~ throughout the conditions of atmospheric icing (including freezing fog on ground) and in falling and blowing snow defined in the turbine engines air intake system ice protection specifications (CS 23.1093(b), CS 25.1093(b), CS 27.1093(b), or CS 29.1093(b)) of the certification specifications applicable to the aircraft on which the Engine is to be installed, as specified in CS-E 20(b), without unacceptable:

(1) Immediate or ultimate reduction of Engine performance,
(2) Increase of Engine operating temperatures,
(3) Deterioration of Engine handling characteristics, and
(4) Mechanical damage.

~~(b) *(Reserved)*~~

(b~~c~~) ~~During the tests of~~ In showing compliance with the specifications of CS-E 780(a), all ~~optional~~ Engine bleeds and mechanical power offtakes permitted during icing conditions must be ~~in the position~~ set at the level assumed to be the most critical, or their effect must be simulated by other acceptable means. It must be established, however, that other likely use of bleed or mechanical power offtake will not lead to Engine malfunctioning.

~~(d) Where the Engine is considered to be vulnerable to operation in ice crystal cloud conditions, in mixed ice crystals and liquid water conditions, or in snow, such additional tests as may be necessary to establish satisfactory operation in these conditions must be made. *(Reserved)*~~

(c~~e~~) In showing compliance with the specifications of this paragraph CS-E 780, the conditions associated with a representative installation must be taken into account.

(d~~f~~) If after the tests it is found that significant damage has occurred, further running or other evidence may be required to show that subsequent Failures are unlikely to occur.

(e~~g~~) Where an air intake guard is fitted, compliance with the specifications of this paragraph CS-E 780 must be established with the guard in position, unless the guard is required to be retracted during icing conditions, in which case it must be established that its retraction is not affected immediately after a representative delay period.

(f) Ice ingestion

(1) *Objective*. To demonstrate that the engine will function satisfactorily following the ingestion of defined quantities of ice, as part of compliance with CS-E 540. Ingestion of ice may result from ice released by the engine air intake (including after delayed selection of the ice protection system) or from other aircraft surfaces. Compliance with the requirements of this sub-paragraph shall be demonstrated by Engine ice slab ingestion test or by validated analysis showing equivalence to other means for demonstrating soft body damage tolerance.

(2) Following the ingestion of ice under the conditions of this paragraph the engine shall comply with CS-E 780(a).

(3) For an Engine that incorporates or requires the use of a protection device, compliance with this paragraph need not be demonstrated with respect to ice formed forward of the protection device if it is shown that:

(i) Such ice is of a size that will not pass through the protection device;

(ii) The protection device will withstand the impact of the ice; and

(iii) The ice stopped by the protection device will not obstruct the flow of air into the engine resulting in unacceptable effects under CS-E 780 (a).

(4) In establishing the ice slab ingestion conditions, the assumed ice quantity and dimensions, the ingestion velocity and the Engine operating conditions must be determined. Those conditions shall be appropriate to the Engine installation on the aircraft. These assumptions must be included in the manuals containing instructions for installing and operating the Engine under CS-E 20(d).

Appendix B — Attachments

Comments for NPA2011-04_PWC.pdf

Attachment #1 to comment #16

Tables_1&2.pdf

Attachment #2 to comment #18

2764-RC-Snecma comments on NPA Icing.pdf

Attachment #3 to comment #32

B. Appendix C — Updated NPA 2011-04 Explanatory Note

1. Summary

NPA 2011-04 proposed to update turbine engine certification specifications (CS-E) for operation in icing conditions. The proposed amendment to CS-E in this NPA was mainly triggered by the need to update the icing conditions used to evaluate turbine engines installed on CS-25 aircraft. This proposal takes into account the service experience from large aeroplanes and turbine engines. A new icing environment, including supercooled large drop (SLD) icing conditions, mixed phase and ice crystal icing conditions, is being concurrently introduced in CS-25; these changes were proposed under NPA 2011-03. The proposed CS-E rule update requires the engine to function satisfactorily throughout the conditions of atmospheric icing, including freezing fog, and in falling and blowing snow which are defined in the turbine engines air intake system ice protection specifications of the Certification Specifications applicable to the aircraft on which the engine is to be installed.

We also included a clarification on the engine bleeds and mechanical power offtakes to be considered when showing compliance with the specifications of CS-E 780.

2. 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.

Several accidents and incidents occurred in severe icing conditions including supercooled large drop (SLD) icing conditions. Please refer to NPA 2011-03 for details on the history of these events.

Other incidents involved turbine engine power losses or flameouts in ice crystal and mixed phase icing conditions. From 1988–2003, there were over 100 documented cases of ice crystal and mixed phase engine power loss events. Some of these events (11) resulted in total power loss from engine flameouts. During the same period there were 54 aircraft level events of SLD icing engine damage where 56 % occurred on multiple engines on an aircraft and two events resulted in air-turnback. Those events resulted from exposure to freezing fog during taxi operation.

These particular severe icing conditions are not included in the current certification icing environment for aircraft and engines.

In December 1997, the Aviation Rulemaking Advisory Committee (ARAC) was tasked by the Federal Aviation Administration (FAA), 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 operate safely without restrictions in these conditions or operate safely 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.

Current 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.

In-service events 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). Therefore, an update of the freezing fog icing conditions of CS 25.1093(b)(2) has been proposed and must be taken into account by the engine manufacturers for engine type certification. Moreover, it has also been proposed to include in the powerplant limitations the conditions demonstrated during the CS 25.1093(b)(2) idle ground test, as well as any other limitations identified by the engine type certification (see the proposed CS 25.1521 revision).

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. For this reason, CS 25.1093(b)(1) is proposed to be amended to include falling and blowing snow. This has to be taken into account by the engine manufacturer.

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[2]. This report was prepared using the recommendations from the EHWG (Engine Harmonization Working Group) and the PPIHWG (Powerplant Installation Harmonization Working Group).

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).

3. Existing CS-E certification specifications for flight in icing conditions

CS-E 780 'Test in ice-forming conditions' provides through CS-E 780(a) a set of requirements in the icing environment of CS-Definitions (which is identical to CS-25 Appendix C icing environment). The objective is to ensure that the engine will function normally when operated in icing conditions.

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: 0–6 700 m (0–22 000 ft) for the continuous maximum icing conditions (stratiform clouds) and 1 000–9 500 m (3 000–31 000 ft) for the intermittent maximum icing (cumuliform clouds). It can be noticed that the Appendix C maximum mean effective diameter of the cloud droplets is 40 µm. Supercooled Large Drops can exceed this value and are thus outside the CS-Definitions icing conditions. Similarly, CS-Definitions do not address neither ice crystals nor mixed phase (supercooled liquid and ice crystals).

Nevertheless, CS-E 780(d) requires the engine manufacturer to consider the engine vulnerability to ice crystal conditions, mixed ice crystals and liquid water conditions, or snow. However, no criteria are provided to evaluate engine vulnerability and there is no obligation for the applicant to conduct particular tests in these icing conditions. In

[2] Under Regulations & Policies\Advisory and Rulemaking Committees\Advisory Committees\Aviation Rulemaking Advisory Committee\Transport Airplane and Engine\Active Working Groups\Ice Protection Harmonization: http://www.faa.gov/regulations_policies/rulemaking/committees/arac/media/tae/TAE_IP_T2.pdf.

practice, engine manufacturers have not provided objective pre-certification evidence of substantiated operation in these conditions.

AMC E 780 (dedicated to turbine engines for aeroplanes) clearly states that engines with 'Pitot' type intakes are not considered vulnerable, which is not consistent with the incidents experience mentioned previously. Table 2 provides ice crystals environmental conditions likely to be encountered in service; meanwhile engine events occurred outside these conditions (mainly at lower temperature, and also higher altitude).

Finally, there is currently no requirement addressing the operation in freezing fog conditions (on ground) or in falling and blowing snow.

4. Discussion of the CS-E rule change proposal

a. General

The proposed CS-E 780 amendment requires that turbine engines function satisfactorily when operated throughout the atmospheric icing conditions (including freezing fog) and falling and blowing snow that are defined in the turbine engines air intake system ice protection specifications of the Certification Specifications applicable to the aircraft on which the engine is to be installed. For CS-25 aircraft, these conditions were proposed to be updated through NPA 2011-03.

A new sub-paragraph (f) has been created to require protection of the engine against the risk of ice ingestion when the aircraft is operated in the icing conditions identified in the applicable aircraft Certification Specifications.

Finally, a clarification is provided on the engine bleeds and mechanical power offtakes to be considered when showing compliance to CS-E 780(a).

As engine testing is not the only purpose of CS-E 780, we also proposed to change the current title 'Test In Ice Forming Conditions' and call it 'Icing Conditions'.

b. The new icing environment for CS-25 aircraft

The proposed revision to CS-E 780, associated to the proposed revision to CS 25.1093, would change the icing environmental requirements used to evaluate engine protection and operation in icing conditions. The reason for these changes is that the accidents and incidents history of CS-25 large aeroplanes has shown that the current icing environmental requirements need to be updated. The effect of the change would be to require an evaluation of safe operation in the revised icing environment.

The revised CS-E 780(a) would require engines to operate safely throughout conditions of atmospheric icing conditions (including freezing fog on ground) and falling and blowing snow defined in the turbine engines air intake system ice protection specifications (CS 23.1093(b), CS 25.1093(b), CS 27.1093(b), or CS 29.1093(b)) of the Certification Specifications applicable to the aircraft on which the Engine is to be installed. In addition to the existing CS-25 Appendix C environment (identical to the CS-Definitions icing environment), the proposed CS-25 amendment provides Supercooled Large Drops (SLD) conditions defined in the proposed new CS-25 Appendix O, and ice crystal and mixed phase conditions defined in the proposed new CS-25 Appendix P. 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 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 please refer to FAA report DOT/FAA/AR–09/13 Technical Compendium from Meetings of the Engine Harmonization Working Group, March 2009.

CS-E 780(d) is deleted, because the assessment of engine vulnerability against ice crystal, mixed phase or snow is now required under CS-E 780(a).

c. Ice ingestion

The objective of the proposed new sub-paragraph (f) is to require a demonstration that the engine will not be adversely affected by the ingestion of ice which may be encountered when operated in the icing conditions for which the aircraft is certified, as identified under CS-E 780(a). This means that an analysis must be performed in cooperation with the aircraft manufacturer to identify the characteristics (dimensions, mass, velocity) of the ice fragments which may be released to the engine intake.

We provide guidance in the proposed amendment of AMC E 780 on how to make the analysis and demonstration.

d. Mechanical power offtake

We proposed to revise CS-E 780(c), now CS-E 780(b), to add requirements on the expected engine power offtake conditions used when showing compliance with CS-E 780(a).

First, we clarify that in addition to bleeds offtakes, mechanical power offtakes must also be taken into account and set or simulated to the most critical level during testing.

Second, other likely use of bleed or mechanical power offtake must also be analysed to demonstrate that this cannot lead to engine malfunctioning.