NOTICE OF PROPOSED AMENDMENT (NPA) NO 2011-04

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

amending Decision No 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')

'Turbine Engine Certification Specifications in 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 2003/9/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]. The scope of this rulemaking activity is outlined in the Terms of Reference (ToR) E.009 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 E.009.

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(4) 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 email to NPA@easa.europa.eu.
Correspondence:	If you do not have access to internet or e-mail you can send your comment by mail to: Process Support Rulemaking Directorate EASA Postfach 10 12 53 D-50452 Cologne Germany

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[1] Decision as last amended by Executive Director Decision 2009/18/R of 11 December 2010 (CS-E Amendment 2).

[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, 19.3.2008, 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.

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 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 are 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 Certification Specifications applicable to the aircraft on which the engine is to be installed.

We also include a clarification on the engine power offtake to be considered when showing compliance with the specifications of CS-E 780.

The Agency will publish another NPA dedicated to the update of CS-E 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 2003/9/RM ('CS-E') are:

In Book 1, amend CS-E 780.

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.

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.

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[4]. 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).

11. 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

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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: http://www.faa.gov/regulations_policies/rulemaking/committees/arac/media/tae/TAE_IP_T2.pdf.

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: 0–6700m (0–22,000ft) for the continuous maximum icing conditions (stratiform clouds) and 1000–9500m (3000–31,000ft) for the intermittent maximum icing (cumuliform clouds). It can be noticed that the Appendix C maximum mean effective diameter of the cloud droplets is 40µm. 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 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.

12. 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 Certification Specifications applicable to the aircraft on which the engine is to be installed. For CS-25 aircraft, these conditions are proposed to be updated through NPA 2011-03 published in parallel to this NPA, see the explanations below.

A new sub-paragraph (h) 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 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 propose 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. 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.

However, based on EASA experience, there is at least one engine occurrence which occurred outside the proposed CS-25 Appendix P, figure 1 envelope (at approximately Altitude = 42,000ft and SAT= –65 °C). The proposed Appendix P would also be applicable to flight instrument probes. Some pitot probes incidents occurred outside the proposed Appendix P, figure 1 (refer to explanations in NPA 2011-03). For those reasons, <u>EASA is considering the extension of Appendix P, figure 1 to encompass all the events. Comments are welcome on this extension proposal.</u>

Consequently, 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 (h) 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 will provide guidance in the revised AMC E 780 on how to make the analysis and demonstration; we will also provide indication related to ice slab dimensions which should be considered in the frame of this analysis.

d. Mechanical power offtake

We propose to revise CS-E 780(c) 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 to the most critical level during testing.

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

V. Regulatory Impact Assessment

0. Process and consultation

The impact assessment method has been based on the recommendations from the ARAC IPHWG to FAA (refer to task 2 final report) 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 turbine engines fleet characteristics.

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.

Several accidents and incidents occurred in severe icing conditions including supercooled large drop (SLD) icing conditions.

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.

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.

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

1.2 Who is affected?

This issue mainly concerns turbine engines installed on CS-25 aeroplanes. Therefore the main affected stakeholders are turbine engine manufacturers. CS-25 aeroplane manufacturers and operators are also affected as installers and customers of these products.

1.3 What are the risks (probability and severity)?

There are more than 100 documented cases of engine power loss events between 1988 and 2003 caused by ice crystals or mixed phase icing conditions. There were 11 total power loss events from engine flameouts, and one of the events has engines total power loss at top of descent and could not relight the engines. This last case scenario could have catastrophic consequences if the aircraft is not able to reach a runway and land safely. This has not happened so far, but the risk cannot be ignored.

SLD icing conditions, although they have not caused major events on turbine engines, constitute a threat and turbine engines must be protected against it if the aircraft operating envelope includes such conditions.

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 is to propose a CS-E 780 amendment requiring 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 Certification Specifications applicable to the aircraft on which the engine is to be installed. For CS-25 aircraft, these conditions are proposed to be updated through a dedicated NPA published in parallel to this NPA. In addition to the existing CS-25 Appendix C environment, the proposed CS-25 amendment provides Supercooled Large Drops (SLD) conditions defined in the proposed new CS-25 Appendix O, ice crystal and mixed phase conditions defined in the proposed new CS-25 Appendix P, updated freezing fog conditions, and falling and blowing snow.

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-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.

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) as a basis and adapted it to the EU case in order to evaluate the impacts of the option identified as compared to the baseline situation (no regulatory action).

4.2 Data requirements

Cost impacts were provided by engine 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 at 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 Impact Assessment Guidelines (2009). This discount rate is expressed in real terms, taking account of inflation.

5. Analysis of impacts

5.1 Safety impact

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

Option 1 would provide a safety benefit by preventing the occurrences of engine power losses or flameouts when operating in some icing conditions. New turbine engines installed on CS-25 aircraft would be demonstrated for safe operation throughout the updated atmospheric icing environment of the aircraft on which they are installed.

<u>Option 1 benefit assessment</u>

From 1988–2003, there were over 100 documented cases of ice crystal and mixed phase engine power loss events. <u>These events are directly related to the proposed CS-E requirements.</u> From these events, eleven related to total power loss[5] 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).

Clearly having to relight engines during a flight is a serious event, which can result in an accident. The FAA has examined these historical events and found that they resulted in about a 12 % diversion rate[6].

We have selected five of the most significant recent events and included some basic information on each accident and the justification for applicability. Each of these events could have been mitigated by the CS-E requirements contained in the proposed rule.

We also did not include engine damage events where power loss did not occur, but there was core damage. We believe these <u>damage costs will also be averted once the rule is in place</u>.

1) Beechjet Incident

NTSB Identification: ENG04IA021

14 CFR 91: General Aviation

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5 Total power loss events are events where all engines lose power at the same time.

6 FAA Engine and Propeller Directorate. This 12 % diversion rate comes from 17 known diversions out of 141 known power loss events. The list includes the following engine models: JT8D, JT15D, Tay 615/620, CF6-80C2, Trent, and ALF502.

Incident occurred Monday, July 12, 2004, in Sarasota, FL

Probable Cause Approval Date: 12/20/2007

Aeroplane: Raytheon Corporate Jets Beechjet 400A, registration: N455CW

Note: CAAM 3 due to loss of >3k feet with both engines out.

See NTSB web site for narrative:

http://www.ntsb.gov/ntsb/brief.asp?ev_id=20040804X01143&key=1

Event description: The Hawker-Beech Beechjet 400A was descending through flight level 390 when both of the engines flamed out and lost all power while operating in instrument meteorological conditions with convective storms in the area. The pilots, after several attempts, were able to get one engine restarted as the aeroplane was descending through 10,000 feet and diverted to a nearby airport. High-altitude ice crystals had accreted on the compressor vanes and were ingested into the high pressure compressor when the pilots retarded the power levers causing compressor surges and flameouts of both engines.

Justification for Revised Rule Applicability: Proposed revisions to CS-E 780 would require turbine engines to demonstrate acceptable and safe operation in the proposed mixed phase and ice crystal icing environment of CS-25 Appendix P (Ice crystal and mixed phase environment).

2) Beechjet Incident

NTSB Identification: DCA06IA007.

14 CFR 91: General Aviation

Incident occurred November 28, 2005, in Jacksonville, FL

Probable Cause Approval Date: 6/30/2008

Aeroplane: Raytheon Corporate Jets Beechjet 400A, registration: N691TA

Note: CAAM 4 due to forced landing with both engines out.

See NTSB web site for narrative:

http://www.ntsb.gov/ntsb/brief.asp?ev_id=20060104X00004&key=1

Event description: The Hawker-Beech Beechjet 400A was descending through flight level 380 in visual meteorological conditions in the vicinity of cumulonimbus build-ups. Upon reducing power to initiate descent the crew heard a ‘popping’ noise, and both engines rolled back. The crew declared an emergency, elected to divert to Jacksonville airport, and initiated emergency procedures. All attempts to restart the engines were unsuccessful. The crew executed a successful emergency dead-stick landing.

Justification for Revised Rule Applicability: Proposed revisions to CS-E 780 would require turbine engines to demonstrate acceptable and safe operation in the proposed mixed phase and ice crystal icing environment of CS-25 Appendix P (Ice crystal and mixed phase environment).

3) Beechjet Incident

NTSB Identification: ENG06IA020.

14 CFR 91: General Aviation

Incident occurred Wednesday, June 14, 2006, in Norfolk, VA

Probable Cause Approval Date: 1/31/2008

Aeroplane: Raytheon Corporate Jets Beechjet 400A, registration: N440DS

Note: CAAM 3 due to loss of >3k feet with both engines out.

See NTSB web site for narrative:

http://www.ntsb.gov/ntsb/brief.asp?ev_id=20060712X00929&key=1

Event description: The Raytheon Beechjet 400A was cruising at flight level 380 when both of the engines flamed out after the pilots had reduced power prior to turning on the engine anti-ice systems. The aeroplane was in visual meteorological conditions, but was approaching clouds that were known to be remnants of a tropical storm. The left and right engines restarted on their own as the aeroplane descended through flight levels 300 and 240, respectively.

Justification for Revised Rule Applicability: Proposed revisions to CS-E 780 would require turbine engines to demonstrate acceptable and safe operation in the proposed mixed phase and ice crystal icing environment of CS-25 Appendix P (Ice crystal and mixed phase environment).

4) MD-82 Incident

NTSB Identification: CHI02IA151.

Scheduled 14 CFR 121: Air Carrier SPIRIT AIRLINES INC.

Incident occurred Tuesday, June 4, 2002, in Wichita, KS

Probable Cause Approval Date: 1/28/2005

Aeroplane: McDonnell Douglas MD-82, registration: N823NK

Note: CAAM 3 due to loss of >3k feet with both engines out.

See NTSB web site for narrative:

http://www.ntsb.gov/ntsb/brief.asp?ev_id=20020612X00866&key=1

Event description: The aeroplane experienced a roll back of engine power on both engines and subsequently stalled while in cruise flight at flight level 330. The weather conditions were consistent with the presence of ice crystals at the cruise altitude. The engine inlet probes became blocked due to the ice crystals, resulting in a false engine pressure ratio (EPR) indication and subsequent retarding of the throttles by the auto-throttle system. The NTSB stated that factors included the presence of ice crystals at altitude, and the icing of the engine inlet probes resulting in a false engine pressure ratio indication.

Justification for Revised Rule Applicability: Engine inlet probes and engine inlet systems are addressed in the proposed revisions to CS-E 780, which would require turbine engines to demonstrate acceptable and safe operation in the proposed mixed phase and ice crystal icing environment of CS-25 Appendix P (Ice crystal and mixed phase environment).

5) Fokker 70 Accident

Date: January 5, 2004

Location: Near Munich Airport

Type of aeroplane: Transport Category Aeroplane

Manufacturer/Model: Fokker Aircraft B.V./F28 MK0070 (Fokker 70)

Injuries to persons: Three minor injuries

Damage to aeroplane: Aeroplane severely damaged

Note: CAAM 4 due to forced landing off airport and damaged aircraft.

See German BFU accident report at BFU web site for narrative:

http://www.bfu-web.de/cln_007/nn_226462/EN/Publications/Investigation_20Report/2004/Report__04__AX001-0__MUC__Fokker,templateId=raw,property=publicationFile.pdf/Report_04_AX001-0_MUC_Fokker.pdf

Event description: A Fokker 70 with Rolls-Royce Tay 620 engines departed from Vienna for a scheduled flight to Munich. While in descent to Munich, at flight level 90, heavy engine vibrations were indicated. This occurred after a prolonged time under moderate mixed phase icing conditions (snow) and low engine thrust where ice accreted on the rotors of the low pressure compressors of both engines. The accreted ice then shed and impacted the ice-impact-panels thereby dislodging them and blocking the fan bypass duct that provides primary thrust. The crew declared an emergency due to engine problems and requested to be cleared for an immediate landing. The airplane was immediately cleared for a descent. Because the airplane could not maintain the glide slope it was forced to land approximately 2.5 NM short of the beginning of the runway on a snow covered field with the landing gear partially extended. The fuselage undercarriage was heavily damaged.

Justification for Revised Rule Applicability: This event occurred while operating in moderate snow conditions. Proposed revisions to CS-E 780 would require turbine engines to demonstrate acceptable and safe operation in the proposed mixed phase and ice crystal icing environment of CS-25 Appendix P (Ice crystal and mixed phase environment).

The continued incidents, accidents, diversions, and power losses demonstrate the need for the proposed engine requirements. The above events are precursor events that, if not addressed through rulemaking, could result in an unrecoverable power loss and consequent fatal accident.

5.2 Environmental impact

None identified.

5.3 Social impact

None identified.

5.4 Economic impact

Certification costs

The costs to be evaluated are the ones induced by the new icing conditions environment required for certification of CS-25 aircraft.

Industry has provided data to the IPHWG and FAA for several different engine sizes. The data have been aggregated to determine an average cost per engine certification. The data is further sub-divided into certification and additional capital costs.

The following table presents the average estimated cost for a certification project.

	Average Certification costs (Euros)
Engine Analysis (Mixed Phase Glaciated)	21429
Engine Analysis SLD	35714
Engine Icing Tests	214286
Soft Body Tolerance Analysis	82857
Test Facilities	71429
Total:	**425714**

We have reviewed the CS-E turbine engine projects that were launched over the past 60 years in the EU. Considering only the engines installed on large aeroplanes (CS-25), we found 32 different engine types.

Therefore we can estimate that there will be 5.33 new projects in the next 10 years.

We conservatively assume that all these new engines will be certificated in 2013, i.e. 1 year after the assumed entry into force of the new rule.

Using a nominal cost of 425.714 Euros for each project, the total certification cost is **2.270.476 Euros** (present value: **2.099.183 Euros**).

Capital costs

In addition to the certification costs, there would be additional capital costs to modify engine manufacturers' facilities in order to provide an ice crystal cloud (to show compliance with the proposed requirements). The estimated cost is 714,286 Euros per manufacturer.

We expect the two European manufacturers of CS-E turbine engines for CS-25 aircraft (Rolls-Royce and Snecma), to incur this cost for a total cost of **1.428.571 Euros** (present value: **1.320.795 Euros**).

Cost summary

The total cost for manufacturers is calculated by adding the certification costs and the capital cost; the result is **3.699.048 Euros** (present value: **3.419.977 Euros**).

5.5 Proportionality issues

None identified.

5.6 Impact on regulatory coordination and harmonisation

The proposed rule text is not fully harmonised with the FAA proposal for Part 33 amendment in their NPRM. We propose to extend the icing environment of turbine engines installed on CS-25 aircraft, although the FAA draft rule would require certification of any turbine engine throughout the new environment.

Moreover, FAA proposed detailed criteria for analysis and tests in their rule; the Agency propose instead to provide guidance in an AMC E 780 amendment which will be published later in 2011.

6. Conclusion and preferred option

The Agency prefers Option 1: rulemaking action.

The associated total cost for engine manufacturers of **3.699.048 Euros** (present value: **3.419.977 Euros**) is considered balanced by the safety and economic benefit gained by the proposed rule.

Although there has not been any catastrophic event caused by the engines, we consider that the numerous events presented above are precursors of a potential fatal event.

In terms of economic benefit, the proposed rule would provide cost savings for operators by preventing aircraft diversions and engine damages; this benefit has not been quantified by the IPHWG but it is not negligible.

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 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[7]

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.[8]

[7] 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.

[8] 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[9]	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.

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

9 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 6: Description of the different risk indices

Risk index		**Description**[10]
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.

[10] 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-E

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 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)*

(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. 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)*

(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.

(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.

(g) Where an 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.

(h) Ice ingestion

(1) 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 540(b).

(3) 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:

(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.

(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 Engine instructions for installation required under CS-E 20(d).