NOTICE OF PROPOSED AMENDMENT (NPA) No 16/2004
DRAFT DECISION OF THE EXECUTIVE DIRECTOR OF THE AGENCY,
on certification specifications for large aeroplanes (CS-25)

Flight in Icing Conditions

CONTENTS

This Notice of Proposed Amendment is made up of four different parts:

A. **Explanatory Note**
Describing the development process and explaining the contents of the proposal.

B. **Proposals**
The actual proposed amendments.

C. **Original JAA NPA 25BEF-332 proposals justification**
The proposals were already circulated for comments as a JAA NPA. This part contains the justification for the JAA NPA including an economic impact evaluation.

D. **JAA NPA 25BEF-332 Comment-Response Document**
This part summarizes the comments made on the JAA NPA and the responses to those comments.

A EXPLANATORY NOTE

General

1. The initial issue of CS-25 was based upon JAR-25 at amendment 16. During the transposition of airworthiness JARs into certification specifications the rulemaking activities under the JAA system were not stopped. In order to assure a smooth transition from JAA to EASA the Agency has committed itself to continue as much as possible of the JAA rulemaking activities. Therefore it has included most of the JAA rulemaking activities in the Agency's rulemaking programme for 2004 and planning for 2005-2007.

2. The purpose of this Notice of Proposed Amendment (NPA) is to propose changes to the certifications specifications for large aeroplanes (CS-25), related to performance and handling characteristics in icing conditions. The reason for this proposal is outlined further below. This measure is included in the Agency's 2004 rulemaking programme.

3. The NPA has been adapted to the EASA regulatory context by the Agency. It is now submitted for consultation of all interested parties in accordance with Article 6 of the EASA rulemaking procedure[1].
The review of comments will be made by the Agency unless the comments are of such nature that they necessitate the establishment of a group.

Consultation

4. Because the content of this NPA was already agreed for adoption in the Joint Aviation Authorities (JAA) system and was the subject of a full worldwide consultation (JAA NPA 25BEF-332), the transitional arrangements of article 15 of the EASA rulemaking procedure apply. They allow for a shorter consultation period of six weeks instead of the standard three months and also exempt from the requirement to produce a full Regulatory Impact Assessment. However, a brief economic impact evaluation is part of the original JAA NPA justification.

5. To achieve optimal consultation, the Agency is publishing the draft decision on its internet site in order to reach its widest audience and collect the related comments.

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[1] Decision of the Management Board concerning the procedure to be applied by the Agency for the issuing of opinions, certification specifications and guidance material ("rulemaking procedure"), EASA MB/7/03, 27.6.2003.

Comments on this proposal may be forwarded *(preferably by e-mail)*, using the attached comment form, to:

By e-mail: **NPA@easa.eu.int**

By correspondence: Ms. Inge van Opzeeland
Postfach 10 12 53
D-50452 Köln, Germany
Tel: +49 221 89990 5008

Comments should be received by the Agency **before 25-01-2005** and if received after this deadline they might not be treated. Comments may not be considered if the form provided for this purpose is not used.

Comment response document

6. All comments received will be responded to and incorporated in a Comment Response Document (CRD). This will contain a list of all persons and/or organisations that have provided comments. The CRD will be widely available ultimately before the Agency adopts its final decision.

Originally JAA NPA 25BEF-332, Performance and handling characteristics in icing conditions contained in Appendix C, CS-25.

7. The text of the NPA 25BEF-332 was developed by the JAA in the framework of the Harmonisation Work Programme and was sponsored by the Flight Steering Group (FStG). It is based upon a report prepared by the Flight Test Harmonisation Working Group (FTHWG), a group of European and North American airworthiness authorities' and industry flight specialists, and pilot representatives working to harmonise subpart B of JAR-25, FAR 25 and Transport Canada's Part 525.

Following parts of CS 25 are proposed to be amended:

A- CS 25 Sub-Part B relevant paragraphs and associated AMC
B- CS 25.941(c)
C- CS 25.1419
D- CS-25 Appendix C
E- AMC 25.1329

8. JAA NPA 25BEF-332 was reviewed and accepted by the JAA Regulation Sectorial Team in September 2003.

B. PROPOSALS

The proposal for each paragraph is identified as follows: text to be deleted is crossed out and the text to be added is in bold print.

The following amendments should be included in Decision No. 2003/2/RM of the Executive Director of the Agency of 17 October 2003:

BOOK 1 **CS 25**

Proposal 1

CS 25.21 Proof of compliance

Add CS 25.21(g)

"(g) If certification for flight in icing conditions is desired, the following requirements apply (see AMC 25.21(g)):

(1) Unless otherwise prescribed, each requirement of this subpart, except CS 25.121(a), 25.123(c), 25.143(b)(1) and (2), 25.149, 25.201(c)(2), 25.207(c) and (d), and 25.251(b) through (e), must be met for flight in icing conditions with the ice accretions defined in Appendix C during normal operation of the aeroplane in accordance with the operating limitations and operating procedures established by the applicant and contained in the aeroplane Flight Manual.

(2) The aeroplane must meet the requirements of CS 25.143(j) and 25.207(h) with the ice accretion as specified in Appendix C, Part II(e), prior to normal operation of the ice protection system.

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

Proposal 2

CS 25.103 Stall speed

Amend CS 25.103(b)(3)

(3) The aeroplane in other respects (such as flaps, ~~and~~ landing gear, **and ice accretions)** in the condition existing in the test or performance standard in which V_{SR} is being used;

<u>Proposal 3</u>

CS 25.105 Take-off

Amend CS 25.105(a)

"(a) The take-off speeds described in CS 25.107, the accelerate-stop distance described in CS 25.109, the take-off path described in CS 25.111, ~~and~~ the take-off distance and take-off run described in CS 25.113, **and the net take-off flight path described in CS 25.115**, must be determined ~~–~~

~~(1) At each weight, altitude, and ambient temperature within the operational limits selected by the applicant; and~~

~~(2) In the selected configuration for take-off.~~

in the selected configuration for take-off at each weight, altitude, and ambient temperature within the operational limits selected by the applicant -

(1) In non-icing conditions; and

(2) In icing conditions, if in the configuration of CS 25.121(b) with the "Take-off Ice" accretion defined in Appendix C:

(i) The stall speed at maximum take-off weight exceeds that in non-icing conditions by more than the greater of 5.6 km/h (3 knots) CAS or 3% V_{SR}**; or**

(ii) The degradation of the gradient of climb determined in accordance with CS 25.121(b) is greater than one-half of the applicable actual-to-net take-off flight path gradient reduction defined in CS 25.115(b).

<u>Proposal 4</u>

CS 25.107 Take-off speeds

Amend CS 25.107(c)(3)

(3) A speed that provides the manoeuvring capability specified in CS 25.143(**h**).

Amend CS 25.107(g)(2)

(2) A speed that provides the manoeuvring capability specified in CS 25.143(**h**).

Add a new CS 25.107(h)

(h) In determining the take-off speeds V_1, V_R, and V_2 for flight in icing conditions, the values of V_{MCG}, V_{MC}, and V_{MU} determined for non-icing conditions may be used."

<u>Proposal 5</u>

CS 25.111 Take-off path

Amend CS 25.111(c)(3)(iii)

(iii) 1.7% for four-engined airplanes, ~~and~~

Amend CS 25.111(c)(4)

(4) ~~Except for gear retraction and automatic propeller feathering, the aeroplane configuration may not be changed~~ **The aeroplane configuration may not be changed, except for gear retraction and automatic propeller feathering,** and no change in power or thrust that requires action by the pilot may be made until the aeroplane is 122 m (400 ft) above the take-off surface**; and**

Add a new CS 25.111(c)(5)

(5) If CS 25.105(a)(2) requires the take-off path to be determined for flight in icing conditions, the airborne part of the take-off must be based on the aeroplane drag:

(i) With the "Take-off Ice" accretion defined in Appendix C, from a height of 11 m (35 ft) above the take-off surface up to the point where the aeroplane is 122 m (400 ft) above the take-off surface; and

(ii) With the "Final Take-off Ice" accretion defined in Appendix C, from the point where the aeroplane is 122 m (400 ft) above the take-off surface to the end of the take-off path.

<u>Proposal 6</u>

CS 25.119 Landing climb: all engines operating

Amend CS 25.119

"In the landing configuration, the steady gradient of climb may not be less than 3.2%, with ~~-~~ ~~(a)~~ the engines at the power or thrust that is available 8 seconds after initiation of movement of the power or thrust controls from the minimum flight idle to the go-around power or thrust setting <u>(see AMC 25.119~~(a)~~)</u> ~~--and~~

~~(b) A climb speed which is -~~

~~(1) Not less than -~~

~~(i) 1·08 V_{SR} for aeroplanes with four engines on which the application of power results in a significant reduction in stalling speed; or~~

~~(ii) 1·13 V_{SR} for all other aeroplanes;~~

~~(2) Not less than V_{MCL}; and~~

~~(3) Not greater than V_{REF}.~~

(a) In non-icing conditions, with a climb speed of V_{REF} determined in accordance with CS 25.125(b)(2)(i); and

(b) In icing conditions with the "Landing Ice" accretion defined in Appendix C, and with a climb speed of V_{REF} determined in accordance with CS 25.125(b)(2)(ii)."

Proposal 7

CS 25.121 Climb: one engine inoperative

Amend CS 25.121(b)

(b) *Take-off; landing gear retracted.* In the take-off configuration existing at the point of the flight path at which the landing gear is fully retracted, and in the configuration used in CS 25.111 but without ground effect**:**

(1) The steady gradient of climb may not be less than 2.4% for two-engined aeroplanes, 2.7% for three-engined aeroplanes, and 3.0% for four-engined aeroplanes, at V_2 ~~and~~ with -

(i) The critical engine inoperative, the remaining engines at the take-off power or thrust available at the time the landing gear is fully retracted, determined under CS 25.111, unless there is a more critical power operating condition existing later along the flight path but before the point where the aeroplane reaches a height of 122 m (400 ft) above the take-off surface (see AMC 25.121(b)(1)**(i)**); and

(ii) The weight equal to the weight existing when the aeroplane's landing gear is fully retracted, determined under CS 25.111.

(2) The requirements of sub-paragraph (b)(1) of this paragraph must be met:

(i) In non-icing conditions; and

(ii) In icing conditions with the "Take-off Ice" accretion defined in Appendix C, if in the configuration of CS 25.121(b) with the "Take-off Ice" accretion:

(A) The stall speed at maximum take-off weight exceeds that in non-icing conditions by more than the greater of 5.6 km/h (3 knots) CAS or 3% V_{SR}; or

(B) The degradation of the gradient of climb determined in accordance with CS 25.121(b) is greater than one-half of the applicable actual-to-net take-off flight path gradient reduction defined in CS 25.115(b).

Amend CS 25.121(c)

(c) Final take-off. In the en-route configuration at the end of the take-off path determined in accordance with CS 25.111**:**

(1) The steady gradient of climb may not be less than 1.2% for two-engined aeroplanes, 1.5% for three-engined aeroplanes, and 1.7% for four-engined aeroplanes, at V_{FTO} with -

(i) The critical engine inoperative and the remaining engines at the available maximum continuous power or thrust**;** and

(ii) The weight equal to the weight existing at the end of the take-off path, determined under CS 25.111.

(2) The requirements of sub-paragraph (c)(1) of this paragraph must be met:

(i) In non-icing conditions; and

(ii) In icing conditions with the "Final Take-off Ice" accretion defined in Appendix C, if in the configuration of CS 25.121(b) with the "Take-off Ice" accretion:

(A) The stall speed at maximum take-off weight exceeds that in non-icing conditions by more than the greater of 5.6 km/h (3 knots) CAS or 3% V_{SR};

or

(B) The degradation of the gradient of climb determined in accordance with CS 25.121(b) is greater than one-half of the applicable actual-to-net take-off flight path gradient reduction defined in CS 25.115(b).

Amend CS 25.121(d)

(d) *Approach.* In a configuration corresponding to the normal all-engines-operating procedure in which V_{SR} for this configuration does not exceed 110% of the V_{SR} for the related all-engines-operating landing configuration~~,~~**:**

(1) The steady gradient of climb may not be less than 2.1% for two-engined aeroplanes, 2.4% for three-engined aeroplanes, and 2.7% for four-engined aeroplanes, with -

(i) The critical engine inoperative, the remaining engines at the go-around power or thrust setting;

(ii) The maximum landing weight;

(iii) A climb speed established in connection with normal landing procedures, but not exceeding 1.4 V_{SR}: and

(iv) Landing gear retracted.

(2) The requirements of sub-paragraph (d)(1) of this paragraph must be met:

(i) In non-icing conditions; and

(ii) In icing conditions with the "Holding Ice" accretion defined in Appendix C; the climb speed selected for non-icing conditions may be used if the climb speed for icing conditions, computed in accordance with sub-paragraph (d)(1)(iii) of this paragraph, does not exceed that for non-icing conditions by more than the greater of 5.6 km/h (3 knots) CAS or 3%."

__Proposal 8__

CS 25.123 En-route flight path

Amend CS 25.123(a)

"(a) For the en-route configuration, the flight paths prescribed in sub-paragraphs (b) and (c) of this paragraph must be determined at each weight, altitude, and ambient temperature, within the operating limits established for the aeroplane. The variation of weight along the flight path, accounting for the progressive consumption of fuel and oil by the operating engines, may be included in the computation. The flight paths must be determined at **a** ~~any selected~~ speed **not less than V_{FTO}**, with -

(1) The most unfavourable centre of gravity;

(2) The critical engines inoperative;

(3) The remaining engines at the available maximum continuous power or thrust, and

(4) The means for controlling the engine-cooling air supply in the position that provides adequate cooling in the hot-day condition;

Amend CS 25.123(b)

(b) The one-engine-inoperative net flight path data must represent the actual climb performance diminished by a gradient of climb of 1.1% for two-engined aeroplanes, 1.4% for three-engined aeroplanes, and 1.6% for four-engined aeroplanes~~.~~ **-**

(1) In non-icing conditions; and

(2) In icing conditions with the "En-route Ice" accretion defined in Appendix C, if:

(i) 1.18V_{SR} with the "En-route Ice " accretion exceeds the en-route speed selected in non-icing conditions by more than the greater of 5.6 km/h (3 knots) CAS or 3% V_{SR}, or

(ii) The degradation of the gradient of climb is greater than one-half of the applicable actual-to-net flight path reduction defined in sub-paragraph (b) of this paragraph.

<u>Proposal 9</u>

CS 25.125 Landing

Amend CS 25.125

"(a) The horizontal distance necessary to land and to come to a complete stop from a point 15.2 m (50 ft) above the landing surface must be determined (for standard temperatures, at each weight, altitude and wind within the operational limits established by the applicant for the aeroplane) **-** ~~as follows~~:

(1) In non-icing conditions; and

(2) In icing conditions with the "Landing Ice" accretion defined in Appendix C if V_{REF} in icing conditions is greater than V_{REF} in non-icing conditions by more than 9.3 km/h (5 knots) CAS.

(b) In determining the distance in (a):

(1) The aeroplane must be in the landing configuration.

(2) A stabilised approach, with a calibrated airspeed of **not less than** V_{REF}, must be maintained down to the 15 m (50 ft) height.

(i) In non-icing conditions, V_{REF} may not be less than:

(**A**) 1.23V_{SR0};

(**B**) V_{MCL} established under CS 25.149(f); and

(**C**) A speed that provides the manoeuvring capability specified in CS 25.143(**h**).

(ii) In icing conditions, V_{REF} may not be less than:

(A) The speed determined in sub-paragraph (b)(2)(i) of this paragraph;

(B) 1.23 V_{SR0} with the "Landing Ice" accretion if that speed exceeds V_{REF} selected in non-icing conditions by more than 5.6 km/h (3 knots) CAS; and

(C) A speed that provides the manoeuvring capability specified in CS 25.143(h).

(3) Changes in configuration,….(See AMC 25.125(**b**)(3).)

(c) The landing distance....(See AMC 25.125(**c**).) In addition –

(2) The brakes….(see AMC 25.125(**c**)(2); and

(d) *Reserved.*

(e) *Reserved.*

(f) The landing distance data.....

(g) If any device....."

Proposal 10

Controllability and Manoeuvrability

CS 25.143 General

Insert a new CS 25.143(c)

(c) It must be shown that the aeroplane is safely controllable and manoeuvrable with the critical ice accretion appropriate to the phase of flight defined in Appendix C, and with the critical engine inoperative and its propeller (if applicable) in the minimum drag position:

(1) At the minimum V_2 for take-off;

(2) During an approach and go-around; and

(3) During an approach and landing.

Renumber and amend old CS 25.143(c) through (g):

(d) The following table prescribes, for conventional wheel type controls, the maximum control forces permitted during the testing required by sub-paragraphs (a) ~~and (b)~~ **through (c)** of this paragraph (See AMC 25.143(**d**)): ....[Table unchanged]

(e) Approved operating procedures .... that are prescribed in sub-paragraph (**d**) of this paragraph. The aeroplane ....

(**f**) When demonstrating compliance .... that are prescribed in sub-paragraph (**d**) of this paragraph, the aeroplane....

(**g**) When manoeuvring .... (see AMC No 1 to CS 25.143(**g**)), and must .... over-controlling. (See AMC No 2 to AMC 25.143(**g**)).

(**h**) (See AMC 25.143(**h**)). The manoeuvring capabilities ....[Table unchanged]

Add new CS 25.143(i) and (j)

(i) When demonstrating compliance with CS 25.143 in icing conditions -

(1) Controllability may be demonstrated with the ice accretion described in Appendix C that is most critical for the particular flight phase. For aeroplanes with unpowered elevator controls, "Sandpaper Ice" must also be considered in determining the critical ice accretion; and

(2) It must be shown that a push force is required throughout a pushover manoeuvre down to zero g or the lowest load factor obtainable if limited by elevator power. It must be possible to promptly recover from the manoeuvre without exceeding 222 N. (50 lbf) pull control force; and

(3) Changes in longitudinal control force to maintain speed with increasing sideslip angle must be progressive with no reversals or unacceptable discontinuities.

(j) For flight in icing conditions prior to activation of normal operation of the ice protection system, the following apply:

(1) If activation of normal operation of any ice protection system is dependent upon visual recognition of a specified ice accretion on a reference surface, the requirements of CS 25.143 are applicable with the ice accretion defined in Appendix C, Part II(e).

(2) If activation of normal operation of any ice protection system is dependent upon means of recognition other than that defined in sub-paragraph (j)(1) of this paragraph, it must be shown that the aeroplane is controllable in a pull-up manoeuvre up to 1.5g and there is no longitudinal control force reversal during a pushover manoeuvre down to 0.5g with the ice accretion defined in Appendix C, Part II(e)."

Proposal 11

CS 25.207 Stall warning

Amend CS 25.207(b)

(b) The warning must be furnished either through the inherent aerodynamic qualities of the aeroplane or by a device that will give clearly distinguishable indications under expected conditions of flight. However, a visual stall warning device that requires the attention of the crew within the cockpit is not acceptable by itself. If a warning device is used, it must provide a warning in each of the aeroplane configurations prescribed in sub-paragraph (a) of this paragraph at the speed prescribed in sub-paragraphs (c) and (d) of this paragraph**. Except for**

the stall warning prior to normal operation of the ice protection system prescribed in sub-paragraph (h)(2) of this paragraph, the stall warning for flight in icing conditions prescribed in sub-paragraph (e) of this paragraph must be provided by the same means as the stall warning for flight in non-icing conditions. (See AMC 25.207(b).)

Insert a new CS 25.207(e)

(e) In icing conditions, when the speed is reduced at decelerations of up to 0.5 m/sec^2 (1 knot per second) , the stall warning margin in straight and turning flight must be sufficient to allow the pilot to prevent stalling (as defined in CS 25.201(d)) when recovery, using the same test technique as for the non-contaminated aeroplane, is initiated not less than 3 seconds after the onset of stall warning, with -

(1) The "Holding Ice" accretion described in Appendix C for the en-route, holding, approach, landing, and go-around high-lift configurations; and

(2) The more critical of the "Take-off Ice" and "Final Take-off Ice" accretions described in Appendix C for each high-lift configuration used in the take-off phase.

Renumber and amend old CS 25.207(e):

(f) The stall warning margin must be sufficient to allow the pilot to prevent stalling ~~(as defined in CS 25.201(d))~~ when recovery is initiated not less than one second after the onset of stall warning in slow-down turns with at least 1.5g load factor normal to the flight path and airspeed deceleration rates of at least 1 m/sec^2 (2 knots per second) , with the flaps and landing gear in any normal position, with the aeroplane trimmed for straight flight at a speed of 1.3 V_{SR}, and with the power or thrust necessary to maintain level flight at 1.3 V_{SR}. **When demonstrating compliance with this sub-paragraph with ice accretions, the same test technique as for the aeroplane without ice accretions must be used for recovery.**

Renumber old CS 25.207(f):

(g) Stall warning must ....

Add a new 25.207(h):

(h) For flight in icing conditions prior to activation of normal operation of the ice protection system, the following apply:

(1) If activation of normal operation of any ice protection system is dependent upon visual recognition of a specified ice accretion on a reference surface, the requirements of this paragraph except sub-paragraphs (c) and (d) are applicable with the ice accretion defined in Appendix C, Part II(e).

(2) If activation of normal operation of any ice protection system is dependent upon means of recognition other than that defined in sub-paragraph (h)(1) of this paragraph:

(i) If stall warning is provided by the same means as for flight in non-icing conditions, when the speed is reduced at rates not exceeding 0.5 m/sec^2 (1

knot per second), the stall warning margin in straight and turning flight must be sufficient to allow the pilot to prevent stalling, using the same test technique as for the non-contaminated aeroplane, without encountering any adverse characteristics when recovery is initiated not less than 1 second after the onset of stall warning, with the ice accretion defined in Appendix C, Part II(e).

(ii) If stall warning is provided by a different means than for flight in non-icing conditions, when the speed is reduced at rates not exceeding 0.5 m/sec^2 (1 knot per second), the stall warning in straight and turning flight must be sufficient to allow the pilot to prevent stalling, using the same test technique as for the non-contaminated aeroplane, without encountering any adverse characteristics when recovery is initiated not less than 3 seconds after the onset of stall warning, with the ice accretion defined in Appendix C, Part II(e). Additionally, compliance with CS 25.203 must be shown using the demonstration means prescribed by CS 25.201, except that 1.5 m/sec^2 (3 knots per second) airspeed deceleration rates of CS 25.201(c)(2) need not be demonstrated."

Proposal 12

CS 25.237 Wind velocities

Amend CS 25.237:

"(a) **__The following applies:**

(1) A 90° cross component of wind velocity, demonstrated to be safe for take-off and landing, must be established for dry runways and must be at least 37 km/h (20 knots) or 0.2 V_{SR0}, whichever is greater, except that it need not exceed 46 km/h (25 knots)

(2) The crosswind component for take-off established without ice accretions is valid in icing conditions.

(3) The landing crosswind component must be established for:

(i) Non-icing conditions, and

(ii) Icing conditions with the "Landing Ice" accretion defined in Appendix C.

<u>Proposal 13</u>

CS 25.253 High-speed characteristics

Amend CS 25.253 (b)

(b) *Maximum speed for stability characteristics, V_{FC}/M_{FC}.* V_{FC}/M_{FC} is the maximum speed at which the requirements of CS 25.143**(g)**, 25.147(e), 25.175(b)(1), 25.177**(a) through (c)**, and 25.181 must be met with wing-flaps and landing gear retracted. **Except as noted in CS 25.253(c),** it may not be less than a speed midway between V_{MO}/M_{MO} and V_{DF}/M_{DF}, except that, for altitudes where Mach number is the limiting factor, M_{FC} need not exceed the Mach number at which effective speed warning occurs.

Add CS 25.253 (c)

(c) The maximum speed for stability characteristics with the ice accretions defined in Appendix C, at which the requirements of CS 25.143(g), 25.147(e), 25.175(b)(1), 25.177 and 25.181 must be met, is the lower of:

(1) 556 km/h (300 knots) CAS,

(2) $V_{FC,}$ or

(3) A speed at which it is demonstrated that the airframe will be free of ice accretion due to the effects of increased dynamic pressure."

<u>Proposal 14</u>

CS 25.941 Inlet, engine and exhaust compatibility

Amend CS 25.941(c):

"(c) In showing compliance with sub-paragraph (b) of this paragraph, the pilot strength required may not exceed the limits set forth in CS 25.143(**d**) subject to the conditions set forth in sub-paragraphs (**e**) and (**f**) of CS 25.143."

<u>Proposal 15</u>

CS 25.1419 Ice protection

Amend CS 25.1419:

"If certification for flight in icing conditions is desired, the aeroplane must be able to safely operate in the continuous maximum and intermittent maximum icing conditions of Appendix C. To establish **this** ~~that the aeroplane can operate within the continuous maximum and intermittent maximum conditions of Appendix C~~ **–**

<u>Proposal 16</u>

BOOK 1 **CS-25**

APPENDICES

Appendix C

Amend Appendix C

Part I - Atmospheric Icing Conditions

(a) *Continuous Maximum Icing. ....*

(b) *Intermittent Maximum Icing. ....*

(c) *Take-off maximum icing*. The maximum intensity of atmospheric icing conditions for take-off (take-off maximum icing) is defined by the cloud liquid water content of 0.35 g/m^3, the mean effective diameter of the cloud droplets of 20 microns, and the ambient air temperature at ground level of -9 degrees C. The take-off maximum icing conditions extend from ground level to a height of 457 m (1500 ft) above the level of the take-off surface.

Part II - Airframe Ice Accretions for Showing Compliance with Subpart B

(a) *Ice accretions - General*. CS 25.21(g) states that in the icing conditions of Appendix C the applicable requirements of subpart B must be met (except as specified otherwise). The most critical ice accretion in terms of handling characteristics and/or performance for each flight phase must be determined, taking into consideration the atmospheric conditions of part I of this Appendix, and the flight conditions (e.g. configuration, speed, angle-of-attack, and altitude). The following ice accretions must be determined:

(1) <u>Take-off Ice</u> is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, occurring between lift-off and 122 m (400 ft) above the take-off surface, assuming accretion starts at lift-off in the take-off maximum icing conditions of Part I, paragraph (c) of this Appendix.

(2) <u>Final Take-off Ice</u> is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, between 122 m (400 ft) and 457 m (1500 ft) above the take-off surface, assuming accretion starts at lift-off in the take-off maximum icing conditions of Part I, paragraph (c) of this Appendix.

(3) <u>En-route Ice</u> is the critical ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system

operation, during the en-route phase. At the applicant's option, *Holding Ice* may be used in showing compliance with requirements that specify *En-route Ice*.

(4) Holding Ice is the critical ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, during the holding flight phase.

(5) Landing Ice is normally *Holding Ice*, unless modified by ice protection system operation during the landing phase.

(6) Sandpaper Ice is a thin, rough layer of ice.

(b) In order to reduce the number of ice accretions to be considered when demonstrating compliance with the requirements of CS 25.21(g):

(1) The more critical of *Take-off Ice* and *Final Take-off Ice* may be used throughout the take-off phase.

(2) *Holding Ice* may be used for the en-route, holding, approach, landing and go-around flight phases.

(3) *Holding Ice* may also be used for the take-off phase provided it is shown to be more conservative than *Take-off Ice* and *Final Take-off Ice.*

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

(d) Ice accretions for the take-off phase. For both unprotected and protected parts, the ice accretion may be determined by calculation, assuming the take-off maximum icing conditions defined in Appendix C, and that:

(1) Aerofoils, control surfaces and, if applicable, propellers are free from frost, snow, or ice at the start of the take-off,

(2) The ice accretion starts at lift-off,

(3) The critical ratio of thrust/power-to-weight,

(4) Failure of the critical engine occurs at V_{EF}, and

(5) Crew activation of the ice protection system is in accordance with an AFM procedure, except that after commencement of the take-off roll no crew action to activate the ice protection system should be assumed to occur until the aeroplane is 122 m above the take-off surface.

(e) Ice accretion prior to normal system operation. The ice accretion prior to normal system operation is the ice accretion formed on the unprotected and normally protected surfaces prior to activation and effective operation of any ice protection system in continuous maximum atmospheric icing conditions."

BOOK 2 CS-25

Proposal 17

AMC 25.119(a)
Landing climb: all engines operating

Renumber AMC 25.119(a) as AMC 25.119 and amend references to CS 25.119(a) accordingly.

Proposal 18

AMC 25.121(b)(1)
Climb: one engine inoperative

Renumber AMC 25.121(b)(1) as AMC 25.121(b)(1)(i) and amend references to CS 25.121(b)(1) accordingly.

Proposal 19

AMC 25.125(a)(3)
Change of configuration

Renumber AMC 25.125(a)(3) as AMC 25.125(b)(3) and amend references to CS 25.125(a)(3) accordingly.

Proposal 20

AMC 25.125(b)
Landing

Renumber AMC 25.125(b) as AMC 25.125(c) and amend references to CS 25.125(b) accordingly.

Proposal 21

AMC 25.125(b)(2)
Landing

Renumber AMC 25.125(b)(2) as AMC 25.125(c)(2) and amend references to CS 25.125(b)(2) accordingly.

Proposal 22

AMC 25.143(c)
Controllability and Manoeuvrability

Renumber AMC 25.143(c) as AMC 25.143(d) and amend references to CS 25.143(c) accordingly.

Proposal 23

AMC No 1 and No 2 to CS 25.143(f)
Controllability and Manoeuvrability

Renumber AMCs No 1 and No 2 to CS 25.143(f) as AMCs No 1 and No 2 to CS 25.143(g) and amend references to CS 25.143(f) accordingly, and to CS 25.143(c) as above.

Proposal 24

AMC 25.143(g)
Manoeuvre capability

Renumber AMC 25.143(g) as AMC 25.143(h) and amend references to CS 25.143(g) accordingly.

Proposal 25

AMC 25.1329
Automatic Pilot

Amend the cross-references in paragraphs 4.3(a) and 5.3.1(b) of AMC 25.1329 to refer to CS 25.143(d).

<u>Proposal 26</u>

Introduce a new AMC 25.21(g):

AMC 25.21(g)
Performance and Handling Characteristics in Icing Conditions Contained in Appendix C, Part 25 (Acceptable Means of Compliance) (see CS 25.21(g))

Table of Contents

1 *Purpose*.

1.1 This AMC describes an acceptable means for showing compliance with the requirements related to performance and handling characteristics of Large Aeroplanes as affected by flight in the icing conditions that are defined in Appendix C to CS-25. The means of compliance described in this AMC is intended to provide guidance to supplement the engineering and operational judgement that should form the basis of any compliance findings relative to handling characteristics and performance in Appendix C icing conditions.

1.2 The guidance information is presented in sections 4 to 6 and three appendices.

1.3 Section 4 explains the various performance and handling requirements in relation to the flight conditions that are relevant for determining the shape and texture of ice accretions for the aeroplane in the atmospheric conditions of CS-25, Appendix C.

1.4 Section 5 describes acceptable methods and procedures that an applicant may use to show that an aeroplane meets these requirements. Depending on the design features of a specific aeroplane as discussed in Appendix 3 of this AMC, its similarity to other types or models, and the service history of those types or models, some judgement will often be necessary for determining that any particular method or procedure is adequate for showing compliance with a particular requirement.

1.5 Section 6 provides an acceptable flight test programme where flight testing is selected by the applicant and agreed by the Authority as being the primary means of compliance.

1.6 The three appendices provide additional reference material associated with ice accretion, artificial ice shapes, and aeroplane design features.

2 *Related Requirements.* The following paragraphs of CS-25 are related to the guidance in this AMC:

- CS 25.21 (Proof of compliance)
- CS 25.103 (Stall speed)
- CS 25.105 (Takeoff)
- CS 25.107 (Takeoff speeds)
- CS 25.111 (Takeoff path)
- CS 25.119 (Landing climb)
- CS 25.121 (Climb: One-engine-inoperative)
- CS 25.123 (En-route flight paths)
- CS 25.125 (Landing)
- CS 25.143 (Controllability and Manoeuvrability - General)
- CS 25.207 (Stall warning)
- CS 25.237 (Wind velocities)
- CS 25.253 (High-speed characteristics)
- CS 25.1309 (Equipment, systems, and installations)
- CS 25.1419 (Ice protection)
- CS 25.1581 (Aeroplane Flight Manual)
- CS-25, Appendix C

3 *Reserved.*

4 *Requirements and Guidance.*

4.1 *General.* This section provides guidance for showing compliance with Subpart B requirements for flight in the icing conditions of Appendix C to CS-25.

4.1.1 Operating rules for commercial operation of large aeroplanes (e.g. JAR-OPS 1.345) require that the aeroplane is free of any significant ice contamination at the beginning of the take-off roll due to application of appropriate ice removal and ice protection procedures during flight preparation on the ground.

4.1.2 Appendix C to CS-25 defines the ice accretions to be used in showing compliance with CS 25.21(g). Appendix 1 of this AMC provides details on ice accretions, including accounting for delay in the operation of the ice protection system and consideration of ice detection systems.

4.1.3 Certification experience has shown that it is not necessary to consider ice accumulation on the propeller, induction system or engine components of an inoperative engine for handling qualities substantiation. Similarly, the mass of the ice need not normally be considered.

4.1.4 Flight in icing conditions includes operation of the aeroplane after leaving the icing conditions, but with ice accretion remaining on the critical surfaces of the aeroplane.

4.2 *Proof of Compliance (CS 25.21(g)).*

4.2.1 Demonstration of compliance with certification requirements for flight in icing conditions may be accomplished by any of the means discussed in paragraph 5.1 of this AMC.

4.2.2 Certification experience has shown that aeroplanes of conventional design do not require additional detailed substantiation of compliance with the requirements of the following paragraphs of CS-25 for flight in icing conditions or with ice accretions:

25.23,
25.25,
25.27,
25.29,
25.31,
25.231,
25.233,
25.235,
25.253(a) and (b), and
25.255

4.2.3 Where normal operation of the ice protection system results in changing the stall warning system and/or stall identification system activation settings, it is acceptable to establish a procedure to return to the non icing settings when it can be demonstrated that the critical wing surfaces are free of ice accretion.

4.3 *Propeller Speed and Pitch Limits (CS 25.33).* Certification experience has shown that it may be necessary to impose additional propeller speed limits for operations in icing conditions.

4.4 *Performance - General (CS 25.101).*

4.4.1 The propulsive power or thrust available for each flight condition must be appropriate to the aeroplane operating limitations and normal procedures for flight in icing conditions. In general, it is acceptable to determine the propulsive power or thrust available by suitable analysis, substantiated when required by appropriate flight tests (e.g. when determining the power or thrust available after 8 seconds for CS 25.119). The following aspects should be considered:

a. Operation of induction system ice protection.

b. Operation of propeller ice protection.

c. Operation of engine ice protection.

d. Operation of airframe ice protection system.

4.4.2 The following should be considered when determining the change in performance due to flight in icing conditions:

a. Thrust loss due to ice accretion on propulsion system components with normal operation of the ice protection system, including engine induction system and/or engine components, and propeller spinner and blades.

b. The incremental airframe drag due to ice accretion with normal operation of the ice protection system.

c. Changes in operating speeds due to flight in icing conditions.

4.4.3 Certification experience has shown that any increment in drag (or decrement in thrust) due to the effects of ice accumulation on the landing gear, propeller, induction system and engine components may be determined by a suitable analysis.

4.4.4 Apart from the use of appropriate speed adjustments to account for operation in icing conditions, any changes in the procedures established for take-off, balked landing, and missed approaches should be agreed with the Authority.

4.4.5 Performance associated with flight in icing conditions is applicable after exiting icing conditions until the aeroplane critical surfaces are free of ice accretion and the ice protection systems are selected “Off.”

4.5 *Stall speed (CS 25.103).* Certification experience has shown that for aeroplanes of conventional design it is not necessary to make a separate determination of the effects of Mach number on stall speeds for the aeroplane with ice accretions.

4.6 *Failure Conditions (CS 25.1309).*

4.6.1 The failure modes of the ice protection system and the resulting effects on aeroplane handling and performance should be analysed in accordance with CS 25.1309.

In determining the probability of a failure condition, it should be assumed that the probability of entering icing conditions is one. The "Failure Ice" configuration is defined in Appendix 1, paragraph A1.3.

4.6.2 For probable failure conditions that are not annunciated to the flight crew, the guidance in this AMC for a normal condition is applicable with the "Failure Ice" configuration.

4.6.3 For probable failure conditions that are annunciated to the flight crew, with an associated procedure that does not require the aeroplane to exit icing conditions, the guidance in this AMC for a normal condition is applicable with the "Failure Ice" configuration.

4.6.4 For probable failure conditions that are annunciated to the flight crew, with an associated operating procedure that requires the aeroplane to leave the icing conditions as soon as practicable, it should be shown that the aeroplane is capable of continued safe flight and landing with the “Failure Ice" configuration. The operating procedures and related speeds should provide an adequate operating envelope and acceptable performance and handling characteristics to ensure continued safe flight and landing.

4.6.5 For failure conditions that are improbable but not extremely improbable, the analysis and substantiation of continued safe flight and landing, in accordance with CS 25.1309, should take into consideration whether annunciation of the failure is provided and the associated operating procedures and speeds to be used following the failure condition.

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

a. The ice protection systems may not anti-ice or de-ice properly at all power or thrust settings. This may result in a minimum power or thrust setting for operation in icing conditions which affects descent and/or approach capability.

b. Ice blockage of control surface gaps and/or freezing of seals causing increased control forces, control restrictions or blockage.

c. Airspeed, altitude and/or angle of attack sensing errors due to ice accretion forward of the sensors (e.g. radome ice). Dynamic pressure ("q") operated feel systems using separate sensors also may be affected.

d. Ice blockage of unprotected inlets and vents that may affect the propulsive thrust available, aerodynamic drag, powerplant control, or flight control.

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

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

g. Automatic flight control systems operation.

h. Installed thrust. This includes operation of ice protection systems when establishing acceptable power or thrust setting procedures, control, stability, lapse rates, rotor speed margins, temperature margins, Automatic Reserve Power (ARP) operation, and power or thrust lever angle functions.

4.8 *Aeroplane Flight Manual (CS 25.1581).*

4.8.1 *Limitations.*

4.8.1.1 Where limitations are required to ensure safe operation in icing conditions, these limitations should be stated in the AFM.

4.8.1.2 The Limitations section of the AFM should include, as applicable, a statement similar to the following: "In icing conditions the aeroplane must be operated, and its ice protection systems used, as described in the operating procedures section of this manual. Where specific operational speeds and performance information have been established for such conditions, this information must be used."

4.8.2 *Operating Procedures.*

4.8.2.1 AFM operating procedures for flight in icing conditions should include normal operation of the aeroplane including operation of the ice protection system and operation of the aeroplane following ice protection system failures. Any changes in procedures for other aeroplane system failures that affect the capability of the aeroplane to operate in icing conditions should be included.

4.8.2.2 Normal operating procedures provided in the AFM should reflect the procedures used to certify the aeroplane for flight in icing conditions. This includes configurations, speeds, ice protection system operation, power plant and systems operation, for take-off, climb, cruise, descent, holding, go-around, and landing.

4.8.2.3 Abnormal operating procedures should include the procedures to be followed in the event of annunciated ice protection system failures and suspected unannunciated failures. Any changes to other abnormal procedures contained in the AFM, due to flight in icing conditions, should also be included.

4.8.3 *Performance Information.* Performance information, derived in accordance with subpart B of CS-25, must be provided in the AFM for all relevant phases of flight.

5 *Acceptable Means of Compliance - General.*

5.1 *General.*

5.1.1 This section describes acceptable methods and procedures that an applicant may use to show that an aeroplane meets the performance and handling requirements of subpart B in the atmospheric conditions of Appendix C to CS-25.

5.1.2 Compliance with CS 25.21(g) should be shown by one or more of the methods listed in this section.

5.1.3 The compliance process should address all phases of flight, including take-off, climb, cruise, holding, descent, landing, and go-around as appropriate to the aeroplane type, considering its typical operating regime.

5.1.4 The design features included in Appendix 3 of this AMC should be considered when determining the extent of the substantiation programme.

5.1.5 Appropriate means for showing compliance include the actions and items listed in Table 1. These are explained in more detail in the following sections of this AMC.

TABLE 1: Means for Showing Compliance

Flight Testing	Flight testing in dry air using artificial ice shapes or with ice shapes created in natural icing conditions.
Wind Tunnel Testing and Analysis	An analysis of results from wind tunnel tests with artificial or actual ice shapes.
Engineering Simulator Testing and Analysis	An analysis of results from engineering simulator tests.
Engineering Analysis	An analysis which may include the results from executing an agreed computer code.
Ancestor Aeroplane Analysis	An analysis of results from a closely related ancestor aeroplane.

5.1.6 Various factors that affect ice accretion on the airframe with an operative ice protection system and with ice protection system failures are discussed in Appendix 1 of this AMC.

5.1.7 An acceptable methodology to obtain agreement on the artificial ice shapes is given in Appendix 2 of this AMC. That appendix also provides the different types of artificial ice shapes to be considered.

5.2 *Flight Testing.*

5.2.1 *General*.

5.2.1.1 The extent of the flight test programme should consider the results obtained with the non-contaminated aeroplane and the design features of the aeroplane as discussed in Appendix 3 of this AMC.

5.2.1.2 It is not necessary to repeat an extensive performance and flight characteristics test programme on an aeroplane with ice accretion. A suitable programme that is sufficient to demonstrate compliance with the requirements can be established from experience with aeroplanes of similar size, and from review of the ice protection system design, control system design, wing design, horizontal and vertical stabiliser design, performance characteristics, and handling characteristics of the non-contaminated aeroplane. In particular, it is not necessary to investigate all weight and centre of gravity combinations when results from the non-contaminated aeroplane clearly indicate the most critical combination to be tested. It is not necessary to investigate the flight characteristics of the aeroplane at high altitude (i.e. above the upper limit specified in Appendix C to CS-25). An acceptable flight test programme is provided in section 6 of this AMC.

5.2.1.3 Certification experience has shown that tests are usually necessary to evaluate the consequences of ice protection system failures on handling characteristics and performance and to demonstrate continued safe flight and landing.

5.2.2 *Flight Testing Using Approved Artificial Ice Shapes*.

5.2.2.1 The performance and handling tests may be based on flight testing in dry air using artificial ice shapes that have been agreed with the Authority.

5.2.2.2 Additional limited flight tests should be conducted in natural icing conditions, which are discussed in paragraph 5.2.3, below.

5.2.3 *Flight Testing In Natural Icing Conditions.*

5.2.3.1 Where flight testing in natural atmospheric icing conditions is the primary means of compliance, the conditions should be measured and recorded. The tests should ensure good coverage of Appendix C conditions and, in particular, the critical conditions. The conditions for accreting ice (including the icing atmosphere, configuration, speed and duration of exposure) should be agreed with the Authority.

5.2.3.2 Where flight testing with artificial ice shapes is the primary means of compliance, additional limited flight tests should be conducted in natural icing conditions. The objective of these tests is to corroborate the handling characteristics and performance results obtained in flight testing with artificial ice shapes. As such, it is not necessary to measure the atmospheric characteristics (i.e. liquid water content (LWC) and median volumetric diameter (MVD)) of the flight test icing conditions. For some derivative aeroplanes with similar aerodynamic characteristics as the ancestor, it may not be necessary to carry out additional flight test in natural icing conditions if such tests have been already performed with the ancestor.

5.3 *Wind Tunnel Testing and Analysis.* Analysis of the results of dry air wind tunnel testing of models with artificial ice shapes, as defined in Part II of Appendix C to CS-25, may be used to substantiate the performance and handling characteristics.

5.4 *Engineering Simulator Testing and Analysis.* The results of an engineering simulator analysis of an aeroplane that includes the effects of the ice accretions as defined in Part II of Appendix C to CS-25 may be used to substantiate the handling characteristics. The data used to model the effects of ice accretions for the engineering simulator may be based on results of dry air wind tunnel tests, flight tests, computational analysis, and engineering judgement.

5.5 *Engineering Analysis.* An engineering analysis that includes the effects of the ice accretions as defined in Part II of Appendix C to CS-25 may be used to substantiate the performance and handling characteristics. The effects of the ice shapes used in this analysis may be determined by an analysis of the results of dry air wind tunnel tests, flight tests, computational analysis, engineering simulator analysis, and engineering judgement.

5.6 *Ancestor Aeroplane Analysis.*

5.6.1 An ancestor aeroplane analysis that includes the effect of the ice accretions as defined in Part II of Appendix C to CS-25 may be used to substantiate the performance and handling characteristics. This analysis should consider the similarity of the configuration, operating envelope, performance and handling characteristics, and ice protection system of the ancestor aeroplane.

5.6.2 The analysis may include flight test data, dry air wind tunnel test data, icing tunnel test data, engineering simulator analysis, service history, and engineering judgement.

6 *Acceptable Means of Compliance - Flight Test Programme.*

6.1 *General.*

6.1.1 This section provides an acceptable flight test programme where flight testing is selected by the applicant and agreed by the Authority as being the primary means for showing compliance.

6.1.2 Where an alternate means of compliance is proposed for a specific paragraph in this section, it should enable compliance to be shown with at least the same degree of confidence as flight test would provide (see CS 25.21(a)(1)).

6.1.3 This test programme is based on the assumption that the applicant will choose to use "Holding Ice" for the majority of the testing on the basis that this is the most conservative shape. Where this is not so, the applicant may choose to use an ice shape appropriate to the particular phase of flight.

6.2 *Stall Speed (CS 25.103).*

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

6.2.2 *Acceptable Test Programme*. The following represents an acceptable test programme subject to the provisions outlined above:

a. Forward centre of gravity position appropriate to the configuration.

b. Normal stall test altitude.

c. In the configurations listed below, trim the aeroplane at an initial speed of 1.13 to 1.30 V_{SR}. Decrease speed until an acceptable stall identification is obtained.

i. High lift devices retracted configuration, "Final Take-off Ice."

ii. High lift devices retracted configuration, "En-route Ice."

iii. Holding configuration, "Holding Ice."

iv. Lowest lift take-off configuration, "Holding Ice."

v. Highest lift take-off configuration, "Take-off Ice."

vi. Highest lift landing configuration, "Holding Ice."

6.3 *Accelerate-stop Distance (CS 25.109).* The effect of any increase in V_1 due to take-off in icing conditions may be determined by a suitable analysis.

6.4 *Take-off Path (CS 25.111).* If V_{SR} in the configuration defined by CS 25.121(b) with the “Takeoff Ice" accretion defined in Appendix C to CS-25 exceeds V_{SR} for the same configuration without ice accretions by more than the greater of 5.6 km/h (3 knots) or 3%, the take-off demonstrations should be repeated to substantiate the speed schedule and distances for take-off in icing conditions. The effect of the take-off speed increase, thrust loss, and drag increase on the take-off path may be determined by a suitable analysis.

6.5 *Landing Climb: All-engines-operating (CS 25.119). Acceptable Test Programme*. The following represents an acceptable test programme:

a. "Holding Ice."

b. Forward centre of gravity position appropriate to the configuration.

c. Highest lift landing configuration, landing climb speed no greater than V_{REF}.

d. Stabilise at the specified speed and conduct 2 climbs or drag polar checks as agreed with the Authority.

6.6 *Climb: One-engine-inoperative (CS 25.121). Acceptable Test Programme*. The following represents an acceptable test programme:

a. Forward centre of gravity position appropriate to the configuration.

b. In the configurations listed below, stabilise the aeroplane at the specified speed with one engine inoperative (or simulated inoperative if all effects can be taken into account) and conduct 2 climbs in each configuration or drag polar checks substantiated for the asymmetric drag increment as agreed with the Authority.

i. High lift devices retracted configuration, final take-off climb speed, "Final Take-off Ice."

ii. Lowest lift take-off configuration, landing gear retracted, V_2 climb speed, "Take-off Ice."

iii. Approach configuration appropriate to the highest lift landing configuration, landing gear retracted, approach climb speed, "Holding Ice."

6.7 *En-route Flight Path (CS 25.123). Acceptable Test Programme*. The following represents an acceptable test programme:

a. "En-route Ice."

b. Forward centre of gravity position appropriate to the configuration.

c. En-route configuration and climb speed.

d. Stabilise at the specified speed with one engine inoperative (or simulated inoperative if all effects can be taken into account) and conduct 2 climbs or drag polar checks substantiated for the asymmetric drag increment as agreed with the Authority.

6.8 *Landing (CS 25.125).* The effect of landing speed increase on the landing distance may be determined by a suitable analysis.

6.9 *Controllability and Manoeuvrability - General (CS 25.143 and 25.177).*

6.9.1 A qualitative and quantitative evaluation is usually necessary to evaluate the aeroplane's controllability and manoeuvrability. In the case of marginal compliance, or the force limits or stick force per g limits of CS 25.143 being approached, additional substantiation may be necessary to establish compliance. In general, it is not necessary to consider separately the ice accretion appropriate to take-off and en-route because the "Holding Ice" is usually the most critical.

6.9.2 *General Controllability and Manoeuvrability*. The following represents an acceptable test programme for general controllability and manoeuvrability, subject to the provisions outlined above:

a. "Holding Ice."

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. In the configurations listed in Table 2, trim at the specified speeds and conduct the following manoeuvres:

i. 30° banked turns left and right with rapid reversals;

ii. Pull up to 1.5g (except that this may be limited to 1.3g at V_{REF}), and pushover to 0.5g (except that the pushover is not required at V_{MO} and V_{FE}); and

iii. Deploy and retract deceleration devices.

TABLE 2: Trim Speeds

Configuration	*Trim Speed*
High lift devices retracted configuration:	• 1.3 V_{SR}, and • V_{MO} or 463 km/h (250 knots) IAS , whichever is less
Lowest lift takeoff configuration:	• 1.3 V_{SR}, and • V_{FE} or 463 km/h (250 knots) IAS, whichever is less
Highest lift landing configuration:	• V_{REF}, and • V_{FE} or 463 km/h (250 knots) IAS, whichever is less.

d. Lowest lift take-off configuration: At the greater of 1.13 V_{SR} or $V_{2\ MIN}$, with one engine inoperative (simulated), conduct 30° banked turns left and right with normal turn reversals and, in wings-level flight, a 9.3 km/h (5 knot) speed decrease and increase.

e. Conduct an approach and go-around with all engines operating using the recommended procedure.

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

g. Conduct an approach and landing using the recommended procedure. In addition satisfactory controllability should be demonstrated during a landing at V_{REF} minus 9.3 km/h (5 knots). These tests should be done at heavy weight and forward centre of gravity.

h. Conduct an approach and landing with one engine inoperative (simulated) using the recommended procedure.

6.9.3 *Low g Manoeuvres and Sideslips.* The following represents an acceptable test programme for compliance with controllability requirements in low g manoeuvres and in sideslips.

6.9.3.1 It should be shown that a push force is required throughout a pushover manoeuvre down to zero g or the lowest load obtainable if limited by elevator power. It should be possible to promptly recover from the manoeuvre without exceeding 222 N (50 lbf) pull control force.

6.9.3.2 For sideslips, changes in longitudinal control force to maintain speed with increasing sideslip should be progressive, with no reversals or unacceptable discontinuities (see paragraph 6.15.1 of this AMC).

6.9.3.3 The test manoeuvres described in paragraphs 6.9.3.1 and 6.9.3.2, above, should be conducted using the following configurations and procedures:

a. "Holding Ice." For aeroplanes with unpowered elevators, these tests should also be performed with "Sandpaper Ice."

b. Medium to light weight, the most critical of aft or forward centre of gravity position, symmetric fuel loading.

c. In the configurations listed below, with the aeroplane in trim, or as nearly as possible in trim, at the specified trim speed, perform a continuous manoeuvre (without changing trim) to reach zero g normal load factor or, if limited by elevator control authority, the lowest load factor obtainable at the target speed.

i. Highest lift landing configuration at idle power or thrust, and the more critical of:

- Trim speed 1.23 V_{SR}, target speed not <u>more</u> than 1.23 V_{SR}, or

- Trim speed V_{FE}, target speed not <u>less</u> than V_{FE} - 37 km/h (20 knots)

ii. Highest lift landing configuration at go-around power or thrust, and the more critical of:

- Trim speed 1.23 V_{SR}, target speed not <u>more</u> than 1.23 V_{SR}, or

- Trim speed V_{FE}, target speed not <u>less</u> than V_{FE} - 37 km/h (20 knots)

iii. Conduct steady heading sideslips to full rudder authority, 356 N. (180 lbf) rudder force or full lateral control authority (whichever comes first), with highest lift landing configuration, trim speed 1.23 V_{SR}, and power or thrust for -3° flight path angle.

6.9.4 *Controllability prior to Normal Operation of the Ice Protection System*. The following represents an acceptable test programme for compliance with controllability requirements with the ice accretion prior to normal operation of the ice protection system.

6.9.4.1 Where the ice protection system is activated as described in paragraph A1.2.3.3.a of Appendix 1 of this AMC, paragraphs 6.9.1, 6.9.2 and 6.9.3 of this AMC are applicable with the ice accretion prior to normal system operation.

6.9.4.2 Where the ice protection system is activated as described in paragraphs A1.2.3.3.b,c,d or e of Appendix 1 of this AMC, it is acceptable to demonstrate adequate controllability with the ice accretion prior to normal system operation, as follows:

a. In the configurations listed below, trim the aeroplane at the specified speed. Conduct pull up to 1.5g and pushover to 0.5g without longitudinal control force reversal.

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

ii. Landing configuration, V_{REF} for non-icing conditions, power or thrust for landing approach (limit pull up to stall warning).

6.10 *Longitudinal Control (CS 25.145).*

6.10.1 No specific quantitative evaluations are required for demonstrating compliance with CS 25.145(b) and (c). Qualitative evaluations should be combined with the other testing. The results from the non-contaminated aeroplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, these cases should be repeated with ice.

6.10.2 *Acceptable Test Programme*. The following represents an acceptable test programme for compliance with CS 25.145(a):

a. "Holding ice."

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. In the configurations listed below, trim the aeroplane at 1.3 V_{SR}. Reduce speed using elevator control to stall warning plus one second and demonstrate prompt recovery to the trim speed using elevator control.

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

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

6.11 *Directional and Lateral Control (CS 25.147).* Qualitative evaluations should be combined with the other testing. The results from the non-contaminated aeroplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, these cases should be repeated with ice.

6.12 *Trim (CS 25.161).* Qualitative evaluations should be combined with the other testing. The results from the non-contaminated aeroplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, these cases should be repeated with ice.

6.13 *Stability - General (CS 25.171).* Qualitative evaluations should be combined with the other testing. Any tendency to change speed when trimmed or requirement for frequent trim inputs should be specifically investigated.

6.14 *Demonstration of Static Longitudinal Stability (CS 25.175).*

6.14.1 Each of the following cases should be tested. In general, it is not necessary to test the cruise configuration at low speed (CS 25.175(b)(2)) or the cruise configuration with landing gear extended (CS 25.175(b)(3)); nor is it necessary to test at high altitude. Although the maximum speed for substantiation of stability characteristics is the lower of 556 km/h (300 knots) CAS or V_{FC} (CS 25.253(c)), the maximum speed for demonstration can be limited to 519 km/h (280 knots) CAS, provided that the stick force gradient can be satisfactorily extrapolated to 556 km/h (300 knots) CAS or V_{FC} (e.g. there is no gradient decrease with increasing speed).

6.14.2 *Acceptable Test Programme*. The following represents an acceptable test programme for demonstration of static longitudinal stability:

a. "Holding Ice."

b. High landing weight, aft centre of gravity position, symmetric fuel loading.

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

i. <u>Climb</u>: With high lift devices retracted, trim at 1.3 V_{SR}.

ii. <u>Cruise</u>: With high lift devices retracted, trim at V_{MO} or 463 km/h (250 knots) CAS, whichever is lower.

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

iv. <u>Landing</u>: With the highest lift landing configuration, trim at 1.3V_{SR}.

6.15 *Static Directional and Lateral Stability (CS 25.177).*

6.15.1 Compliance should be demonstrated using steady heading sideslips to show compliance with directional and lateral stability. The maximum sideslip angles obtained should be recorded and may be used to substantiate a crosswind value for landing (see paragraph 6.19 of this AMC).

6.15.2 *Acceptable Test Programme*. The following represents an acceptable test programme for static directional and lateral stability:

a. "Holding Ice."

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. In the configurations listed below, trim the aeroplane at the specified speed and conduct steady heading sideslips to full rudder authority, 801 N. (180 lbf) rudder pedal force, or full lateral control authority, whichever comes first.

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

ii. Lowest lift take-off configuration: Trim at the all-engines-operating initial climb speed.

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

6.16 *Dynamic Stability (CS 25.181).* Provided that there are no marginal compliance aspects with the non-contaminated aeroplane, it is not necessary to demonstrate dynamic stability in specific tests. Qualitative evaluations should be combined with the other testing. Any tendency to sustain oscillations in turbulence or difficulty in achieving precise attitude control should be investigated.

6.17 *Stall Demonstration (CS 25.201).*

6.17.1 Sufficient stall testing should be conducted to demonstrate that the stall characteristics comply with the requirements. In general, it is not necessary to conduct a stall programme which encompasses all weights, centre of gravity positions (including lateral asymmetry), altitudes, high lift configurations, deceleration device configurations, straight and turning flight stalls, power off and power on stalls. Based on a review of the stall characteristics of the non-contaminated aeroplane, a reduced test matrix can be established. However, additional testing may be necessary if:

- the stall characteristics with ice accretion show a significant difference from the non-contaminated aeroplane,

- testing indicates marginal compliance, or

- a stall identification system (e.g. stick pusher) is required to be reset for icing conditions.

6.17.2 *Acceptable Test Programme*. The following represents an acceptable test programme subject to the provisions outlined above. Turning flight stalls at decelerations greater than 1 knot/sec are not required.

a. "Holding Ice."

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. Normal stall test altitude.

d. In the configurations listed below, trim the aeroplane at the same initial stall speed factor used for stall speed determination. For power-on stalls, use the power setting as defined in CS 25.201(a)(2) but with ice accretions on the aeroplane. Decrease speed to stall identification and recover using the same test technique as for the non-contaminated aeroplane.

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

ii. Lowest lift take-off configuration: Straight/Power On, Turning/Power Off.

iii. Highest lift take-off configuration: Straight/Power Off, Turning/Power On.

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

6.18 *Stall Warning (CS 25.207).*

6.18.1 Stall warning should be assessed in conjunction with stall speed testing and stall characteristics testing (CS 25.103, CS 25.203 and paragraphs 6.2 and 6.17 of this AMC, respectively) and in tests with faster entry rates.

6.18.2 *Normal Ice Protection System Operation*. The following represents an acceptable test programme for stall warning in slow down turns of at least 1.5g and at entry rates of at least 1 m/sec^2 (2 knot/sec):

a. "Holding Ice."

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. Normal stall test altitude.

d. In the configurations listed below, trim the aeroplane at $1.3V_{SR}$ with the power or thrust necessary to maintain straight level flight. Maintain the trim power or thrust during the test demonstrations. Increase speed as necessary prior to establishing at least 1.5g and a deceleration of at least 1 m/sec^2 (2 knot/sec). Decrease speed until 1 sec after stall warning and recover using the same test technique as for the non-contaminated aeroplane.

i. High lift devices retracted configuration;

ii. Lowest lift take-off configuration; and

iii. Highest lift landing configuration.

6.18.3 *Ice Accretion Prior to Normal System Operation*. The following represent acceptable means for evaluating stall warning margin with the ice accretion prior to normal operation of the ice protection system.

6.18.3.1 Where the ice protection system is activated as described in paragraph A1.2.3.3.a, of Appendix 1 of this AMC, paragraphs 6.18.1 and 6.18.2 of this AMC are applicable with the ice accretion prior to normal system operation.

6.18.3.2 Where the ice protection system is activated as described in paragraphs A1.2.3.3.b,c,d or e of Appendix 1 of this AMC, it is acceptable to demonstrate adequate stall warning with the ice accretion prior to normal system operation, as follows:

a. In the configurations listed below, trim the aeroplane at 1.3 V_{SR}.

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

i. Landing configuration: Straight/Power Off.

b. At decelerations of up to 0.5 m/sec^2 (1 knot per second), reduce the speed to stall warning plus 1 second, and demonstrate that stalling can be prevented using the same test technique as for the non-contaminated aeroplane, without encountering any adverse characteristics (e.g., a rapid roll-off). As required by CS 25.207(h)(2)(ii), where stall warning is provided by a different means than for the aeroplane without ice accretion, the stall characteristics must be satisfactory and the delay must be at least 3 seconds.

6.19 *Wind Velocities (CS 25.237).*

6.19.1 Crosswind landings with "Landing Ice" should be evaluated on an opportunity basis.

6.19.2 The results of the steady heading sideslip tests with “Landing Ice” may be used to establish the safe cross wind component. If the flight test data show that the maximum sideslip angle demonstrated is similar to that demonstrated with the non-contaminated aeroplane, and the flight characteristics (e.g. control forces and deflections) are similar, then the non-contaminated aeroplane crosswind component is considered valid.

6.19.3 If the results of the comparison discussed in paragraph 6.19.2, above, are not clearly similar, and in the absence of a more rational analysis, a conservative analysis based on the results of the steady heading sideslip tests may be used to establish the safe crosswind component. The crosswind value may be estimated from:

$$V_{CW} = V_{REF} \times \sin(\text{sideslip angle}) / 1.5$$

where:

V_{CW} is the crosswind component,
V_{REF} is the landing reference speed appropriate to a minimum landing weight, and
sideslip angle is that demonstrated at V_{REF} (see paragraph 6.15 of this AMC).

6.20 *Vibration and Buffeting (CS 25.251).*

6.20.1 Qualitative evaluations should be combined with the other testing, including speeds up to the maximum speed obtained in the longitudinal stability tests (see paragraph 6.14 of this AMC).

6.20.2 It is also necessary to demonstrate that the aeroplane is free from harmful vibration due to residual ice accumulation. This may be done in conjunction with the natural icing tests.

6.20.3 An aeroplane with pneumatic de-icing boots should be evaluated to V_{DF}/M_{DF} with the de-icing boots operating and not operating. It is not necessary to do this demonstration with ice accretion.

6.21 *Natural Icing Conditions.*

6.21.1 *General.*

6.21.1.1 Whether the flight testing has been performed with artificial ice shapes or in natural icing conditions, additional limited flight testing described in this section should be conducted in natural icing conditions. Where flight testing with artificial ice shapes is the primary means for showing compliance, the objective of the tests described in this section is to corroborate the handling characteristics and performance results obtained in flight testing with artificial ice shapes.

6.21.1.2 It is acceptable for some ice to be shed during the testing due to air loads or wing flexure, etc. However, an attempt should be made to accomplish the test manoeuvres as soon as possible after exiting the icing cloud to minimise the atmospheric influences on ice shedding.

6.21.1.3 During any of the manoeuvres specified in paragraph 6.21.2, below, the behaviour of the aeroplane should be consistent with that obtained with artificial ice shapes. There should be no unusual control responses or uncommanded aeroplane motions. Additionally, during the level turns and bank-to-bank rolls, there should be no buffeting or stall warning.

6.21.2 *Ice Accretion/Manoeuvres*.

6.21.2.1 *Holding scenario.*

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

i. *On unprotected Parts*: A thickness of 8 cm (3 inches) on those parts of the aerofoil where the collection efficiency is highest should be the objective. (A thickness of 5 cm (2 inches) is normally a minimum value, unless a lesser value is agreed by the Authority.)

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

b. For aeroplanes with control surfaces that may be susceptible to jamming due to ice accretion (e.g. elevator horns exposed to the air flow), the holding speed that is critical with respect to this ice accretion should be used.

TABLE 3: Holding Scenario - Manoeuvres

Configuration	*c.g.*	*Trim speed*	*Manoeuvre*
Flaps up, gear up	Optional (aft range)	Holding	• Level, 40° banked turn, • Bank-to-bank rapid roll, 30° - 30°, • Speedbrake extension, retraction, • Full straight stall.
Flaps in intermediate positions, gear up	Optional (aft range)	1.3 V_{SR}	Deceleration to stall warning.

Landing flaps, gear down	Optional (aft range)	V_{REF}	• Level, 40° banked turn, • Bank-to-bank rapid roll, 30° - 30°, • Speedbrake extension, retraction (if approved), • Full straight stall.

6.21.2.2 *Approach/Landing Scenario.* The manoeuvres specified in Table 4, below, should be carried out with successive accretions in different configurations on unprotected surfaces. Each test condition should be accomplished with the ice accretion that exists at that point. The final ice accretion (Test Condition 3) represents the sum of the amounts that would accrete during a normal descent from holding to landing in icing conditions.

TABLE 4: Approach/Landing Scenario - Manoeuvres

Test Condition	*Ice accretion thickness (*)*	*Configuration*	*c.g.*	*Trim speed*	*Manoeuvre*
–	First 13 mm (0.5 in.)	Flaps up, gear up	Optional (aft range)	Holding	No specific test
1	Additional 6.3 mm (0.25 in.) (19 mm (0.75 in.) total)	First intermediate flaps, gear up	Optional (aft range)	Holding	• Level 40° banked turn, • Bank-to-bank rapid roll, 30°- 30°, • Speed brake extension and retraction (if approved), • Deceleration to stall warning.
2	Additional 6.3 mm (0.25 in.) (25 mm (1.00 in.) total)	Further intermediate flaps, gear up (as applicable)	Optional (aft range)	1.3 V_{SR}	• Bank-to-bank rapid roll, 30° - 30°, • Speed brake extension and retraction (if approved), • Deceleration to stall warning.
3	Additional 6.3 mm (0.25 in.) (31 mm (1.25 in.) total)	Landing flaps, gear down	Optional (aft range)	V_{REF}	• Bank-to-bank rapid roll, 30° - 30°, • Speed brake extension and retraction (if approved), • Bank to 40°, • Full straight stall.

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

6.21.3 For aeroplanes with unpowered elevator controls, in the absence of an agreed substantiation of the criticality of the artificial ice shape used to demonstrate compliance with the controllability requirement, the pushover test of paragraph 6.9.3 should be repeated with a thin accretion of natural ice.

6.21.4 Existing propeller speed limits or, if required, revised propeller speed limits for flight in icing, should be verified by flight tests in natural icing conditions.

6.22 *Failure Conditions (CS 25.1309).*

6.22.1 For failure conditions which are annunciated to the flight crew, credit may be taken for the established operating procedures following the failure.

6.22.2 *Acceptable Test Programme*. In addition to a general qualitative evaluation, the following test programme (modified as necessary to reflect the specific operating procedures) should be carried out for the most critical probable failure condition where the associated procedure requires the aeroplane to exit the icing condition:

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

i. On the unprotected surfaces - the “Holding ice” accretion described in paragraph A1.2.1 of this AMC;

ii. On the normally protected surfaces that are no longer protected - the “Failure ice” accretion described in paragraph A1.3.2 of this AC; and

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

b. Medium to light weight, aft centre of gravity position, symmetric fuel loading.

c. In the configurations listed below, trim the aeroplane at the specified speed. Conduct 30° banked turns left and right with normal reversals. Conduct pull up to 1.5g and pushover to 0.5g.

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

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

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

d. In the configurations listed below, trim the aeroplane at estimated 1.3 V_{SR}. Decrease speed to stall warning plus 1 second, and demonstrate prompt recovery using the same test technique as for the non-contaminated aeroplane. Natural stall warning is acceptable for the failure case.

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

ii. Landing configuration: Straight/Power Off.

e. Conduct an approach and go-around with all engines operating using the recommended procedure.

f. Conduct an approach and landing with all engines operating (unless the one-engine-inoperative condition results in a more critical probable failure condition) using the recommended procedure.

6.22.3 For improbable failure conditions, flight test may be required to demonstrate that the effect on safety of flight (as measured by degradation in flight characteristics) is commensurate with the failure probability or to verify the results of analyses and/or wind tunnel tests. The extent of any required flight test should be similar to that described in paragraph 6.22.2, above, or as agreed with the Authority for the specific failure condition.

Appendix 1 - Airframe Ice Accretion

A1.1 *General.*

The most critical ice accretion in terms of handling characteristics and/or performance for each flight phase should be determined. The parameters to be considered include:

- the flight conditions (e.g. aeroplane configuration, speed, angle of attack, altitude) and

- the icing conditions of Appendix C to CS-25 (e.g. temperature, liquid water content, mean effective drop diameter).

A1.2 *Operative Ice Protection System.*

A1.2.1 *All flight phases except take-off.*

A1.2.1.1 For unprotected parts, the ice accretion to be considered should be determined in accordance with CS 25.1419.

A1.2.1.2 Unprotected parts consist of the unprotected aerofoil leading edges and all unprotected airframe parts on which ice may accrete. The effect of ice accretion on protuberances such as antennae or flap hinge fairings need not normally be investigated. However aeroplanes that are characterised by unusual unprotected airframe protuberances, e.g. fixed landing gear, large engine pylons, or exposed control surface horns or winglets, etc., may experience significant additional effects, which should therefore be taken into consideration.

A1.2.1.3 For "Holding Ice," certification experience has shown that the amount of ice on the most critical unprotected main aerofoil surface (e.g. wing, horizontal or vertical stabilisers) to be considered need not exceed a pinnacle height of typically 8 cm (3 inches) in a plane in the direction of flight. For other unprotected main surfaces an analysis may be performed to determine the maximum ice accretion associated with this maximum pinnacle height. In the absence of such an acceptable analysis a uniform pinnacle height of 8 cm (3 inches) should be assumed. The shape and texture of the ice are important and should be agreed with the Authority.

A1.2.1.4 For protected parts, the ice protection systems are normally assumed to be operative. However, the applicant should consider the effect of ice accretion on the protected surfaces that results from:

a. The rest time of a de-icing cycle. Performance may be established on the basis of a representative intercycle ice accretion for normal operation of the de-icing system (consideration should also be given to the effects of any residual ice accretion that is not shed.) The average drag increment determined over the de-icing cycle may be used for performance calculations.

b. Runback ice which occurs on or downstream of the protected surface.

c. Ice accretion prior to normal operation of the ice protection system (see paragraph A1.2.3, below).

A1.2.2 *Take-off phase.*

A1.2.2.1 For both unprotected and protected parts, the ice accretion identified in Appendix C to CS-25 for the take-off phase may be determined by calculation, assuming that the Takeoff Maximum icing conditions defined in Appendix C exist, and:

- aerofoils, control surfaces and, if applicable, propellers are free from frost, snow, or ice at the start of the take-off;
- the ice accretion starts at lift-off;
- the critical ratio of thrust/power-to-weight;
- failure of the critical engine occurs at V_{EF}; and
- flight crew activation of the ice protection system in accordance with an AFM procedure, except that after commencement of the take-off roll no flight crew action to activate the ice protection system should be assumed to occur until the aeroplane is 122 m (400 ft) above the take-off surface.

A1.2.2.2 The ice accretions identified in Appendix C to CS-25 for the take-off phase are:

- "Take-off ice": The most critical ice accretion between lift-off and 122 m (400 ft) above the takeoff surface, assuming accretion starts at lift-off in the icing environment.
- "Final Take-off ice": The most critical ice accretion between 122 m (400 ft) and 457 m (1500 ft) above the take-off surface, assuming accretion starts at lift-off in the icing environment.

A1.2.3 *Ice accretion prior to normal system operation.*

A1.2.3.1 Ice protection systems are normally operated as anti-icing systems (i.e. designed to prevent ice accretion on the protected surface) or de-icing systems (i.e. designed to remove ice from the protected surface). In some cases, systems may be operated as anti-icing or de-icing systems depending on the phase of flight. Operation of ice protection systems can also include a resetting of stall warning and/or stall identification system (e.g. stick pusher) activation thresholds.

A1.2.3.2 The aeroplane Flight Manual contains the operating limitations and operating procedures established by the applicant. Since ice protection systems are normally only operated when icing conditions are encountered or when airframe ice is detected, means of flight crew determination of icing conditions and/or airframe ice should be considered in determining the ice accretion prior to normal system operation. This includes the ice accretion appropriate to the specified means of identification of icing conditions and an additional ice accretion, represented by a time in the Continuous Maximum icing conditions of Appendix C. This additional ice accretion is to account for flight crew delay in either identifying the conditions and activating the ice protection systems (see paragraphs A1.2.3.3(a), (b) and (c) below), or activating the ice protection system following indication from an ice detection system (see paragraph A1.2.3.3 (d) below). In addition the system response time should be considered. System response time is defined as the time interval between activation of the ice protection system and the performance of its intended function (e.g. for a thermal ice protection system, the time to heat the surface and remove the ice).

A1.2.3.3 The following examples indicate the ice accretion to be considered on the unprotected and normally protected aerodynamic surfaces:

a. If activation of normal operation of any ice protection system is dependent on visual recognition of a specified ice accretion on a reference surface (e.g. ice accretion probe, wing leading edge), the ice accretion should not be less than that corresponding to the ice accretion on the reference surface taking into account probable flight crew delays in recognition of the specified ice accretion and operation of the system, determined as follows:

i. the specified accretion, plus

ii. the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part I(a), plus

iii. the ice accretion during the system response time.

b. If activation of normal operation of any ice protection system is dependent on visual recognition of the first indication of ice accretion on a reference surface (e.g. ice accretion probe), the ice accretion should not be less than that corresponding to the ice accretion on the reference surface taking into account probable flight crew delays in recognition of the ice accreted and operation of the system, determined as follows:

i. the ice accretion corresponding to first indication on the reference surface, plus

ii. the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part I(a), plus

iii. the ice accretion during the system response time.

c. If activation of normal operation of any ice protection system is dependent upon pilot identification of icing conditions (as defined by an appropriate static or total air temperature and visible moisture conditions), the ice accretion should not be less than that corresponding to the ice accreted during probable crew delays in recognition of icing conditions and operation of the system, determined as follows:

i. the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part I(a), plus

ii. the ice accretion during the system response time.

d. If activation of normal operation of any ice protection system is dependent on pilot action following indication from an ice detection system, the ice accretion should not be less than that corresponding to the ice accreted prior to indication from the ice detection system, plus that accreted due to probable flight crew delays in activating the ice protection system and operation of the system, determined as follows:

i. the ice accretion corresponding to the time between entry into the icing conditions and indication from the ice detection system, plus

ii. the ice accretion equivalent to ten seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part I(a), plus

iii. the ice accretion during the system response time.

e. If activation of normal operation of any ice protection system is automatic following indication from an ice detection system, the ice accretion should not be less than that corresponding to the ice accreted prior to indication from the ice protection system and operation of the system, determined as follows:

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

ii. the ice accretion during the system response time.

A1.3 *Ice Protection System Failure Cases.*

A1.3.1 *Unprotected parts.* The same accretion as in paragraph A1.2.1 is applicable.

A1.3.2 *Protected parts following system failure*. "Failure Ice" is defined as follows:

A1.3.2.1 In the case where the failure condition is not annunciated, the ice accretion on normally protected parts where the ice protection system has failed should be the same as the accretion specified for unprotected parts.

A1.3.2.2 In the case where the failure condition is annunciated and the associated procedure does not require the aeroplane to exit icing conditions, the ice accretion on normally protected parts where the ice protection system has failed should be the same as the accretion specified for unprotected parts.

A1.3.2.3 In the case where the failure condition is annunciated and the associated procedure requires the aeroplane to exit icing conditions as soon as possible, the ice accretion on normally protected parts where the ice protection has failed, should be taken as one-half of the accretion specified for unprotected parts unless another value is agreed by the Authority.

Appendix 2 - Artificial Ice Shapes

A2.1 *General.*

A2.1.1 The artificial ice shapes used for flight testing should be those which have the most adverse effects on handling characteristics. If analytical data show that other reasonably expected ice shapes could be generated which could produce higher performance decrements, then the ice shape having the most adverse effect on handling characteristics may be used for performance tests provided that any difference in performance can be conservatively taken into account.

A2.1.2 The artificial shapes should be representative of natural icing conditions in terms of location, general shape, thickness and texture. Following determination of the form and surface texture of the ice shape under paragraph A2.2, a surface roughness for the shape should be agreed with the Authority as being representative of natural ice accretion.

A2.1.3 "Sandpaper Ice" is addressed in paragraph A2.3.

A2.2 *Shape and Texture of Artificial Ice.*

A2.2.1 The shape and texture of the artificial ice should be established and substantiated by agreed methods. Common practices include:

- use of computer codes,
- flight in measured natural icing conditions,
- icing wind tunnel tests, and
- flight in a controlled simulated icing cloud (e.g. from an icing tanker).

A2.2.2 In the absence of another agreed definition of texture the following may be used:

A2.2.2.1 For small amounts of ice (for example the amount of ice accreted during a de-icing system rest time), the roughness should be typically:

- roughness height: 1 mm
- particle density: 8 to 10/cm^2

A2.2.2.2 For large amounts of ice (for example on an unprotected, exposed surface), the roughness should be typically:

- roughness height: 3 mm
- particle density: 8 to 10/cm^2

A2.3 *"Sandpaper Ice."*

A2.3.1 "Sandpaper Ice" is the most critical thin, rough layer of ice. Any representation of "Sandpaper Ice" (e.g. carborundum paper no. 40) should be agreed by the Authority.

A2.3.2 The spanwise and chordwise coverage should be consistent with the areas of ice accretion determined for the conditions of CS-25, Appendix C except that, for the zero g pushover manoeuvre of paragraph 6.9.3 of this AMC, the "Sandpaper Ice" may be restricted to the horizontal stabiliser if this can be shown to be conservative.

Appendix 3 - Design Features

A3.1 *Aeroplane Configuration and Ancestry* . An important design feature of an overall aeroplane configuration that can affect performance, controllability and manoeuvrability is its size. In addition, the safety record of the aeroplane's closely-related ancestors may be taken into consideration.

A3.1.1 *Size.* The size of an aeroplane determines the sensitivity of its flight characteristics to ice thickness and roughness. The relative effect of a given ice height (or ice roughness height) decreases as aeroplane size increases.

A3.1.2 *Ancestors.* If a closely related ancestor aeroplane was certified for flight in icing conditions, its safety record may be used to evaluate its general arrangement and systems integration.

A3.2 *Wing*. Design features of a wing that can affect performance, controllability, and manoeuvrability include aerofoil type, leading edge devices and stall protection devices.

A3.2.1 *Aerofoil.* Aerofoils with significant natural laminar flow when non-contaminated may show large changes in lift and drag with ice. Conventional aerofoils operating at high Reynolds numbers make the transition to turbulent flow near the leading edge when non-contaminated, thus reducing the adverse effects of the ice.

A3.2.2 *Leading Edge Device.* The presence of a leading edge device (such as a slat) reduces the percentage decrease in C_{LMAX} due to ice by increasing the overall level of C_L. Gapping the slat may improve the situation further. Leading edge devices can also reduce the loss in angle of attack at stall due to ice.

A3.2.3 *Stall Protection Device.* An aeroplane with an automatic slat-gapping device may generate a greater C_{LMAX} with ice than the certified C_{LMAX} with the slat sealed and a non-contaminated leading edge. This may provide effective protection against degradation in stall performance or characteristics.

A3.2.4 *Lateral Control.* The effectiveness of the lateral control system in icing conditions can be evaluated by comparison with closely related ancestor aeroplanes.

A3.3 *Empennage*. The effects of size and aerofoil type also apply to the horizontal and vertical tails. Other design features include tailplane sizing philosophy, aerofoil design, trimmable stabiliser, and control surface actuation. Since tails are usually not equipped with leading edge devices, the effects of ice on tail aerodynamics are similar to those on a wing with no leading edge devices. However, these effects usually result in changes to aeroplane handling and/or control characteristics rather than degraded performance.

A3.3.1 *Tail Sizing.* The effect on aeroplane handling characteristics depends on the tailplane design philosophy. The tailplane may be designed and sized to provide full functionality in icing conditions without ice protection, or it may be designed with a de-icing or anti-icing system.

A3.3.2 *Horizontal Stabiliser Design.* Cambered aerofoils and trimmable stabilisers may reduce the susceptibility and consequences of elevator hinge moment reversal due to ice-induced tailplane stall.

A3.3.3 *Control Surface Actuation.* Hydraulically powered irreversible elevator controls are not affected by ice-induced aerodynamic hinge moment reversal.

A3.3.4 *Control Surface Size.* For mechanical elevator controls, the size of the surface significantly affects the control force due to an ice-induced aerodynamic hinge moment reversal. Small surfaces are less susceptible to control difficulties for given hinge moment coefficients.

A3.3.5 *Vertical Stabiliser Design.* The effectiveness of the vertical stabiliser in icing conditions can be evaluated by comparison with closely-related ancestor aeroplanes.

A3.4 *Aerodynamic Balancing of Flight Control Surfaces.* The aerodynamic balance of unpowered or boosted reversible flight control surfaces is an important design feature to consider. The design should be carefully evaluated to account for the effects of ice accretion on flight control system hinge moment characteristics. Closely balanced controls may be vulnerable to overbalance in icing. The effect of ice in front of the control surface, or on the surface, may upset the balance of hinge moments leading to either increased positive force gradients or negative force gradients.

A3.4.1 This feature is particularly important with respect to lateral flight control systems when large aileron hinge moments are balanced by equally large hinge moments on the opposite aileron. Any asymmetric disturbance in flow which affects this critical balance can lead to a sudden uncommanded deflection of the control. This auto deflection, in extreme cases, may be to the control stops.

A3.5 *Ice Protection/Detection System*. The ice protection/detection system design philosophy may include design features that reduce the ice accretion on the wing and/or tailplane.

A3.5.1 *Wing Ice Protection/Detection.* An ice detection system that activates a wing de-icing system may ensure that there is no significant ice accretion on wings that are susceptible to performance losses with small amounts of ice.

A3.5.1.1 If the entire wing leading edge is not protected, the part that is protected may be selected to provide good handling characteristics at stall, with an acceptable performance degradation.

A3.5.2 *Tail Ice Protection/Detection.* An ice detection system may activate a tailplane de-icing system on aeroplanes that do not have visible cues for system operation.

A3.5.2.1 An ice protection system on the unshielded aerodynamic balances of aeroplanes with unpowered reversible controls can reduce the risk of ice-induced aerodynamic hinge moment reversal."

C. ORIGINAL JAA NPA 25BEF-332 PROPOSALS JUSTIFICATION

1. Summary

This NPA, proposing new and revised requirements for JAR-25, details the minimum aeroplane performance and handling qualities necessary for certification for flight in the icing conditions of JAR-25 Appendix C. It also introduces new material into JAR-25 Appendix C to enable appropriate ice accretions to be defined for these revised requirements. It is based upon a report prepared by the Flight Test Harmonisation Working Group (FTHWG), a group of European and North American airworthiness authorities' and industry flight specialists, and pilot representatives working to harmonise subpart B of JAR-25, FAR 25 and Transport Canada's Part 525.

As an element of the Harmonisation Work Programme, the FTHWG reported to the JAA Flight Study Group (FSG) and to the Transport Aeroplane and Engine Issues Group (TAEIG). The FSG, in turn, reported to the JAA Regulation Director, working with the JAA Regulation Sectorial Team composed of representatives from the authorities and industry. The TAEIG is empowered by and reports to the Aviation Rulemaking Advisory Committee (ARAC), a standing committee established by the FAA in February 1991 that consists of representatives from aviation associations and industry to provide industry input in the form of information, advice, and recommendations to be considered in the full range of FAA rule-making activities.

It is proposed to amend JAR-25 to introduce new requirements to evaluate aeroplane performance and handling characteristics in the icing conditions of Appendix C to JAR-25 and to revise, in part, the requirements related to ice protection systems. Harmonised advisory material providing guidance on compliance with these requirements has also been developed. Several of the proposed requirements were the subject of considerable debate within the FTHWG. Consensus was eventually reached on the majority of these requirements, but the draft proposals submitted with the FTHWG report contained four issues on which consensus was not reached. These issues are identified in the proposals and the text presented represents the JAA position. However, all proposals for these issues are presented at the end of paragraph 3, together with accompanying justifications and dispositions.

2. Background

The FAA, JAA and Transport Canada had various documents addressing performance and handling characteristics in icing conditions. These documents have been amended over the years to record policies and/or advisory material developed as a result of information acquired from research, and incidents and accidents that have occurred in icing conditions; for the most part each airworthiness authority developed this material independently.

The JAA took a major step in developing a comprehensive set of criteria for certificating transport category aeroplanes for flight in icing conditions with the publication of NPA 25F-219 Issue 2 in 1992; NPA 25F-219 presented draft Advisory Material Joint (AMJ) 25.1419, "Flight in Icing Conditions - Acceptable Handling Characteristics and Performance Effects."

To develop this material, the JAA Flight Study Group had established an Icing Sub-Group, comprising Flight and Systems specialists from the European airworthiness authorities and industry. The Icing Sub-Group's initial task was to consider tailplane stall/elevator over-balance and a pushover manoeuvre to zero "g" was developed to evaluate an aeroplane's susceptibility to this phenomenon. A further task was to develop policy on aeroplane performance and handling qualities criteria for flight in icing conditions, based on the identification of existing practices and a review of the clear air flight test requirements. The intention was to formalise and harmonise the various European practices and this aim was made more urgent by the advent of JAA joint certifications.

At this stage the French DGAC prepared Special Conditions for the type certification of a turboprop aeroplane based on the early work of the Sub-Group, Transport Canada Advisory Material and its own experience. With modifications to accommodate wider application, these Special Conditions subsequently formed the basis for the further work of the Sub-Group, resulting in the development of NPA 25F-219.

NPA 25F-219 Issue 2 was published for subscribers' comments on 23 April 1993. During its development, the NPA had been used in many certifications and it was also formally adopted for certification as JAA Interim Policy INT/POL/25/10, pending formal acceptance for JAR-25. This was later re-classified as Temporary Guidance Material TGM/25/02, following the introduction by the JAA of this latter category.

Concurrently, the FAA was proposing revisions to Advisory Circular (AC) 25-7 "Flight Test Guide for Certification of Transport Category Airplanes" which included new material addressing flight characteristics in icing conditions. Similar to the JAA's effort with NPA 25F-219, this was the FAA's first attempt to publish guidance dedicated to the evaluation of transport category aeroplane performance and handling characteristics in icing conditions. Following discussion of NPA 25F-219 and the proposed AC 25-7 material in the JAA Flight Study Group (FSG), the subject was raised in 1994 as a FAA/JAA harmonisation item and the Flight Test Harmonisation Working Group was tasked with reviewing NPA 25F-219 and the comments received during the public consultation.

Currently, there are no specific performance and handling requirements to address flight in icing conditions. The key was previously JAR/FAR 25.1419 which requires the ability "to safely operate" in these conditions. Hence, as a first step, it is proposed to harmonise on the introductory wording of current JAR 25.1419, which, unlike current FAR 25.1419, relates the need to demonstrate the ability of an aeroplane to safely operate in the icing conditions of Appendix C to the applicant's desire to have the aeroplane certificated for flight in icing conditions (See Proposal 15).

However, it is now proposed to define a set of JAR-25 subpart B aeroplane performance and handling characteristics standards that must be met by transport category aeroplanes with the ice accretion appropriate to the phase of flight being investigated; compliance with these requirements, to be specified in JAR 25.21, "Compliance," will demonstrate the ability of an aeroplane to safely operate in the icing conditions of Appendix C. In addition, it is proposed to amend Appendix C of JAR-25 to define the ice shapes appropriate to each phase of flight.

As a preface to the following discussions of the individual proposals, it is important to understand the underlying philosophy that was employed in the development of the performance and handling qualities criteria. The requirements that follow were primarily determined by a detailed review of the existing JAR/FAR 25 subpart B requirements with consideration given to those aspects deemed significant for flight in icing conditions such that they should be re-investigated with ice accretions on the aeroplane. This determination was based on a review of incidents and accidents attributed to ice accretion and engineering judgement of what flight aspects are critical for all aeroplanes.

The review of incidents and accidents revealed that, though icing-related performance shortfalls had been the cause of several incidents, due to the negative effects on maximum lift and drag that are inherent with ice accretion, the icing-related accidents resulted from a loss of control that could be attributed to degraded handling characteristics due to ice accretion. Consequently, the FTHWG focused on developing a somewhat reduced matrix of subpart B handling characteristics (i.e. stability, controllability and manoeuvrability, stall characteristics, and high speed flight characteristics) with which compliance would have to be shown for the aeroplane with ice accretions. Where it was recognised that special circumstances existed for icing conditions that would make a particular handling characteristics regulation not completely appropriate, alternate criteria were developed for icing conditions.

With regard to performance, the FTHWG report adopts a modified version of the concept utilised by the JAA that permits some tolerance on performance (of the aeroplane without ice accretion) before requiring that performance be recomputed specifically for operation in icing conditions. The FTHWG considers this performance tolerance approach to be acceptable not only on the basis of service history, but also by introducing certain safeguards into the proposed requirements for the aeroplane with ice accretions. This approach is discussed in more detail in relation to Proposal 3.

The proposals make reference to the “ice accretion” to be used in showing compliance. These ice accretions are defined in a new subsection of Appendix C. It should also be noted that the FTHWG discarded the term “ice shape” in favour of “ice accretion,” a term that better describes the formation process and includes the physical characteristics of the ice such as texture and surface roughness particle height in addition to the shape. In adopting this terminology, the FTHWG recognises that the widely used descriptor “ice accumulations” would have served the same purpose.

3. Discussion of the Proposals

Simple editorial changes, such as re-numbering arising from the addition of new sub-paragraphs, are not discussed in the following sections.

Proposal 1 - JAR 25.21 Proof of compliance

Proposed Revision:

It is proposed to revise this paragraph to add sub-paragraph (g), which would specify the requirements that must be met in icing conditions if an applicant elects to seek certification for flight in icing. A review of icing-related incidents and accidents revealed loss of control to be the greatest threat to safety of flight in icing conditions. Consequently, the FTHWG identified the subpart B requirements that could prevent loss of control from occurring if complied with for icing conditions. The result was that, with the few exceptions listed in sub-paragraph (g)(1), compliance with most of subpart B was deemed relevant to ensuring safe flight in icing conditions. The regulations that are exempted by sub-paragraph (g)(1) were determined to be beyond what was necessary to determine an aeroplane’s ability to be safely operated in icing conditions.

Reason for Revision:

JAR 25.21(g)(1) - The objective of the proposed requirements of sub-paragraph (g)(1) is to have essentially no degradation in handling qualities when operating in icing conditions (or after operating in icing conditions with residual ice remaining) and with the ice protection systems operating normally. Sub-paragraph (g)(1) also requires compliance with the bulk of the subpart B performance requirements, though as noted in the introductory discussion, some tolerance is permitted when showing compliance with the requirements for non-icing conditions; these tolerances are stated in the individual performance regulations. Furthermore, Appendix C to JAR-25 defines the icing conditions in which compliance must be shown with the proposed requirements.

JAR 25.21(g)(2) - Proposed sub-paragraph (g)(2) would ensure that aeroplanes will have adequate handling characteristics in the period between the aeroplane entering icing conditions and the ice protection system performing its intended function. During this period, ice will accrete on both the unprotected and normally protected surfaces; this ice accretion may have a detrimental effect on aeroplane handling characteristics due to its insidious nature and expanse of coverage. An ice accretion definition is proposed to be added to Appendix C of JAR-25. Additionally, it is proposed that advisory material would provide guidance for further defining this accretion based on the means of detection.

JAR 25.21(g)(3) - Proposed sub-paragraph (g)(3) would prevent the use of different load, weight, and centre-of-gravity limits for flight in icing. The basis of these proposed requirements is that operation in icing conditions should be essentially transparent to the flight crew in that no icing-specific methods of operation (other than activating ice protection systems) should be required. This philosophy is also based on human factors issues to reduce operational complexity and flight crew workload.

Alternatives Considered:

The FTHWG discussed incorporating material related to testing in supercooled large droplet (SLD) icing environments. The group generally felt that such action would be premature, because the IPHWG was tasked with reviewing available data and redefining, if necessary, the icing atmosphere for aeroplane certification. An important element of proposed JAR 25.21(g)(1) is the closing text, which states that the aeroplane is to be operated in accordance with operating limitations and operating procedures contained in the aeroplane Flight Manual (AFM). Besides prescribing the operating conditions, this sub-paragraph also provides an avenue to include in the AFM the limitations and operating procedures that are specific to operating in icing conditions.

Proposal 2 - JAR 25.103 Stalling speed

Proposed Revision:

It is proposed to revise JAR 25.103 to include considerations for icing conditions. The proposed requirements for icing conditions would require applicants to determine stall speeds with ice for each aeroplane configuration. This is conveyed in sub-paragraph JAR 25.103(b)(3), which adds ice accretion as a configuration variable related to the performance standard for which it will be used.

Reason for Revision:

The determination of stall speeds with ice accretions is necessary to quantify any increase relative to stall speeds for non-icing conditions in each flap/gear configuration. This change in stall speed due to ice accretion is then compared with the allowable stall and operating speed tolerances in later subpart B performance standards to determine whether or not the AFM performance for a particular flight phase needs to be recalculated for icing conditions.

Proposal 3 - JAR 25.105 Take-off

Proposed Revision:

It is proposed to revise JAR 25.105(a) to add a requirement that take-off performance be considered for flight in the icing conditions of Appendix C to JAR-25. Specifically, the text of sub-paragraph (a) would be revised:

- To add that the net take-off flight path described in JAR 25.115 must also be determined in the selected configuration for take-off; and

- To specify the conditions under which the identified take-off performance must be determined for operation in icing conditions and the ice accretion to be used in making that determination.

The revised text also would refer to other paragraphs that this NPA proposes to revise.

Reason for Revision:

The proposed changes to sub-paragraph (a) would specify the conditions under which take-off performance must be determined for icing conditions and the specific ice accretion of proposed Appendix C, part II, of JAR-25 to be used in making that determination.

The proposed changes are necessary to ensure the safety of take-off operations in icing conditions. The formation of ice accretions can degrade the aerodynamic characteristics of wings and control surfaces resulting in reduced margins to stall, degraded climb performance, and controllability problems. In developing the proposals of this NPA, the FTHWG acknowledged that many transport category aeroplanes have safely operated in icing conditions using take-off speeds determined for an aeroplane with no ice contamination. However, the FTHWG believes it is in the interest of safety to:

1. investigate the effects of ice accretion on take-off performance, and

2. to establish limits on those effects.

Accordingly, the proposed amendment to JAR 25.105(a) establishes limits on the increase in the stall reference speed (V_{SR}) and degradation in second segment (i.e. take-off flap/gear retracted) climb gradient beyond which take-off performance must be recomputed to take into account the effects of ice accretion. (Note: Detailed discussion of the origins of these limits is provided in the following "Alternatives Considered" paragraph.) Since JAR 25.105 references all regulations related to the take-off path, the performance for the entire take-off path must be determined specifically for icing conditions if the aforementioned stall speed or climb performance degradation limits are exceeded.

An important part of determining the effects of ice accretion on take-off performance is establishing at what point in the take-off the ice accretion process begins. In making this determination for the proposed regulatory amendments, the FTHWG took into consideration the regulations that govern the operation of transport category aeroplanes. Existing operating rules prohibit flight crews from conducting take-offs in aeroplanes with frost, snow, or ice adhering to certain aeroplane surfaces, or when the take-off would not be in compliance with an approved ground de-icing/anti-icing program. To comply with those requirements, operators have developed ground de-icing/anti-icing programs that require the use of de-icing and anti-icing fluids in accordance with established holdover times to ensure that aeroplanes are clear of ice and snow at the beginning of take-off. In cases where snow and ice have accumulated on an aeroplane, de-icing fluids will be applied to remove those contaminants. In conditions conducive to icing where precipitation is falling, anti-icing fluids will be applied. These anti-icing fluids are formulated so they will not depart the aeroplane surfaces until an airspeed of 167 km/h to 204 km/h is reached, which is well into the take-off ground roll phase for transport category aeroplanes. Based on this means of compliance with the referenced operating requirements, the proposed requirements of this NPA assume that ice accretion begins at lift-off.

Alternatives Considered:

In developing this harmonised proposal, the FTHWG considered the provisions contained in the JAA's NPA 25F-219. The JAA acknowledged the fact that transport category aeroplane service history shows some tolerance to the effects of ice on aeroplane performance. Consequently, the JAA's NPA 25F-219 permits the stall speed to increase by the greater of 9.3 km/h CAS or 5% of the 1g stall speed (V_{SR}) before take-off path performance has to be recalculated using the stall speeds determined for the aeroplane with ice accretions. (The JAA already has applied the provisions of the NPA to numerous certification projects.) Several commenters to the JAA's NPA expressed concern with the size of this allowable increase in stall speed, noting the considerable reductions in manoeuvre capability and stall margin, particularly for the take-off climb with landing gear retracted (commonly referred to as "second segment climb").

The proposals of this NPA would retain the tolerance philosophy of NPA 25F-219, but would introduce a smaller and more operationally viable stall speed tolerance. The proposal would require applicants to determine take-off path performance specifically for icing conditions if the increase in the 1g stall speeds, relative to the values determined with no ice accretion, are the greater of 5.6 km/h CAS or 3% V_{SR} with the "Take-off Ice" accretion defined in proposed part II of Appendix C to JAR-25 (discussed further below).

In addition to the 9.3 km/h/5% V_{SR} tolerance on 1g stall speeds, the JAA's NPA 25F-219 also allows a 5% increase in drag due to ice accretion before take-off performance has to be recomputed specifically for operation in icing conditions.

Climb performance is expressed in terms of a climb gradient for a given weight, altitude, and temperature (WAT) condition. The climb gradient for any WAT condition is a function of thrust, lift, and drag, all of which are dependent on airspeed. Therefore, the FTHWG recommended that it would be more appropriate to express the acceptable tolerance on climb performance in terms of climb gradient reduction due to ice, which would take into account all relevant operating parameters, rather than just the effect of ice on the drag component alone. The AFM take-off climb performance is presented in terms of "net" climb gradient, which is computed as the actual climb gradient reduced by specific values prescribed in JAR 25.115(b). Since operational take-off performance determinations base obstacle clearance on the "net" take-off flight path, the actual take-off flight path will have increasing obstacle clearance as the distance from the starting point of the take-off flight path increases. Airworthiness authorities have, on occasion, permitted applicants to use up to half of this gradient reduction to account for variables that affect performance. The FTHWG recommended that half of the take-off climb gradient reduction would be an appropriate tolerance on take-off performance with ice. If the effect of ice exceeds one-half of this gradient reduction, the take-off flight path performance must be recomputed specifically for icing. The allowable climb gradient reduction method proposed in this NPA results in slightly more conservative criteria (i.e. less reduction in climb gradient) than the drag increment method of the JAA's NPA 25F-219 for determining when take-off path performance must be recalculated to reflect the effects of ice accretion.

Although the "Take-off Ice" accretion is defined as the most critical ice accretion from lift-off to 122 m above the take-off surface, its effects on stall reference speeds and climb performance generally make it a representative performance parameter for the entire take-off path (which ends at 457 m above the take-off surface). The take-off climb with landing gear retracted, which comprises the majority of the climb segment for "Take-off Ice" accretion, is generally the most limiting segment of the take-off path due to a much higher gradient requirement than for the landing gear extended climb segment. A review of existing certification data for aeroplanes that were certificated to the similar icing criteria of NPA 25F-219 showed that this segment of climb remains the most limiting when the effects of ice are taken into account. The proposed revision of JAR 25.105(a)(2), for determining when take-off performance must be calculated for icing conditions, refers to proposed JAR 25.121(b), which prescribes the configuration and conditions for the take-off climb with landing gear retracted (second segment). In addition to the "Take-off Ice" accretion being defined in the most limiting segment of the take-off path, some conservatism also results from the requirement of JAR 25.111(d)(3) and 25.121(b) for take-off path performance to be determined without ground effect.

Proposal 4 - JAR 25.107 Take-off speeds

Proposed Revision:

It is proposed to revise JAR 25.107(g) to change the reference for manoeuvre capability considerations from JAR 25.143(g) to JAR 25.143(h). This change results from the proposed addition of JAR 25.143(c), which prescribes controllability and manoeuvrability requirements for flight in icing conditions.

It is also proposed to revise JAR 25.107 by adding a new sub-paragraph (h). This new sub-paragraph would specify that the minimum control and minimum unstick speeds, determined as limits on take-off speeds for the aeroplane without ice, may be used as limits for determining take-off speeds for the aeroplane with ice accretions. Specifically, the proposal states that, when determining the take-off speeds V_1, V_R, and V_2 for flight in icing conditions, the values of V_{MCG}, V_{MC}, and V_{MU} determined for non-icing conditions may be used.

Reason for Revision:

The minimum unstick speed (V_{MU}) is defined in JAR 25.107(d) as the ". . . airspeed at and above which the aeroplane can safely lift off the ground and continue the take-off." It is used as a limitation on the lift-off speed, which, in turn, affects all other take-off speeds. Since one of the premises for applying the proposed take-off rules, established in the discussion of JAR 25.105, is that ice accretion does not begin until lift-off, use of V_{MU} speeds determined for non-icing conditions is justified for determining take-off speeds in icing conditions.

The ground minimum control speed (V_{MCG}) is applied as a minimum limit to the engine failure speed (V_{EF}) in JAR 25.107(a)(1), which, in turn, determines the speed V_1 (at which the pilot is either continuing the take-off or is initiating the first action to abort the take-off) to ensure adequate directional control for the continued take-off case should the critical engine fail during the acceleration run. Since V_{MU} is applied as a limit prior to lift-off, the use of V_{MCG} speeds determined for non-icing conditions is justified for determining take-off speeds for icing conditions.

The air minimum control speed (commonly referred to as V_{MCA}) is defined in JAR 25.149(b) as the airspeed at which it is possible to maintain control of the aeroplane, with no more than 5 degrees of bank, when the critical engine is suddenly made inoperative. Multiples of V_{MCA} are used in JAR 25.107 to define minimum limits for the rotation speed (V_R) and the take-off safety speed (V_2). Again, since V_R occurs before lift-off (lift-off being the point where ice accretion is assumed to begin), the use of the V_{MCA} determined for non-icing conditions is considered appropriate for determining limits on V_R for icing conditions.

The case for V_2 is different. In the event of an engine failure, the airborne portion of the take-off path from 11 m to 122 m above the take-off surface may be flown at V_2. It should be noted that V_2 is a function of several variables, including thrust-to-weight ratio and minimum limits on other take-off speeds. JAR 25.111(c)(4) limits aeroplane configuration changes during this segment to landing gear retraction and automatic propeller feathering. The impact of this limitation is that ice protection systems are typically not activated until the aeroplane is more than 122 m above the take-off surface, and sometimes considerably higher if close-in obstacle clearance is a concern. Another concern for the use of the V_{MCA} determined for non-icing conditions is that many aeroplanes do not have any ice protection on the vertical stabiliser, a situation that could lead to reduced directional control due to ice accretion in the take-off path that in turn could increase the air minimum control speed. To alleviate these concerns, the proposed JAR 25.143 would require applicants to show that aeroplanes are safely controllable and manoeuvrable at the minimum V_2 for take-off with the critical engine inoperative and with the “Take-off Ice” accretion. (See proposal 10 for further discussion on proposed revisions to JAR 25.143.)

Proposal 5 - JAR 25.111 Take-off path

Proposed Revision:

Currently, JAR 25.111 defines the take-off path and describes the applicable aeroplane configuration and performance. It is proposed to revise JAR 25.111 by adding a new sub-paragraph (c)(5) to specify that the definitions of ice accretion contained in proposed Appendix C to JAR-25 are to be used for determining the aeroplane’s drag during specified airborne segments of the take-off path.

It is also proposed to revise the structure of JAR 25.111(c)(4) to improve the order of the requirements. Additionally, the connective “and” would be moved from the end of sub-paragraph (c)(3) to the end of sub-paragraph (c)(4), indicating that the provisions of all five sub-paragraphs of (c) must be considered during the determination of the take-off path.

Reason for Revision:

JAR 25.111 defines the take-off path, including limitations on the climb performance that must be available, and the aeroplane configuration. The take-off path ends at 457 m above the take-off surface and typically incorporates two distinct climb segments: one up to 122 m and the other from 122 to 457 m above the take-off surface. The proposed changes to JAR 25.111 identify the ice accretion of proposed part II of Appendix C to JAR-25 that is appropriate to these two climb segments. The new sub-paragraph (c)(5) would be a conditional statement, relating back to the discriminating criteria of proposed JAR 25.105(a)(2) that determine whether or not take-off path performance must be recalculated for flight in icing conditions. The criteria contained in new sub-paragraph (c)(5) would be applicable only to the airborne portions of the take-off path, since it is assumed ice accretion does not begin until lift-off. Additionally, if take-off path performance is required to be determined for icing conditions (by use of the proposed criteria of JAR 25.105(a)(2)), then the take-off speeds contained in JAR 25.107 that are determined for icing conditions must be used for determining the aeroplane's drag with the ice accretion specified in sub-paragraph (c)(5) for the particular take-off path segment.

Proposal 6 - JAR 25.119 Landing climb: All-engines-operating

Proposed Revision:

It is proposed to revise JAR 25.119 by:

- Reformatting the introductory text that specifies the aeroplane configuration, power/thrust setting, and gradient requirements;
- Creating new sub-paragraphs (a) and (b) to require all-engines-operating landing climb performance to be determined for both non-icing conditions and icing conditions, respectively;
- Including a reference in sub-paragraphs (a) and (b) to the appropriate sub-paragraph of proposed revised JAR 25.125 for the landing climb speed applicable to the conditions;
- Including a reference in sub-paragraph (b) to the ice accretion of proposed Appendix C to JAR-25 that is to be used in calculating landing climb performance during icing conditions.

It is also proposed to harmonise JAR and FAR 25.119 to specify (in sub-paragraph (a)) that the landing climb speed be "V_{REF}" as opposed to the current JAR-25 wording which, with additional constraints arising from V_{MCL} and $1.08/1.13V_{SR}$, limits the climb speed to a narrow band up to, and including, V_{REF}. Current FAR 25 simply requires a climb speed not more than V_{REF}.

Reason for Revision:

The approach and landing phases of flight are likely to be the most affected by icing conditions due to the potential for descending into and holding in icing conditions prior to landing. This increased exposure is one of the reasons that it has been standard FAA certification practice to account for the effects of airframe ice accretion in approach and landing climb performance for the last 40 years. Consequently, there are no conditional performance parameters (i.e. increase in V_{SR0} or decrease in climb gradient due to ice) in the proposed changes to JAR 25.119. Landing climb performance in icing conditions is required to be determined for all transport category aeroplanes.

Proposal 7 - JAR 25.121 Climb: One-engine-inoperative

Proposed Revision:

It is proposed to revise JAR 25.121(b), (c), and (d) to specify the conditions under which the climb performance described by those sub-paragraphs is required to be determined for icing conditions in addition to non-icing conditions.

It is proposed to revise JAR 25.121(b) and (c) by adding the changes in stall reference speed and climb gradient that are permitted before the associated climb performance must be determined specifically for icing conditions.

Proposed JAR 25.121(b)(2)(ii) and JAR 25.121(c)(2)(ii) would also specify which ice accretion of proposed part II of Appendix C to JAR-25 is to be used for determining the climb performance in icing conditions for those take-off climb segments.

Proposed revised JAR 25.121(d) would include a requirement to determine approach climb performance in icing conditions with the "Holding Ice" accretion, as defined in proposed part II of Appendix C to JAR-25. It is also proposed to revise JAR 25.121(d) to include the conditions under which the approach climb speed must be increased to account for the effect of the specified ice accretion.

Reason for Revision:

The proposed revisions to JAR 25.121(b) and (c) would, in part, address the condition where the climb speed during either take-off (with landing gear retracted) or final take-off must be increased for icing conditions, due to the stall speed of the climb configuration increasing by the greater of 5.6 km/h CAS or 3% V_{SR}. In this situation, the aeroplane drag used in the computation of climb performance for icing conditions must be computed at the appropriate climb speed for icing conditions.

The proposed revision to sub-paragraph (d) would specify the criteria for determining the approach climb speed for icing conditions which, unlike the speeds used in the take-off path, is not based on the relationship between the stall speed for the aeroplane with and without ice accretion. Instead, the criteria for determining whether the climb speed needs to be re-determined for icing conditions are based on the increase in that speed over the approach climb speed for non-icing conditions. If the climb speed computed using the stall speed determined with the "Holding Ice" accretion, within the limits established by JAR 25.121(d)(1)(iii), does not exceed the climb speed for non-icing conditions by more than the greater of 5.6 km/h CAS or 3% V_{SR}, then non-icing speeds may be used for calculating approach climb performance for icing conditions. Since there is only a maximum operating speed factor specified for determining the approach climb speed, the proposed rule would allow applicants flexibility in selecting an approach climb speed for icing conditions. Approach climb speed factors as low as 1.2 V_S or 1.13 V_{SR} have been accepted in the past for non-icing conditions. The approach climb speed factor (i.e. stall margin) for icing conditions should not be less than these minimum values that have been accepted for non-icing conditions. The resulting approach climb speeds for icing conditions should also be evaluated to ensure that they provide adequate manoeuvre capability.

This approach represents more "liberal" criteria than the 5.6 km/h/3% V_{SR} discriminant used for take-off path speeds (e.g. if approach climb speed is 1.25 V_{SR} and V_{SR}=185 km/h (low), 3% of the approach speed is 7 km/h whereas 3% V_{SR} would be only 5.6 km/h). However, the FTHWG considers this small alleviation acceptable since the speed discriminant is only used to determine the need for increasing the approach climb speed for icing conditions – the approach climb performance must be recalculated with the “Holding Ice” accretion and presented in the AFM regardless of whether the approach climb speed is adjusted for operations in icing conditions. The effect of this criteria is that the majority of the drag increase attributable to the presence of a “Holding Ice” accretion will be accounted for even at the limits of the discriminant criteria, with only a slight variation arising from use of the non-icing approach climb speed to determine lift and drag. If it is necessary to increase the approach climb speed for icing conditions, the aeroplane drag used in the computation of climb performance for icing conditions would have to be computed at that speed.

Proposal 8 - JAR 25.123 En-route flight paths

Proposed Revision:

It is proposed to revise JAR 25.123(a) by specifying a minimum speed limitation, $V_{FTO,}$ when determining en-route flight paths. That speed is also the minimum limit on the final take-off speed (in the same configuration) as specified in proposed JAR 25.121(c), discussed under proposal 7.

Additionally, JAR 25.123(b) would be revised to state the conditions under which an applicant must determine en-route flight path performance for icing conditions. The revised text would prescribe the ice accretion of proposed part II of Appendix C to JAR-25 to be used in determining en-route flight path performance. Similar to the preceding take-off path climb performance requirements, speed increase and gradient reduction due to the effects of ice are employed as the discriminant criteria for determining whether en-route flight path performance needs to be specifically determined for icing conditions.

Reason for Revision:

The proposed minimum speed limitation added to JAR 25.123(a) ensures that the aeroplane will not experience a decrease in kinetic energy when transitioning from the final take-off to en-route climb segment. It also reflects the inherent limit speed for showing compliance to the manoeuvre capability requirements introduced into JAR-25 at Change 15 by the 1g stall rule.

The icing-related requirements added to sub-paragraph (b) would affect only one-engine-inoperative performance; it is assumed that failure of a second engine would give flight crews considerable cause to avoid or depart icing conditions.

Similar to the proposed take-off path requirements in JAR 25.111, discussed under proposal 5, the en-route climb gradient for non-icing conditions is allowed to be reduced by up to one-half the difference between the actual and net flight paths, as defined in JAR 25.123(b). JAR 25.123 uses an operating speed discriminant similar to the approach climb of JAR 25.121(d) except that, in this case, a speed of $1.18V_{SR}$ determined with the “En-route Ice” accretion of proposed Appendix C is compared with the en-route climb speed selected for non-icing conditions. (Note that V_{FTO} is the minimum allowable en-route climb speed established in the proposed revision to JAR 25.123(a) and $1.18V_{SR}$ is the minimum allowable value of V_{FTO} defined in JAR 25.121(c).). Since propeller-driven aeroplanes will generally use the minimum allowable operating speed factors due to the inverse relationship between thrust and airspeed, while turbojet-powered aeroplanes will use a higher speed selected to maximise climb performance, the proposal to compare the non-icing en-route climb speed with $1.18V_{SR}$ with ice will result in more conservative results for propeller-driven aeroplanes. This inherent conservatism for propeller-driven aeroplanes is a desirable consequence of the proposed speed criteria for several reasons:

- Turbojet aeroplanes typically have an approximate 12% V_{SR} margin above the minimum speed at which compliance can be shown with the manoeuvre capability requirements of JAR 25.143(h), while propeller-driven aeroplanes have very little margin;

- Propeller-driven aeroplanes generally have de-icing systems that permit ice to accrete on the protected surfaces before removing it, resulting in cyclical increases in drag; and

- Due to their slower operating speeds and shorter stage lengths, propeller-driven aeroplanes will probably be subjected to increased exposure to icing conditions.

The proposed criteria acknowledges the fact that two classes of transport category aeroplanes exist with significantly different criteria for determining their operating speeds, protecting one class from the negative effects of ice while not unduly penalising the other. Though this appears to negate one of the basic premises set forth for developing requirements for flight in icing conditions, that all transport category aeroplanes should be treated the same, this differentiation is appropriate since this regulation provides considerable latitude in the selection of the operating speed.

If it is necessary to increase the en-route climb speed for icing conditions, the aeroplane drag used in the computation of climb performance for icing conditions must be computed at that speed.

Proposal 9 - JAR 25.125 Landing

Proposed Revision:

It is proposed to revise JAR 25.125(a) to add the conditions under which the landing distance must be determined in icing conditions with the "Landing Ice" accretion defined in proposed Appendix C to JAR-25. The proposed requirement would specify that the horizontal distance necessary to land and come to a complete stop from a point 15.2 m above the landing surface must be determined in icing conditions with the "Landing Ice" accretion defined in Appendix C, if V_{REF} in icing conditions is greater than V_{REF} in non-icing conditions by more than 9.3 km/h CAS.

Additionally, sub-paragraph (b) would be revised to clarify the landing speeds to be used in determining the landing distances for icing and non-icing conditions.

Reason for Revision:

Both proposed sub-paragraphs (a) and (b) specify a "9.3 km/h CAS" increase criterion in the requirements pertaining to icing conditions. This criterion has its origin in the following four issues:

1. Standard certification practice has been to investigate longitudinal controllability to cover operational landing abuse cases where an inadvertent speed decrease below V_{REF} may occur. This investigation has been conducted by showing the aeroplane can be safely controlled and landed when the airspeed at 15.2 m is V_{REF} - 9.3 km/h;

2. Transport category aeroplanes are typically operated with speed additives to provide gust margins that may or may not be bled off before crossing the threshold;

3. Many transport category aeroplanes have been operated with a 9.3 km/h speed additive during final approach to cover for inadvertent speed loss, which has often been carried to the 15.2 meter point without any indication of a landing distance-related safety problem.

4. A 9.3 km/h increase above the non-contaminated aeroplane landing reference speed equates to approximately 3% of the 1g stall speed (slightly less than 3% for larger aeroplanes) for the same configuration, which is consistent with the allowable stall speed tolerance for the take-off path aeroplane configurations with ice. Considering the information presented above, the FTHWG considers a 9.3 km/h increase in V_{REF} due to ice accretion acceptable.

A second constraint on V_{REF} for icing conditions in the proposed requirements is that it must provide the manoeuvring capability required by JAR 25.143(g) with the "Landing Ice" accretion defined in proposed part II of Appendix C to JAR-25. This entails demonstrating a constant speed 40 degree banked turn without encountering stall warning.

The current JAR 25.125(a)(2), which has been reformatted as proposed JAR 25.125(b)(2)(i), also requires V_{REF} for non-icing conditions to be not less than the Landing Minimum Control Speed, V_{MCL}. This is to ensure that adequate directional control is available in the event the critical engine fails during a go-around executed during the approach and landing phase of flight. Similar to V_{MCG} and V_{MCA} for the take-off phase, the V_{MCL} determined for non-icing conditions is retained as a minimum airspeed limitation on V_{REF} determined for icing conditions. Unlike the take-off case, this is not explicitly stated, but is obvious because proposed JAR 25.125(b)(2)(ii) requires, in part, V_{REF} for icing conditions to be not less than V_{REF} for non-icing conditions, which in turn must be not less than V_{MCL}.

To provide assurance that controllability and manoeuvrability will not be compromised by using the V_{MCL} determined for non-icing conditions as a minimum airspeed limitation on V_{REF} determined for icing conditions, proposed JAR 25.143(c)(2) and (3) would require the applicant to show that the aeroplane will be safely controllable and manoeuvrable during an approach and go-around, and an approach and landing, with the critical engine inoperative. (A more detailed discussion of proposed changes to JAR 25.143 follows under proposal 10.) In the interest of flight test safety, these manoeuvres may be accomplished with a simulated engine failure (as noted in the proposed advisory material associated with this proposal).

Proposal 10 - JAR 25.143 Controllability and Manoeuvrability – General

Proposed Revision:

As noted in discussions related to take-off and landing speeds, above, it is proposed to revise JAR 25.143 to add:

- **A new sub-paragraph (c)** that requires the applicant to show the aeroplane is safely controllable and manoeuvrable in three one-engine-inoperative low speed manoeuvres with the appropriate ice accretion.

- **A new sub-paragraph (i)** that contains a general icing-related application requirement in sub-paragraph (i)(1) and a specific icing conditions test in sub-paragraph (i)(2).

- **A new sub-paragraph (j)** to specify tests for ensuring that the aeroplane has adequate controllability with the ice accretions that exist on the unprotected and protected surfaces prior to normal activation of the ice protection system.

Reason for Revision:

JAR 25.143(c) - The proposed requirements of new sub-paragraph (c) would ensure that use of the minimum control speeds determined for non-icing conditions will not result in controllability and manoeuvrability problems when used as minimum operating speed limits for icing conditions.

JAR 25.143(i) - Proposed sub-paragraph (i)(1) would state, in part, that "… controllability may be demonstrated with the ice accretion described in Appendix C that is most critical for the particular flight phase." This statement requires compliance with all of JAR 25.143 (except sub-paragraphs (b)(1) and (2), which are exempted by proposed JAR 25.21(g)). An allowance is made for the applicant to minimise the number of ice accretions to be tested by using the one that is shown to be the most critical for the flight phase under consideration.

Sub-paragraph (i)(1) would also require applicants to consider "Sandpaper Ice" when determining the critical ice accretion for aeroplanes with unpowered elevator controls. The thin, rough, layer of ice that is defined as "Sandpaper Ice" in the proposed part II of Appendix C to JAR-25, has been shown in many cases to have a more detrimental effect on handling characteristics than larger shapes for aeroplanes with unpowered control systems. In some cases, such an accretion has resulted in control surface hinge moment reversals that required the flight crew to apply extremely high control forces to recover from the resulting upsets.

Proposed sub-paragraph (i)(2) would add a requirement that a longitudinal control push force be required in a pushover manoeuvre down to zero g or the lowest load factor obtainable if limited by elevator power. This requirement is intended to investigate an aeroplane's susceptibility to ice-contaminated tailplane stall (ICTS). Ice-contaminated tailplane stall can be characterised by either completely stalled airflow over the horizontal stabiliser, or by an elevator hinge moment reversal due to separated flow on the lower surface of the horizontal stabiliser. Several incidents and accidents have been attributed to ICTS. These have typically occurred during landing approaches when some form of ice accretion has been on the horizontal tailplane, and the flight crew has selected increased flap deflections and/or decreased pitch attitude abruptly. These actions result in an increase in the angle-of-attack (AOA) of the local airflow over the tailplane and required download (i.e. downward lift) on the tailplane.

The degraded airflow conditions caused by ice accretion can result in a reduced tailplane stall AOA and lift capability, that is manifested by lightening and/or reversal of the longitudinal control push force. A flight test method to conservatively determine an aeroplane's susceptibility to ICTS has been created, which involves:

- Increasing the AOA on an ice-contaminated tailplane,
- Inducing a nose down pitch rate, and
- Performing a pushover to zero g.

The pass/fail criteria proposed for this test method is that a longitudinal control push force be required to zero g. Different airworthiness authorities have applied different test criteria and different pass/fail criteria. For example, early ICTS test criteria called for executing a pushover to 0.3g-0.4g with a pitch rate of not less than 10 degrees/second in an attempt to replicate the documented ICTS accident conditions. It was later determined that an aggressive pushover to zero g would result in the same combination of load factor and pitch rate but with no need for sophisticated test instrumentation.

JAR 25.143(i)(3) - The FAA has also required demonstration of a sideslip manoeuvre with an ice-contaminated tailplane, since this has been shown as a more critical ICTS triggering mechanism for some aeroplanes.

JAR 25.143(j) - JAR 25.143(j) is proposed in recognition of the fact that some amount of ice accretion will form on all aeroplanes before the ice protection system is activated and in its normal operating state (i.e. performing its intended function). In developing the controllability criteria proposed in sub-paragraph (j), consideration was given to the temporary nature of the ice accretion that forms prior to normal operation of the ice protection system. The temporary nature was further classified by relating the controllability test requirements to the means of ice detection, and whether or not the ice protection system required crew action for activation. The proposed advisory material for part II(e) of Appendix C to JAR-25 provides additional guidance for determining the appropriate ice accretion for this testing based on the means of ice detection.

Proposal 11 - JAR 25.207 Stall warning

Proposed Revision:

It is proposed to revise JAR 25.207 as follows:

- Sub-paragraph (b) would be revised to require that stall warning be provided by the same means for both icing and non-icing conditions. It also would reference a new sub-paragraph (e) containing the criteria for stall warning in icing conditions and a new sub-paragraph (h)(2), which provides a specific exception for flight in icing prior to normal operation of the ice protection system.

- A new sub-paragraph (e) would specify the stall warning criteria that must be met in icing conditions, including the new proposed Appendix C ice accretion applicable to the aeroplane high-lift configuration. The proposed criteria require stall warning to be evaluated in straight and turning flight with an entry rate of 1.9 km/sec., using the same recovery technique as for the non-contaminated aeroplane.

- Sub-paragraph (f) (formerly (e)) would be revised to clarify that the pilot must use the same stall recovery technique for the aeroplane with ice accretions as used for demonstrating compliance with JAR 25.207 in non-icing conditions.

- A new sub-paragraph (h) would specify the stall warning margins that must exist with the ice accretions that will form on the unprotected and protected surfaces prior to normal operation of the ice protection system. Proposed sub-paragraph (h) specifies the stall warning that must be provided based on the means of recognition of ice accretion.

Reason for Revision:

JAR 25.207(b) **-** Considering that one of the premises assumed in developing these proposed regulatory changes and guidance material was the probability of icing conditions being one (i.e. 100%), the FTHWG finds that adequate stall warning should be provided. Further, it is logical that the warning should be provided in icing conditions by the same means as in non-icing conditions; this is in much the same sense that current JAR 25.207(b) stipulates that if stall warning is provided by a warning device, it must be provided by that warning device for all aeroplane flap/landing gear configurations.

JAR 25.207(e) **-** In developing the proposed stall warning criteria that must be met in icing conditions, it was necessary to take into consideration the types of transport category aeroplanes that have been involved in icing-related accidents as a result of stalling one or both wings. Those aeroplanes:

- Were not equipped with uninterrupted operation thermal anti-ice systems, and

- Generally experienced a considerable decrease in the stall angle-of-attack due to the effect of ice on the unprotected surfaces, combined with ice on the protected surfaces during those periods when a cyclic ice protection system was not operating (intercycle ice).

The proposed criteria will likely require a reset of the stall warning system for icing conditions on those aeroplanes, but would have a lesser impact on aeroplanes that have demonstrated safe flight in icing conditions. The stall warning settings established for the aeroplane without ice accretions may be retained for operation in icing conditions provided they are still adequate to prevent stalling if the pilot takes no action to recover until three seconds after the initiation of stall warning. Since all modern transport category aeroplanes use some type of artificial stall warning system, and since three seconds is considered adequate time for response by a trained pilot, the FTHWG considers that this icing-specific stall warning definition is acceptable.

Sub-paragraph (e)(1) would permit the use of “Holding Ice” accretion to be used in evaluating the stall warning margin for the en-route, holding, approach, landing and go-around high lift configurations. The “Holding Ice” accretion condition is appropriate for investigating the stall warning margin for those high-lift configurations used from the actual holding manoeuvre through the descent to either a landing or go-around. The defined “Holding Ice” accretion defined in proposed part II of Appendix C to JAR-25 is representative of the ice accretion that has traditionally been used in icing certifications. It is the result of up to a 45-minute hold in the Continuous Maximum Icing Conditions defined in part I of Appendix C to JAR-25 that are assumed to remain on the airframe during the descent and landing. Consistent with the use of the “Holding Ice” accretion for evaluating stall warning in the listed configurations, the proposed definitions in part II of Appendix C for the ice accretions appropriate to the en-route and landing configurations permit the use of “Holding Ice” in lieu of defining additional accretions.

Proposed JAR 25.207(e)(2) would permit the use of the more critical of the “Take-off Ice” or “Final Take-off Ice” accretion to be used in evaluating the stall warning margin for the take-off configuration. The take-off configuration is treated separately due to the different icing atmosphere defined for take-off (see part I of Appendix C to JAR-25) and due to a more limited exposure time. (Note: Exposure time will be more limited during take-off because the aeroplane will be climbing above and flying away from the icing conditions that exist at the point of departure.) As noted in proposed part II of Appendix C, the “Holding Ice” accretion may also be used in lieu of the “Take-off Ice” and “Final Take-off Ice” accretions if it is shown to be more critical. This is particularly important since it has been shown that the ice accretion having the most detrimental effect on aeroplane handling characteristics may not be the large, craggy, multi-horned shape that one would intuitively expect (i.e. "Holding Ice"), but instead may be a thin, rough layer of ice that initially accretes.

JAR25.207(f) **-** The proposed revision of this sub-paragraph, concerning using the same stall recovery techniques for icing as in non-icing conditions, is based on human factors considerations for minimising the number of variations in a common procedure. The operational pilot should not be tasked with deciding what procedure to employ in a high workload environment, such as stall warning, that requires decisive action.

JAR 25.207(h) **-** In developing the stall warning criteria specified in this proposal, the FTHWG considered the temporary nature of the ice accretion prior to normal operation of the ice protection system, and further classified the temporary nature by relating the stall warning margin to the means of ice detection and whether or not the ice protection system required crew action for activation. Of particular concern were aeroplanes where the means of ice detection is the visual recognition of a specified ice accretion on a reference surface. To address this concern, proposed sub-paragraph (h)(1) requires that the stall warning for these aeroplanes be the same as that provided for operation in non-icing conditions (i.e. JAR 25.207, except sub-paragraphs (c) and (d)).

For aeroplanes that use other means of ice detection, proposed sub-paragraph (h)(2) provides distinct stall warning criteria that also take into account the temporary nature of the ice accretion prior to the normal operation of an aeroplane's ice protection system. Though sub-paragraph (h)(2) permits the means by which stall warning is provided to differ from that for non-icing conditions, it is not considered to be in conflict with the stall warning requirements proposed for other phases of flight in icing conditions. This non-conflict of requirements is based on the shorter and consistent time (for a given icing condition) of ice accretion that will result from systems that are installed to alert the flight crew to the detection of ice. (The proposed advisory material developed for this rule (see proposal 26) provides guidance for determining the appropriate ice accretion for this testing, based on the means of ice detection.)

Alternatives Considered:

JAR 25.207(b) **-** An alternative that was considered for the proposed requirements concerning the means of stall warning did not involve dependence specifically on a stall warning system to alert the pilot of an impending stall. Instead, this alternative was based on the supposition that, since airflow separation will begin at a lower angle-of-attack with ice accretions on the wing leading edge, it is reasonable to assume that pre-stall buffet will occur early enough to give the pilot sufficient warning of impending stall; therefore, a separate stall warning for icing conditions would not be necessary. This approach was not adopted for several reasons, the most overriding being the human factors aspects that would need to be considered if pilots were required to be trained to recognise stall warning by two different means.

JAR 25.207(e) **-** One alternative considered in developing the proposed stall warning criteria contained in this sub-paragraph was to require an investigation of stall warning in icing conditions at entry rates greater than 1.9 km/sec. (as required for non-icing conditions) with a one-second (rather than a three-second) delay before pilot action to recover. This reduced delay timeframe was based on the assumption that a high entry rate would most likely be associated with manoeuvres such as collision avoidance or aggressive manoeuvring where the pilot would be flying the aeroplane. A requirement for a high entry rate test with a short delay time for pilot response is not proposed because most artificial stall warning systems incorporate a phase advance that decreases the angle-of-attack for stall warning activation as the rate at which angle-of-attack increase becomes higher, as would occur with a high entry rate; thus, this makes the slow entry rate with longer delay time the critical case.

Proposal 12 - JAR 25.237 Wind velocities

Proposed Revision:

It is proposed to revise JAR 25.237(a) by adding a requirement to determine a landing crosswind component in icing conditions. This revision would include a requirement for non-icing conditions, a specific differentiation of “non-icing” and “icing” conditions, and editorial changes to retain the correct sub-paragraph structure.

Sub-paragraph (a) also would be amended to state that the crosswind component established for take-off without ice accretions may be used for take-offs conducted in icing conditions.

Reason for Revision:

A review of certification data for existing transport category aeroplanes showed that directional control was not detrimentally affected by ice accretions on the leading edge of the vertical stabiliser. This may be attributed to some designs incorporating leading edge protection and others compensating for the accretion of ice during an extended holding condition that will remain on the aeroplane through descent and landing. Since in-flight icing conditions are defined (in this document) as not beginning until lift-off, aeroplanes will accrete very little ice while in close proximity to the ground where crosswinds are a significant safety concern; therefore, the FTHWG finds it unnecessary to demonstrate a crosswind velocity for take-off with an ice accretion.

Proposal 13 - JAR 25.253 High-speed characteristics

Proposed Revision:

It is proposed to revise JAR 25.253 by adding a new sub-paragraph (c) that provides a definition of the “maximum speed for stability characteristics, V_{FC}/M_{FC},” specifically for icing conditions. The proposal would permit applicants to define a V_{FC}/M_{FC} for icing conditions that is less than the V_{FC}/M_{FC} defined for non-icing conditions.

Reason for Revision:

A review of certification data showed that none of the flight tests for which V_{FC}/M_{FC} is an upper boundary had been conducted above 556 km/h CAS with artificial ice accretions. One reason for not exceeding 556 km/h CAS was the difficulty and cost of fabricating ice accretions and attachment methods that would ensure their integrity at such high speeds. A second, more important, reason was the fact that the same airloads that make it difficult to retain artificial ice shapes also result in natural ice shapes separating from aerofoil leading edges at high speeds.

Since the group of aeroplanes defined as “transport category” encompasses a number of configurations with differing propulsive means, the proposed JAR 25.253(c) recognises that not all transport category aeroplanes will have a V_{FC}/M_{FC} as high as 556 km/h CAS; consequently, an allowance is provided for V_{FC} with ice accretions to be the lower of:

- 556 km/h CAS,

- V_{FC} without ice accretions (from JAR 25.253(b)), or
- An airspeed at which the applicant can demonstrate the aeroplane will be free of ice accretions.

Proposal 14 - JAR 25.941 Inlet, engine, and exhaust compatibility

Proposed Revision:

It is proposed to revise the references to JAR 25.143(c), (d), and (e), contained in sub-paragraph (c) of JAR 25.941, to read JAR 25.143(d), (e), and (f).

Reason for Revision:

The proposed changes will maintain references to the correct sub-paragraphs of JAR 25.143 if the changes being proposed by this NPA are adopted.

Proposal 15 - JAR 25.1419 Ice protection

Proposed Revision:

The only change proposed for JAR 25.1419 arising from this harmonisation task is an editorial change. However, the FAA proposes to revise FAR 25.1419 to change the introductory text that currently states, "If certification with ice protection provisions is desired . . ." This phrase makes the demonstration of an aeroplane's ability to operate safely in icing conditions contingent solely upon the desire of the applicant to certificate an ice protection system. The revised phrase would state, "If certification for flight in icing conditions is desired. . ." This revised phrase (which is the text that currently appears in JAR 25.1419) relates the demonstration of safe operation in icing conditions to the applicant's desire to have the aeroplane certificated for flight in icing.

Reason for Revision:

The FTHWG is proposing to amend FAR 25.1419 to incorporate the revised introductory text, explained above. This revision is made for two reasons:

- A literal reading of the current FAR 25.1419 wording could imply that the applicant does not have to demonstrate that the aeroplane can be safely operated in icing conditions, unless an ice protection system is installed.
- The revised text will retain the optional nature of certification for flight in icing conditions which, in turn, will permit the aeroplanes to receive a type certificate (with an appropriate limitation against flight in icing conditions) before the applicant's icing programme is complete.

Alternatives Considered:

One alternative that was considered in developing this proposal was to entirely remove the optional nature of certification for flight in icing conditions that currently exists in both FAR 25.1419 and JAR 25.1419. The basis for that thinking was that, in today's operating environment, with an emphasis on flexibility and minimising interruptions to scheduled service, it is almost inconceivable that a manufacturer would propose designing a transport category aeroplane that is not intended to operate in icing conditions.

Though not objecting to this proposal or the logic behind it, industry representatives have expressed concern for the effect it would have on the long-standing practice of issuing a type certificate with a prohibition against flight in icing conditions before the flight in icing certification programme is completed. This type of approval has been used to permit manufacturers to deliver aeroplanes to customers for non-revenue flying, such as demonstrations, flight crew training, and familiarisation, while the tests and analyses necessary for flight in icing certification were being completed. This type of certification not only permits manufacturers to meet contractual milestone dates for initial certification but also increases flexibility with regard to flight in natural icing conditions, which can be delayed by the ability to find adequate icing conditions; mandatory certification for flight in icing conditions would eliminate this flexibility.

A second alternative discussed by the FTHWG was to add a sub-paragraph to JAR 25.1419 that would explicitly state that a type certificate could be granted prior to completing the flight in icing certification programme, provided the applicant submitted a plan for its completion prior to delivery of the first aeroplane or issuance of a standard Certificate of Airworthiness, whichever occurs later (this would be similar to provisions in JAR 25.1529 that allow an applicant to delay submitting Instructions for Continued Airworthiness at the time of type certification). Although legally acceptable, this option was rejected due to subtle differences in the manner that civil aviation authorities define and grant operational approval.

Proposal 16 - JAR-25, Appendix C

Proposed Revision:

It is proposed to revise Appendix C to JAR-25 to:

- Create two subparagraphs: one to define the icing atmospheric conditions and another to define ice accretions appropriate to each phase of flight;
- Add a definition of the “take-off” icing atmospheric conditions; and
- Define the limiting conditions for determining the ice accretions appropriate to each phase of flight.

New proposed part I of Appendix C would retain the existing definitions of atmospheric icing conditions. Added to it would be a definition of “Take-off Maximum Icing,” which is to be used in determining ice accretions for the take-off phase of flight.

New proposed part II(a) of Appendix C would contain definitions of the ice accretions appropriate to each phase of flight, along with any limiting conditions (e.g. altitude limits for “Take-off Ice” accretion). (Note: Further considerations for the development of artificial and natural ice accretions are contained in the proposed advisory material associated with these proposed regulatory changes (see proposal 26).)

New proposed part II(b) of Appendix C would provide options for reducing the number of ice accretions to be considered for each phase of flight.

New proposed part II(c) of Appendix C would permit applicants to use the ice accretion that has the most adverse effect on handling characteristics for performance testing provided the difference in the effect on performance, relative to the critical ice accretion for performance, is conservatively taken into account.

New proposed part II(d) of Appendix C would define the conditions for determining the ice accretions applicable to the take-off phase of flight.

New proposed part II(e) of Appendix C would define an ice accretion prior to normal ice protection system operation that must be considered. (Note: Further guidance is provided to define this ice accretion in the associated proposed advisory material (see proposal 26).)

Reason for Revision:

Part I - One of the early industry objections to adopting the JAA NPA 25F-219 material for the take-off phase was the inappropriateness of assuming the current Appendix C icing atmosphere exists at ground level. This topic was the subject of considerable discussion, including consultation with FAA meteorologists who provided valuable information relative to determining the icing potential of clouds.

The FAA meteorologists attested that the maximum liquid water contents (LWC) prescribed for "Continuous Maximum Icing" conditions addressed in current Appendix C (0.80 grams per cubic meter (g/m^3)) will only be found near the top of cloud layers that are greater than 1219 meter deep, and with the freezing point near the top of the cloud layer. The FAA meteorologists also stated that the amount of water vapour that can be held without condensation in a given volume of space is independent of the altitude and depends only on the temperature of the gas (water vapour, air, etc.) in that space. This fact would permit a universal definition of a take-off icing atmosphere that would be equally applicable to all of an aeroplane's approved take-off field elevations.

For determining the take-off ice shapes, changes in the LWC must be considered in the segment of the flight path from the take-off surface to 457 m above ground level (AGL), though the lowest cloud base is generally above 30 m AGL. Theory and experiment have shown that the LWC is smallest (usually less than 0.10 g/m^3) at the cloud base and generally increases with distance above the cloud base. The ice accretion on an aeroplane would be due to the gradually increasing LWC and normally decreasing air temperature as the aeroplane climbs from the runway to 457 m AGL. Although measured data at low altitudes AGL are sparse, the FAA Technical Centre's database on inflight icing conditions contains data for 99^{th} percentile LWC limits as low as 762 m AGL. When scaled to 457 m AGL, a maximum LWC value of 0.35 g/m^3 results.

The FAA meteorologists also provided a computation of the theoretical maximum "condensed" water content possible at 457 m. AGL with a temperature of 0° C at the cloud base; the resulting $LWC_{theor.\ max.}$ was 0.71 g/m^3. Measurements have shown that the actual average LWC observed in stratiform clouds is usually no more than half the computed theoretical maximum LWC, which in this case renders the same 0.35 g/m^3.

Another case that may be conducive to take-off ice accretion is dense fog at runway level with an ambient temperature of 0°C or less. In the unlikely event that the fog was to extend from ground level to 457 m AGL, the aeroplane would be exposed to an atmosphere with a uniform LWC of approximately 0.30 g/m^3.

Based on the information discussed above, the proposed part II(a) of Appendix C would define the take-off maximum icing conditions atmosphere as having a constant LWC of 0.35 g/m^3. This provides a conservative estimate of actual conditions.

The two other necessary characteristics to describe the take-off icing atmosphere are:

- A water droplet mean effective diameter (MED), and
- An ambient temperature.

A MED value of 20μ (1μ = 1 micron) was determined to be appropriate to such low level icing conditions by both industry and FAA icing specialists.

Note that the term Median Volumetric Diameter (MVD) is often used in current terminology - MED is retained for consistency with current Appendix C.

Selection of the ambient temperature for take-off icing was predicated on the results of icing computer code predictions that showed the effect of temperature to decrease significantly as the temperature itself decreased. The ambient temperature of the take-off icing atmosphere was selected as -9°C, the point at which any further decrease in temperature had a negligible effect on the resulting ice accretion. The definition of the take-off maximum icing conditions has been added as proposed sub-paragraph (c) of part I. The new Appendix C definition of take-off icing conditions also notes that the take-off maximum icing conditions exist from ground level to 457 m above the take-off surface; this is commensurate with the definition of the take-off path in JAR 25.111.

Part II(a) **-** Each subpart B flight requirement that must be met in icing conditions specifies which of the ice accretion definitions listed in proposed part II(a) is to be used in showing compliance. To reduce the number of artificial ice accretions that must be manufactured, proposed part II would permit the ice accretion determined for one flight phase to be used in showing compliance with the flight requirements of another phase, provided the applicant can show it has a more critical effect on the flight parameter being evaluated. Ultimately, the entire spectrum of flight testing could be done with the "Holding Ice" accretion if the applicant can show it is the most critical for every flight phase and is willing to accept the penalties that will arise in other flight phases (e.g. use of "Holding Ice" in the take-off phase will generally have a large effect on performance).

Part II(b) **-** In developing the contents of proposed part II(b) that address ice accretions for the take-off phase, the FTHWG assumed compliance with operating rules that:

- Prohibit pilots from conducting take-offs with any frost, snow, or ice adhering to certain aeroplane surfaces, or
- Require the aeroplane to be operated in accordance with an approved ground de-icing/anti-icing programme.

Compliance with these operating requirements will result in aeroplanes being free of frost, snow, and ice up to the point of lift-off.

Proposed part II(d) also clarifies that no crew action to activate the ice protection system is assumed until the aeroplane is 122 m above the take-off surface; this is consistent with the existing requirement of JAR 25.111(c)(4) that limits the number of configuration changes requiring crew action before reaching 122 m above the take-off surface (i.e. end of the second segment of the take-off flight path).

Part II(e) **-** Consideration of the ice accretion prior to normal ice protection system operation is necessary, since transport category aeroplanes will be required to fly with some amount of ice accretion, before the ice protection system is activated and performing its intended function; this is just as true for what are commonly referred to as *anti-ice* systems as it is for *de-ice* systems. The ice accretion prior to normal system operation, as addressed by proposed part II(e) and amplified by the proposed ACJ 25.21(g) (see proposal 26), is to be determined as an exposure to the continuous maximum icing conditions of part I of Appendix C, which includes:

- The time for recognition,
- A delay time appropriate to the means of ice detection, and
- The time for the ice protection system to perform its intended function after manual or automatic activation.

Alternatives Considered:

During the development of the proposed amendments to Appendix C, two alternative positions were considered. These are discussed in detail in the appendices to this NPA and include an explanation of why the majority of the interests represented in the FTHWG did not support them.

Proposals 17 to 25

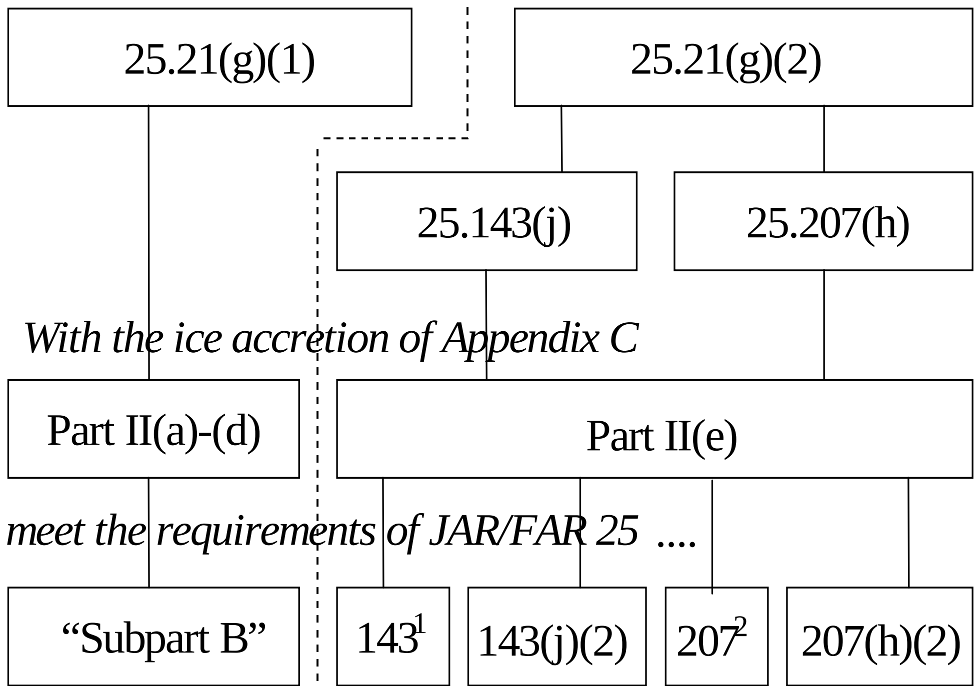
These proposed changes are all editorial, consisting of renumbering ACJs and cross-references contained therein, to correspond with the renumbering of the JAR-25 requirements arising from proposals 6, 7, 9 and 10.

Proposal 26

The FTHWG Report also includes extensive advisory material, which is presented in this NPA as a proposed new ACJ to 25.21(g). This AMC provides acceptable means of compliance for the performance and handling requirements of Subpart B. It also gives advice on other matters pertinent to approval for flight in icing conditions such as:

- Consideration of systems aspects and failure conditions,
- Flight testing and analysis methods, and
- The development of the ice accretions appropriate to various flight phases

Relationship of Proposed JAR 25.21(g)(1) and (2) to other Proposals, including JAR 25.143(j) and 25.207(h)



[1] via 25.143(j)(1), and
[2] via 25.207(h)(1)
as these are applicable to visual recognition of a specified ice accretion on a reference surface.

4. Non-consensus items

All proposals arising from the non-consensus items are given here, together with justifications and dispositions.

4.1 Low g Manoeuvres and Sideslips – JAR 25.143(h)

Low g Manoeuvre - Industry (FTHWG Report) Proposal

JAR 25.143(h)(2)

(2) The aeroplane must be controllable in a pushover manoeuvre down to zero g, or the lowest load factor obtainable if limited by elevator power. It must be shown that a push force is required throughout the manoeuvre down to 0.5g. It must be possible to promptly recover from the manoeuvre without exceeding 50 pounds pull control force.

and

ACJ 25.21(g)

6.9.3.1 For pushover manoeuvres, it should be shown that the aeroplane is controllable down to zero g or the lowest load factor obtainable if limited by elevator power. It should be shown that a push force is required down to 0.5 g load factor, and that it is possible to promptly recover from the manoeuvre without exceeding 50 pounds pull control force.

Low g Manoeuvre - FAA, JAA and ALPA Proposal

25.143(h)(2)

(2) It must be shown that a push force is required throughout a pushover manoeuvre down to zero g or the lowest load factor obtainable if limited by elevator power. It must be possible to promptly recover from the manoeuvre without exceeding 50 pounds pull control force; and

and

ACJ 25.21(g)

6.9.3.1 It should be shown that a push force is required throughout a pushover manoeuvre down to zero g or the lowest load obtainable if limited by elevator power. It should be possible to promptly recover from the manoeuvre without exceeding 50 pounds pull control force.

<u>Basis of FAA, JAA and ALPA Proposal</u>

FAA, JAA and ALPA members of the FTHWG suggested an alternative to JAR 25.143(i)(2), as proposed by the FTHWG, concerning the requirement that an aeroplane must be controllable in a pushover manoeuvre down to zero g, or the lowest load factor obtainable if limited by elevator power. A discussion of this alternative and the basis for it is presented below:

Ice contaminated tailplane stall/elevator hinge moment reversal has been a significant factor in accidents occurring in icing conditions. Rapid pitch divergence, significant changes in control forces, pilot surprise factor, and possible disorientation in poor visibility that can follow from a tailplane stall/elevator hinge moment reversal can result in loss of pitch control. Coupled with the fact that, due to the nature of the phenomenon, this loss of control will usually occur at low altitude, there is a high probability of an accident.

Historically, the pushover test was usually performed to 0.5g total, although this was often done with a high pitch rate and, hence, there was some overshoot of the 0.5g level. A push force on the elevator control was required to reach this g level. Certification testing and service experience have since shown that testing to 0.5g is not adequate, bearing in mind the relatively high frequency of experiencing 0.5g in operations. Since the beginning of the 1980's, the practice of many certification authorities has been to require testing to lower load factors, and the JAA's Notice of Proposed Amendment (NPA) 25F-219 requires a push force throughout the manoeuvre to zero g. The FTHWG agreed that the test manoeuvre should be performed to zero g. However, the supporters of the proposed alternative maintain that the pilot should be required to apply a push force to the longitudinal control system until a zero g condition is attained. (The position reflected in the proposed rule is that reversal of the elevator control force below 0.5g is acceptable within limits.)

Reversal of elevator control force versus normal acceleration is not acceptable within the flight envelope. Existing requirements and advisory material addressing elevator control force characteristics (JAR 25.143(f), JAR 25.255(b)(2), and the guidance material to JAR 25.143(f)) do not allow force reversals. Furthermore, a survey of FAA, JAA, and other flight test personnel showed that a clear majority did not favour anything less than a push force on the elevator control to zero g.

The position on this item reflected in the proposed rule language goes some way in addressing the cause of past accidents. However, the method proposed for determining the acceptability of a control force reversal is subjective and will lead to inconsistent evaluations. The supporters of the alternative position maintain that a push force to zero g with an ice-contaminated tailplane is the minimum standard that can be accepted. Zero g is within the flight envelope of the aeroplane and the criteria addresses the need to have acceptable handling qualities for operational service when the pilot would not expect any control force reversal. Requiring a push force to zero g also removes subjectivity in the assessment of the aeroplane's controllability and provides readily understood criteria of acceptability. Any lesser standard does not give confidence that the problem has been fully addressed or resolved.

While there is no technical disagreement in the FTHWG on the need to address longitudinal control force changes to maintain speed with increasing sideslip angle, and advisory material to JAR 25.143 has been agreed to achieve this, the supporters of the alternative proposal believe that a specific requirement is needed to address longitudinal control force changes to maintain speed with increasing sideslip angle.

Consequently, the minority of FTHWG members presenting this position propose that JAR 25.143(i)(2) be modified to read:

> (2) It must be shown that a push force is required throughout the manoeuvre down to zero g. It must be possible to promptly recover from the manoeuvre without exceeding 50 pounds pull control force.

And that a new JAR 25.143(i)(3) be added that reads:

> (3) Changes in longitudinal control force to maintain speed with increasing sideslip angle must be progressive with no reversals or sudden discontinuities.

Disposition of FAA, JAA and ALPA Proposal

This alternative was not supported by the majority of the FTHWG for the following reasons:

Historically, the pushover test was performed to 0.5g rather than zero g. For example, as practiced by Transport Canada, this demonstration was done with a high pitch rate and, consequently, there was significant overshoot of the 0.5g level, down to approximately .25g or less. This was a controllability test involving an abrupt push, followed by a pull to recover. The intent was not to reach a specific “g” level below 0.5g, but to show that the pilot could effect a satisfactory recovery. This has proven to be an acceptable test technique. To date, airplanes evaluated with this technique have been satisfactory in service.

Since the beginning of the 1980's, the practice of many certification authorities has been to require testing to lower load factors. This evolved until the introduction of the JAA’s NPA 25F-219, which not only requires testing to zero g, but also requires a push force throughout the maneuver to zero g. A zero g pushover is considered an improbable condition, going well beyond any operational maneuver, which does not properly represent gusts, pitch rate, elevator position, and other factors that may contribute to tailplane stalls. Also, since the NPA requirement was developed for a specific turboprop, and motivated by service experience on turboprop airplanes, other requirements were proposed for other types.

After much debate concerning this item, the majority of the FTHWG members eventually accepted use of the pushover maneuver, within limits, as a compromise means of showing that an adequate safety margin exists. However, the supporters of the majority position consider that requiring a push force to zero g is excessive.

The FAA’s Advisory Circular 25-7A, “Flight Test Guide for Certification of Transport Category Airplanes” defines the boundaries of various flight envelopes. With regard to minimum load factor with flaps down:

- The normal flight envelope (NFE) goes to 0.8g;
- The operational flight envelope (OFE) to 0.5g; and
- The limit flight envelope (LFE) to zero g.

Conceptually, the boundaries of the OFE are as far as the pilot is expected to go intentionally, while the LFE is based on structural or other limits that should not be exceeded. Between the OFE and the LFE, handling qualities may be degraded, but the airplane must remain controllable and it must be possible to avoid exceeding the limit load factor [see JAR 25.143(b)]. The position of the majority of the FTHWG members was consistent with these concepts.

Supporters of the alternative position, however, cite existing regulations that do not allow force reversals for the en-route configuration (e.g. JAR 25.143(f) and 25.255(b)(2), and the parallel FAR standards). In practice, the certification tests for these rules do not cover the full structural limit flight envelope, but do cover a reasonable range of load factor sufficient for normal operations. For example, in the en-route configuration, where the limit minimum load factor usually is negative 1g, the JAA’s Advisory Circular Joint (ACJ) No. 2 to JAR 25.143(f) states: “. . . assessment of the characteristics in the normal flight envelope involving normal accelerations from 1g to zero g, will normally be sufficient.”

With flaps up, zero g is the midpoint between the limit load factor and the trim point. The corresponding points for flaps down are zero g for the limit load factor and 0.5g for the midpoint assessment of characteristics. The concern exists that requiring a push force to zero g means this limit load factor will be routinely exceeded in flight tests.

The zero g pushover is not like typical stability tests where it is possible to establish steady state conditions and measure a repeatable control force. The pushover is an extremely dynamic maneuver lasting only a few seconds and involving high pitch rates in both directions. There will always be variability due to pilot technique. The pilot may pull slightly before reaching zero g to reduce the nose-down pitch rate and anticipate the recovery. This makes it impossible to distinguish the force required to reach a given g level from the force applied by the pilot to modulate the pitch rate. At critical conditions, airplanes that meet the criterion suggested in the alternative proposal still require a significant pull force to recover. The position proposed by the FTHWG in its recommendation sets a 50-pound limit on the total control force to recover promptly. This ensures that the pilot is able to control with one hand a combination of:

- The force to halt the nose-down pitch rate,
- The force due to any hinge moment reversal, and
- The force to establish a satisfactory nose-up pitch rate for recovery.

The 50-pound limit is a readily understood criterion of acceptability that is already applied in several other rules. The effect of data scatter and variations in pilot technique is that marginal airplanes will exceed the 50-pound limit too often, and will not pass.

The alternative position has the potential for adversely affecting an entire class of airplanes, namely light to medium business jets with trimmable stabilizers and unpowered elevators. Many of these airplanes exhibit a mild control force reversal between zero g and 0.5g, which is easily controllable. The alternative requirement to push to zero g would reduce the stabilizer incidence available for trim by two to four degrees, requiring either a larger stabilizer (by 20 to 40%) or other design changes to compensate for that reduction in stabilizer trim range. The cost of these changes is not justified by any safety benefit, as these airplanes are not the types having ICTS accidents.

Furthermore, the proposed JAR 25.143(i)(1) requires that “Sandpaper Ice” be considered if the elevator is unpowered, regardless of the ice protection system. Many of the current business jets are equipped with anti-ice systems that prevent ice formation on the stabilizer leading edge when operated normally. Thus, the jets would be evaluated under more critical assumptions (anti-ice off) than the types that have had accidents (de-ice on).

Ice-contaminated tailplanes retain normal linear characteristics until the onset of flow separation. The separation causes the hinge moment coefficient to slope gradually from one level to another over a range of 4 to 10 degrees angle-of-attack. With the elevator down, the hinge moment coefficient changes sign at an angle-of-attack in this range, which results in the control force reversal from a push to a pull. On a particular business jet with a relatively small elevator, this results in a gradually increasing pull force from 0 lb. at approximately 0.4g to 25 lb. at zero g.

On airplanes with large elevators, especially those with long chords, the elevator control forces resulting from a stalled tail can be very high, even exceeding the pilots’ strength capability. For example, assume the elevator dimensions of the previous example are scaled up by a factor of 2.

The elevator chord is then doubled, the area is quadrupled, and a given hinge moment coefficient results in 8 times as much control force. If the control force in the previous example was 25 pounds at zero g, the control force for this larger elevator would be 200 pounds. These examples illustrate how the size and design of elevators for certain airplanes determine whether the control forces would be acceptable or hazardous. The test criteria proposed by the FTHWG would identify those airplanes with the hazardous characteristics.

Results of NASA’s Tailplane Icing Program provide a basis for assessing the requirements. Flight tests were conducted in which a test airplane performed a series of pushovers and other maneuvers with and without ice accretions. Even without ice accretions, reversed control forces were sometimes experienced in the pushover maneuvers for some configurations. With the ice accretions, control forces exceeding 100 pounds were experienced in some of the pushovers although the airplane remained controllable. In one test, a departure from controlled flight occurred during a power transition with a critical ice shape and flaps 40. This event involved a sudden nose-down pitch-over from 1g flight reminiscent of the ICTS accident scenarios. The same ice shape had degraded pushover characteristics to the point that a 50-pound pull was required to recover from zero g with flaps 10 and 100 pounds was required with flaps 20. Accordingly, the criteria proposed by the majority of the FTHWG provide an adequate safety margin, and would have identified the aircraft as unacceptable before it ever got to the flaps 40 configuration at which it lost control.

In summary, the position of the majority of the FTHWG, and the recommendation to the FAA by ARAC, is the right balance between cost and benefit. It is adequate to ensure against uncontrollable tailplane stalls. Combined with measures to ensure proper operation of the ice protection systems, it could have prevented the ICTS accidents. On the other hand, the alternative position would impose an unnecessary burden on some manufacturers and their customers.

Other Positions

A flight test pilot, offered the following in considering the position of the majority of the FTHWG:

Reversal of elevator control force versus normal acceleration is not acceptable within the flight envelope. Existing requirements and advisory material addressing elevator control force characteristics (FAR 25.143(f), FAR 25.255(b)(2), the associated guidance material, and the parallel JAR standards) do not allow force reversals. Further, a survey of FAA/JAA type certification (TC) flight test personnel showed that a clear majority did not favor anything less than a push force on the elevator control to zero g.

A nose down pitch upset is, of course, arrested by a natural and familiar nose-up longitudinal control input; but, if the upset is caused by an ice-contaminated tailplane, this upset may be unexpected and occur at low altitude during normal procedures to configure the airplane for approach and landing. There is no other available primary control input to alleviate forces in the pitch axis as there is with rudder to supplement aileron to recover from a roll upset. This fact accentuates the need for applied or induced control forces in all flight regimes to be in a manner that all pilots are accustomed to and expect. Consequently, the requirement to have no longitudinal control force reversal during the ice-contaminated tailplane stall evaluation pushover maneuver is justified.

The term “controllability,” if it is to be used in this case, must have a definition that is not only understandable, but also irrefutable. In an attempt to use the concept of a specific quantitative test for ‘controllability’ in evaluations of the pushover maneuver, the following is offered as an example:

> Controllability must be maintained throughout the maneuver down to zero g or the minimum load factor that can be achieved. The ability to control pitch attitude and load factor should be maintained with no sudden stick force reversal. Gradual stick force reversals within this range of load factors will be acceptable provided that any pitch down characteristic is mild and does not require exceptional pilot skill to control. After a delay of at least one second at zero g or the minimum load factor that can be achieved, it must be possible to promptly recover to level flight from the maneuver with not greater than 1.5 g load factor without configuration change and without exceeding 50 pounds of pull force.

(The specified time delay before recovery is to standardize the flight test procedure and is consistent with autopilot hard-over testing. Fifty pounds is the "one hand" force criteria stated in FAR 25.143.)

In a survey, several FAA flight test pilots stated that, even though an attempt was made to be quantitative, the procedure and criteria in the sub-paragraph noted above are still too vague and will likely lead to differing interpretations across projects and flight test teams. The pilots stated that a push force to zero g represents a suitable level of controllability that would be consistently interpreted. Several other commenters stated that no force reversals would be acceptable to zero g based on realistic operational concerns of tailplane stalls due to turbulence and gusts, and the element of aircrew surprise with ensuing control difficulties.

Low g Manoeuvres – Transport Canada Proposal

JAR 25.143(h)(2)

(2) The aeroplane must be controllable in a pushover manoeuvre down to zero g, or the lowest load factor obtainable if limited by elevator power. It must be shown that a push force is required throughout the manoeuvre down to 0.25g. It must be possible to promptly recover from the manoeuvre without exceeding 50 pounds pull control force, and

and

ACJ 25.21(g)

6.9.3.1 For pushover manoeuvres, it should be shown that the aeroplane is controllable down to zero g or the lowest load factor obtainable if limited by elevator power. It should be shown that a push force is required down to 0.25 g load factor, and that it is possible to promptly recover from the manoeuvre without exceeding 50 pounds pull control force.

Basis for Transport Canada Proposal

Transport Canada supported a different option:

Ice-contaminated tailplane stall/elevator hinge moment reversal has been a significant factor in accidents occurring in icing conditions. Rapid pitch divergence, significant changes in control forces, pilot surprise factor, and possible pilot disorientation in poor visibility that can follow from a tailplane stall/elevator hinge moment reversal can result in loss of pitch control. Coupled with the fact that, due to the nature of the phenomenon, this loss of control will usually occur at low altitude, there is a high probability of an accident.

Transport Canada advisory material dating back to the mid 1980's specified that ± 0.5g longitudinal control had to be demonstrated. In practice, the demonstration was done in a fairly abrupt maneuver that generated a significantly higher transient pitch rate than that associated with the steady normal acceleration. The minimum normal acceleration obtained was usually around 0.25g or less. It was considered that the pitch rate aspect was just as important as the actual normal acceleration in determining whether there were unsafe characteristics associated with tailplane stall. No pass/fail criteria were provided in the Transport Canada guidance except that the characteristics had to be satisfactory.

The accident record on ice contaminated tailplane stall indicates that a significant factor was the surprise to pilots of an abrupt hinge moment reversal and the magnitude of the control force required to recover the airplane to a normal 1g condition. The position supported by the majority of the FTHWG recognizes this controllability issue by limiting the amount of pull force required to promptly recover the airplane from a zero g condition to a 50-pound pull force. In addition, recognizing that positive stability is also important, the majority position requires a push force down to 0.5g.

Accident data available to Transport Canada indicates that aircraft involved in incidents and/or accidents incurred a tailplane stall at approximately 0.3g/0.4g.

Based on this data and Transport Canada's past practice, the position of the majority of the FTHWG appears reasonable, except that the issue of pitch rate is not specifically identified in the criteria. It is recognized that combining pitch rate with a normal acceleration in a requirement is probably too complex, especially for the wide range of aircraft designs encompassed by FAR-25 and the parallel JAR-25 standards. Thus, Transport Canada considers that, if the requirement is only going to specify a 'g' level, then 0.5g for positive stability is inadequate. A value of 0.25g is considered to be a compromise proposal between 0.5g which is the majority position and zero g, which is the position held by the supporters of the FAA, JAA and ALPA proposal.

Transport Canada considers that the proposal of the majority of the FTHWG was acceptable with the following change in text: "... It must be shown that a push force is required throughout the maneuver down to 0.25g load factor ..."

Disposition of Transport Canada Proposal

Those members of the FTHWG represented by the majority proposal of the FTHWG did not support Transport Canada's alternative position, as noted in the following statement developed by the majority:

While it is a compromise between the other two positions (by specifying 0.25g for the push force requirement), it still entails some adverse economic impact, and has the disadvantage that the proposed "0.25g" figure is not related to existing definitions of flight envelopes.

The Transport Canada position does recognize the importance of pitch rate. An abrupt nose-down control input is required to reach zero g. The majority of the FTHWG consider that testing to zero g, however, ensures that high pitch rates are evaluated adequately without the complication of specifying a pitch rate requirement.

The zero g maneuver does not treat all airplanes equally with respect to pitch rate. Airplanes with lower landing speeds will be required to pitch at a much higher rate to attain zero g and experience a proportionately higher tail angle of attack. In some cases the pitch rate could be unreasonably high. Therefore, a proposal to set upper and lower limits on pitch rates required for the pushover would be preferable to changing the g level for the push force requirement.

Sideslips – Industry (FTHWG Report) Proposal

JAR 25.143(h)(3)

(3) *no text*

and

ACJ 25.21(g)

6.9.3.2 For sideslips, changes in longitudinal control force to maintain speed with increasing sideslip should be progressive, with no reversals or sudden discontinuities (see paragraph 6.15.1 of this ACJ).

Sideslips –Transport Canada, FAA, JAA and ALPA Proposal

JAR 25.143(h)(3)

(3) Changes in longitudinal control force to maintain speed with increasing sideslip angle must be progressive with no reversals or sudden discontinuities.

and

ACJ 25.21(g)
6.9.3.2 For sideslips, changes in longitudinal control force to maintain speed with increasing sideslip should be progressive, with no reversals or sudden discontinuities (see paragraph 6.15.1 of this ACJ).

Basis for Transport Canada, FAA, JAA and ALPA Proposal

Although the text for paragraph 6.9.3.2 of the proposed ACJ 25.21(g) was agreed by the entire FTHWG, Transport Canada, supported by FAA, JAA and ALPA, proposed a requirement to evaluate longitudinal handling characteristics during sideslip manoeuvres, in addition to the pushover manoeuvre of proposed JAR 25.143(i)(2):

Transport Canada considers it reasonable to expect that there are no anomalies in longitudinal control force during sideslip maneuvers. This aspect has been of concern to some accident investigators and regulatory personnel. At one time, the FAA proposed that pushover maneuvers be conducted while in sideslips. Transport Canada considered that this requirement was excessive, but recognizing the concern, supported an additional requirement that would specifically assess longitudinal control stick forces while in sideslip maneuvers. Transport Canada considers that a technical consensus was reached on the proposed requirement and the difference with the majority position appears to be whether the requirement appears in advisory material or in the proposed rule.

Transport Canada considers that this is a specific evaluation requirement and hence it is appropriate to place it in the rule rather than in an AC. It is recognized that AC material may also be needed.

Consequently Transport Canada proposes that the following requirement be added: “Changes in longitudinal control force to maintain speed with increasing sideslip angle must be progressive with no reversals or sudden discontinuities.”

Disposition of Transport Canada, FAA, JAA and ALPA Proposal

Those members of the FTHWG represented by the majority proposal of the FTHWG agreed that longitudinal control forces in sideslips could be important but did not support Transport Canada’s alternative position, as noted in the following statement:

Transport Canada and certain other members of the FTHWG consider there should be a rule concerning this. The majority of the FTHWG consider that this aspect is best included in advisory material to alert evaluation pilots to a possible concern.

A consensus position was reached on proposed language that will be included in the advisory material associated with this proposed rule. At this time, however, there does not appear to be sufficient data to establish criteria that are specific enough to stand as a rule.

Note: In the development of the NPA and NPRM, the word "sudden" in the proposed requirement and AC/ACJ material has been changed to "unacceptable."

4.2 Flight Requirements Prior to Normal Operation of the Ice Protection System – JAR 25.143(j)(1) and 25.207(h)(1)

FTHWG (Report) Proposal

JAR 25.143(j)(1)

(1) If normal operation of any ice protection system is dependent upon visual recognition of a specified ice accretion on a reference surface, the requirements of JAR 25.143 are applicable with the ice accretion defined in Appendix C, Part II(e).

JAR 25.207(h)(1)

(1) If normal operation of any ice protection system is dependent upon visual recognition of a specified ice accretion on a reference surface, the requirements of this paragraph except sub-paragraphs (c) and (d) are applicable with the ice accretion defined in Appendix C, Part II(e).

and

ACJ 25.21(g)

a. If normal operation of any ice protection system is dependent on visual recognition of a specified ice accretion on a reference surface (e.g. ice accretion probe, wing leading edge), the ice accretion should not be less than that corresponding to the ice accretion on the reference surface taking into account probable flight crew delays in recognition of the specified ice accretion and operation of the system, determined as follows:

i. the specified accretion, plus

ii. the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part I(a), plus

iii. the ice accretion during the system response time.

b. If normal operation of any ice protection system is dependent on visual recognition of the first indication of ice accretion on a reference surface (e.g. ice accretion probe), the ice accretion should not be less than that corresponding to the ice accretion on the reference surface taking into account probable flight crew delays in recognition of the ice accreted and operation of the system, determined as follows:

i. the ice accretion corresponding to first indication on the reference surface, plus

ii. the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part I(a), plus

iii. the ice accretion during the system response time.

ALPA Proposal

JAR 25.143(j)(1)

(1) If normal operation of any ice protection system is dependent upon visual recognition of ~~a specified~~ ice accretion ~~on a reference surface~~, the requirements of JAR 25.143 are applicable with the ice accretion defined in Appendix C, Part II(e).

JAR 25.143(h)(1)

(1) If normal operation of any ice protection system is dependent upon visual recognition of ~~a specified~~ ice accretion ~~on a reference surface~~, the requirements of this paragraph except sub-paragraphs (c) and (d) are applicable with the ice accretion defined in Appendix C, Part II(e).

and

ACJ 25.21(g)

a. If normal operation of any ice protection system is dependent on visual recognition of ice accretion (e.g. ice accretion probe, wing leading edge), the ice accretion should not be less than that corresponding to the ice accretion on the reference surface taking into account probable flight crew delays in recognition of the specified ice accretion and operation of the system, determined as follows:

i. the specified accretion, plus

ii. the ice accretion equivalent to two minutes of operation in the Continuous Maximum icing conditions of Appendix C, Part I(a), plus

iii. the ice accretion during the system response time.

b. [RESERVED]

Basis for ALPA Proposal

The Airline Pilots Association (ALPA) considers conditions (a) (specified amount prior to activation) and (b) (activation at first indication of ice accretion) of Sub-paragraph A1.2.3.3 of the associated advisory material to be the same situation with a smaller amount required for condition (b) – both are means of visual recognition that require the flight crew to monitor conditions outside the cockpit. Consequently, ALPA does not believe there is any technical reason to justify the difference in the requirements of JAR 25.143 and JAR 25.207 for the two means of visual recognition described in sub-paragraphs A1.2.3.3.a and (b) of the advisory material. Since checking outside the cockpit (not even close to a primary Instrument Meteorological Conditions (IMC) visual scan pattern) in all visibility and lighting conditions is required for both (a) and (b), the airplane should have the same basic maneuver capabilities and stall protection with the ice accretion that results from the two different means of visual ice recognition.

The 30 second and 10 second times of the associated advisory material are clearly pilot reaction times. ALPA can accept a 10-second reaction time following indication from an ice detection system if the indication meets appropriate warning system criteria for reliability and clarity. As it stands now, the indication could be a light on the overhead panel, which would clearly not be appropriate for a 10-second time delay.

ALPA can accept the reduced maneuver and stall requirements for conditions described by sub-paragraphs A1.2.3.3.c through (e) of the associated advisory material (i.e. not dependent on pilot visual recognition of ice accretion), even though the 30 second reaction time is a stretch for the "pilot identification of icing conditions" case of sub-paragraph A1.2.3.3.c –pilots would have to keep one eye on the TAT gauge whenever in visible moisture and react within 30 seconds to a change on a gauge that is not in anyone's primary scan. However, ALPA cannot accept 30 seconds for the pilot delay with indications outside the cockpit. ALPA would reluctantly accept the 2 minutes as originally proposed because of the precedent in FAR 33.77; although ALPA suspects that any human factors study would certainly produce a longer time between the specified accumulation and recognition by pilots. The problem is not in the time to react to an ice accretion after it is observed. The problem is ensuring that no more than something around 20 seconds passes between checks of the representative surface. Many flights operate for extended periods without ice accumulation in conditions conducive to ice formation. Repeated "dry holes" discourage frequent rechecks. Cockpit workload during the more critical holding and approach phases of flight further decreases the chance that the specified amount of ice will always be visually acquired within 20 seconds. The 5/27/99 Canadian Transportation Safety Board (CTSB) report on the Air Canada RJ accident in Fredericton New Brunswick, clearly shows these workload issues.

A FTHWG industry member has stated that, "If the height of ice is an important factor for drag increase, it is not the major factor for handling qualities." If this is so, the additional ice accreted during the more representative recognition time proposed by ALPA for pilot visual recognition of ice accretion would not have a major effect. Additionally, as the chairman of the Ice Protection Harmonization Working Group (IPHWG) briefed the TAEIG on June 30, 1999, a significant number of IPHWG members feel the rules being proposed by the FTHWG for flight in icing conditions eliminate the need for the operational rule that is nearly finalized by the IPHWG. The IPHWG-proposed rule (driven by incident/accident data analysis) responds to the critical problem of operations with ice accumulation prior to system operation. The proposed rule requires "in conditions conducive to airframe icing" either an active detection and warning system, or operation of the icing system while in holding or on approach, independent of accumulation." In other words, the data shows that pilot detection of icing has proven inadequate to prevent icing incidents/accidents at higher angles-of-attack (during holding and approach).

In consideration of the above discussion, ALPA proposes to modify JAR 25.143(j)(1) and 25.207(h)(1) to state "visual recognition of ice accretion" only. The associated advisory material would also be modified to reflect this change plus an increase in the delay time from 30 seconds to two minutes. ALPA proposes to reword JAR 25.143(j)(1) and 25.207(h)(1) as follows:

"JAR 25.143(j)(1) If normal operation of any ice protection system is dependent upon visual recognition of ~~a specified~~ ice accretion ~~on a reference surface~~, the requirements of JAR 25.143 are applicable with the ice accretion defined in Appendix C, part II(e)."

"JAR 25.207(h)(1) If normal operation of any ice protection system is dependent upon visual recognition of ~~a specified~~ ice accretion ~~on a reference surface~~, the requirements of this paragraph, except sub-paragraphs (c) and (d), are applicable with the ice accretion defined in Appendix C, part II(e)."

<u>Disposition of ALPA Proposal</u>

This alternative was not supported by the majority of the FTHWG for the following reasons:

Between conditions (a) and (b) of Paragraph A1.2.c(3), as discussed during the FTHWG deliberations, there are significant differences in the aerodynamic effects on an airplane. Condition (a) is best exemplified by airplane models with anti-icing boots where the published procedure calls for a specified amount of ice build-up prior to operation of the ice protection system, a process that is repeated frequently during an icing encounter. In this case the airplane is assured of being operated with some level of aerodynamic degradation prior to activation of the ice protection system. Condition (b) is best exemplified by airplane models that are equipped with an ice accretion probe in the pilot's external field of vision, where the published procedure calls for operation of the ice protection system at the first indication of ice buildup on the accretion probe. Such accretion probes, or an equivalent such as a windshield wiper post, are highly efficient ice collectors, and typically will accrete visible ice prior to ice accretion on aerodynamic surfaces. Therefore with condition (b) there may be little or no ice buildup on aerodynamic surfaces prior to normal operation of the ice protection system, and therefore little or no aerodynamic degradation. Conditions (a) and (b) are distinctly different.

The ice-accumulation times in the advisory material do not directly correspond to pilot reaction times, but instead represent FTHWG-consensus time increments to be added during the process of determining likely ice shapes that may be accumulated prior to normal operation of the ice protection system. These time increments are to be applied assuming the Maximum Continuous icing conditions of Appendix C – conditions where the flight crew is expected to exercise a high level of vigilance. In lesser icing conditions considerably more time could be required in order to accumulate the same ice shapes.

Supposition regarding the possible outcome of the IPHWG task that deals with ice detector requirements does not invalidate the FTHWG-proposed changes to Subpart B particularly since, in addition to developing an operational regulation, the IPHWG is understood to be producing an airworthiness regulation associated with ice detectors.

4.3 Ice Accretions

FTHWG (Report) Proposal – JAR-25 Appendix C, Part II (a) and ACJ 25.21(g)

JAR-25 Appendix C, Part II (a)

(a) *Ice accretions - General*. JAR 25.21(g) states that in the icing conditions of Appendix C the applicable requirements of subpart B must be met (except as specified otherwise). The most critical ice accretion in terms of handling characteristics and/or performance for each flight phase must be determined, taking into consideration the atmospheric conditions of part I of this Appendix, and the flight conditions (e.g. configuration, speed, angle-of-attack, and altitude). The following ice accretions must be determined:

and

ACJ 25.21(g)

A1.1 *General.* The most critical ice accretion in terms of handling characteristics and/or performance for each flight phase should be determined. The parameters to be considered include:

- the flight conditions (e.g. aeroplane configuration, speed, angle of attack, altitude) and

- the icing conditions of Appendix C to JAR-25 (e.g. temperature, liquid water content, mean effective drop diameter).

ALPA Proposal

JAR-25 Appendix C, Part II (a)

(a) *Ice accretions - General*. JAR 25.21(g) states that in the icing conditions of Appendix C the applicable requirements of subpart B must be met (except as specified otherwise). The most critical ice accretion in terms of handling characteristics and/or performance for each flight phase must be determined, taking into consideration the atmospheric conditions of part I of this Appendix, and all flight conditions within the operational limits of the aeroplane (e.g. configuration, configuration changes, speed, angle-of-attack, and altitude). The following ice accretions must be determined:

and

ACJ 25.21(g)

A1.1 *General.* The most critical ice accretion in terms of handling characteristics and/or performance for each flight phase should be determined. The parameters to be considered include:

- all flight conditions within the operational limits of the aeroplane (e.g. aeroplane configuration, configuration changes, speed, angle of attack, altitude) and

- the icing conditions of Appendix C to JAR-25 (e.g., temperature, liquid water content, mean effective drop diameter).

<u>Basis for ALPA Proposal</u>

As a member of the FTHWG, the Airline Pilots Association (ALPA) representative did not consider that the combination of the proposed regulatory changes and associated advisory material provided a definitive enough description of the required ice accretions, particularly with regard to the variables that must be considered in determining the critical ice shape for a particular flight phase. This alternative proposal was as follows:

The addition of the clarifying statements, '. . . and all flight conditions within the operational limits of the airplane' and '. . . configuration changes' to the critical ice accretion requirements is intended to ensure that the full range of possible accretion locations for atmospheric conditions defined by this Appendix C are considered.

The primary parameter of concern is location of the ice accretion on the aerofoil. The position held by the majority of the FTHWG is that 'flight conditions' (e.g. configuration, speed, angle-of-attack, and altitude) will provide for the most critical accretion. The proposed change merely ensures that the objective stated by the majority is, in fact, achieved.

In NASA research accomplished following the ATR-72 accident at Roselawn, Indiana, in 1994, and discussed in the NTSB's report, the observation that decreasing AOA causes an increase in aft ice accretion limit on the upper surface of an aerofoil is reported. Likewise, the fact that airflow separation on the negative pressure side (upper surface for a typical wing) is caused by ice accretions on the upper surface is discussed. Research performed by M. B. Bragg and others at the University of Illinois has demonstrated significant variation in the effects on aerofoil aerodynamics of a simulated ice shape depending upon its location on the negative pressure side of the aerofoil.

Differing airspeeds and high lift device configurations significantly change the angle-of-attack and, consequently, the location of the stagnation point around which any ice accretion forms on an aerofoil. For normal operation, this should make no difference on surfaces that are protected by the icing system. But for unprotected surfaces, in the failure case and for ice that accumulates prior to normal system operation, changing the location of ice on the suction side of the aerofoil may be significant. Procedural restrictions (i.e. no holding with flaps extended, speed or configuration restrictions in case of ice system failure, etc.) could be used to limit the configurations necessary to determine the most critical ice accretion. However, the full range of possible accumulation locations must be considered.

In their report on the Embraer Model EMB 120 accident at Monroe, Michigan, the NTSB concluded that:

> The icing certification process has been inadequate because it has not required manufacturers to demonstrate the airplane's flight handling and stall characteristics under a sufficiently realistic range of adverse accretion/flight handling conditions. (Finding #27)

Adoption of this critical accretion requirement clarification is necessary to fully answer this adverse finding and improve safety.

Disposition of ALPA Proposal

The recommendations submitted by the FTHWG, and this proposed rule, consider ice accretions for all phases of flight and all configurations of high lift devices. The proposed rule requires that the effects of the ice accretion during the phases of flight with high lift devices extended be accounted for. The associated advisory material specifically recommends that natural icing flight testing with high lift devices extended in the approach and landing conditions be conducted.

The research referred to in the alternative proposal determined the effect on lift and drag of a spoiler-like protuberance located at various chord locations of a two dimensional aerofoil. These data do not support the alternative position because no data were presented in the references to connect either the protuberance shape or locations with airplane flight conditions or icing conditions, either inside or outside of Appendix C.

There were no data showing the effect of the protuberance on an aerofoil with high lift devices extended.

The effect of a protuberance on a two-dimensional aerofoil is much larger than the effect of a similar protuberance on a complete airplane with high lift devices extended, and the effect of a protuberance diminishes with increasing airplane size.

The effect of ice accretions similar to the protuberances tested in the referenced report were also considered by the FTHWG when it discussed ice accreted in conditions outside of Appendix C. The majority of the FTHWG recommended not including these accretions in the recommendations because the only icing design envelope available is Appendix C. Additionally, this issue falls outside of the FTHWG's tasking by the FAA. However, a different ARAC Working Group may be considering this issue as part of its task.

5 Economic impact evaluation assessment

Historically, it has always been difficult to cost accurately a programme for certification for flight in icing conditions. Although, most usually, the programme is based on the use of artificial ice shapes, validation of the performance of the aeroplane and the ice protection system needs to be performed in natural icing conditions. There is an element of luck involved in getting favourable meteorological conditions at the right time and in the right place.

This NPA concentrates on the performance and handling qualities required in icing conditions and so this economic impact assessment addresses only that part of the certification programme for flight in icing conditions.

This economic impact assessment is broken into two stages, reflecting the historical development of requirements, policies and certification practices for approval for flight in icing conditions. In either case, the adoption of the proposals of this NPA and the corresponding FAA NPRM will provide benefits arising from a harmonised approach to certification for flight in icing conditions by the JAA, FAA and Transport Canada.

5.1 Economic impact of these proposals compared to the text of current CS-25.

This is very difficult to quantify because the baseline standard is not clearly defined. It depends on the interpretation of "to safely operate" in CS 25.1419. If this is interpreted as meeting full Subpart B standards in the icing conditions of Appendix C of CS-25, as it could be, the proposals of this NPA are alleviating. The usual interpretation has been less stringent than this but has not been clearly set down in the past. This lack of guidance was the rationale for developing, firstly NPA 25F-219 and, latterly, the proposals of this NPA. Consequently, it is difficult to make a definitive statement regarding the economic impact of these proposals. However, it is clear that the economic impact is higher than that arising from a less stringent interpretation of “to safely operate” in CS 25.1419. Conversely, there is an anticipated increase in safety arising from a more thorough and harmonised approach to certification of flight in icing conditions.

5.2 Economic impact of these proposals compared to current JAA certification practice.

Current JAA practice is to apply TGM 25/02 for certification for flight in icing conditions. This TGM calls up NPA 25F-219, Issue 2, dated 22 January 1992 which was published for comment in 1993. Whilst this current NPA is more detailed than NPA 25F-219, the proposals are broadly similar in scope and standard and the intended safety level is the same as TGM 25/02. Hence, it is expected that there would not be a significant increase in the cost of an icing certification programme if carried out to these proposals rather than TGM 25/02.

D. JAA NPA 25BEF-332 COMMENT-RESPONSE DOCUMENT

NPA 25B,E,F-332 Draft Final Rule, Version 2 18 August 2003

1. Introduction

Notice of Proposed Amendment 25B,E,F-332, sponsored by the Flight Steering Group (FStG), was published for comment on 1 June 2002. The FStG, at meetings in October 2002, February and June 2003, has considered the comments received on the NPA and the RST's comments on the first version of the draft Final Rule. In consequence, some changes have been accepted for the Final Rule. This Comment and Response Document reviews the comments received and proposes that a final rule be adopted, based on the NPA 25B,E,F-332 as published, with amendments agreed by the FStG.

2. Background

NPA 25B,E,F-332, proposing new and revised requirements and advisory material for JAR-25, details the minimum aeroplane performance and handling qualities necessary for certification for flight in the icing conditions of JAR-25 Appendix C. It also introduces new material into JAR-25 Appendix C to enable appropriate ice accretions to be defined for these revised requirements. It is based upon a report prepared by the Flight Test Harmonisation Working Group (FTHWG).

3. Discussion of Comments

Responses to the consultation on NPA 25B,E,F-332 were received from the following organisations:

ACG, Austria
AECMA, Belgium
AIA, USA
ALPA, USA
Bombardier Aerospace, Canada
CAA, UK
Cessna, USA
DGAC, France
Embraer, Brazil
ERAA, UK
LBA, Germany
NRC, Canada
Raytheon, USA
SLV, Denmark

Four of these organisations offered no comments on the NPA.

Proposals 3 and 7

One comment was received to the effect that the words "is increased" in proposed JAR 25.105(a)(2)(i) lack clarity and it proposed that they should be changed to "exceeds that in non-icing conditions". The commenter made the same point against Proposal 7 regarding paragraphs JAR 25.121(b)(2)(ii)(A) and JAR 25.121(c)(2)(ii)(A). These comments are accepted.

Proposal 5

One commenter proposed that JAR 25.111(c)(5)(i) and (ii) be changed so that the reference to 400 ft above the take-off surface be changed to reflect the activation point of the ice protection system. The FStG does not accept this comment as the ice protection systems are not always activated at this point and the change could be interpreted as mandating operation of the system at 400 ft.

Proposal 8

One comment was made that proposed JAR 25.123(b)(2)(i) should be modified by the addition of "more than" before "the greater of" so that the phraseology is consistent with other requirements addressing speed increments. This comment is accepted.

Proposal 10

One commenter proposed that V_{MCA} or V_{MCL} be specifically revalidated for flight in icing conditions. This was discussed in some detail in the FTHWG meetings but was finally not considered necessary. Instead, proposed JAR 25.143(c)(1) requires that it be demonstrated that the aeroplane is safely controllable and manoeuvrable in icing conditions with the critical engine inoperative at the minimum take-off speed, during an approach and go-around, and during an approach and landing. Advisory Material contained in the proposed ACJ 25.21(g) provides further guidance regarding the speeds and procedures, and the critical ice accretion, appropriate to the phase of flight. The comment is thus not accepted.

The same commenter made suggestions for change for JAR 25.143(i)(1). He proposed that the additional requirement, that "Sandpaper Ice" be specifically considered for aeroplanes with unpowered controls, should be moved to advisory material as, traditionally, the requirements make no distinction regarding types of flight control systems. Whilst it is agreed that, generally, the requirements are applicable to all types of control systems, moving this material as suggested would not be compatible with the agreed approach to rulemaking, which does not allow the inclusion of requirements in advisory material. He also suggested that "Sandpaper Ice", which is a prescriptive ice shape, is at odds with the other ice accretion definitions proposed in Appendix C, Part II(a). Whilst it is agreed that there is some element of inconsistency, there are good grounds for this approach as the combination of "Sandpaper Ice" and unpowered controls has been shown by service experience to be a critical combination for controllability. The comments are therefore not accepted.

The commenter continued that the push-over manoeuvre test of JAR 25.143(i)(1) is specific to the flight in icing case as there is no comparable test for non-icing conditions. Furthermore, the test is not fully prescriptive, allowing compliance by a range of "push-over" manoeuvres. Whilst these statements are not disputed, the test, which has been used now for many years, has shown itself to be a good indicator of potential controllability problems for the critical case of flight in icing conditions. The proposals are not amended as a result of these comments.

The same commenter suggested that proposed JAR 25.143(i)(1) should be revised for consistency with the rest of JAR-25. The word "unacceptable" should be defined as, for example, in JAR 25.177(b) where there is an implicit definition of unacceptability. However, there are many examples of the use of non-specific terms in JAR-25; they are particularly difficult to avoid in requirements that demand qualitative judgement.

The commenter continued that proposed JAR 25.143(i)(2) needs the support of a "non-icing conditions" baseline requirement. However, flight in icing conditions will be the critical case for this test hence the FStG does not agree with the comment.

Several commenters objected to the proposed texts for JAR 25.143(i)(2) and (3) and the corresponding advisory material in ACJ 25.21(g) for JAR 25.143(i)(2). These requirements address longitudinal controllability and are identified as non-consensus issues in the NPA. These commenters supported the texts proposed by the manufacturers in the FTHWG. The FStG, following its authorised procedures, is not able to come to a position on these comments as the group has the same manufacturers/authorities split on these issues as did the FTHWG. Resolution of these comments must therefore be left to Central JAA.

One comment was received supporting the Airline Pilots Association (ALPA) position documented in the Appendix to the NPA on the proposed JAR 25.143(j)(1) and the appropriate advisory material in ACJ 25.21(g) (also a non-consensus issue.) However, several other commenters expressed their support for the position taken in the NPA. The comment is further addressed under Proposal 26.

One commenter asked if proposed JAR 25.143(j)(1) and (2) (note not (k) as quoted by the commenter) should be clarified by the addition of "the point of activation" in relation to normal operation of ice protection systems so that both sentences begin "If the point of activation of normal operation…" The comment is accepted in principle but the FStG prefers to reword the proposals as "If activation of normal operation…" For consistency, the same change should be made to JAR 25.207(h) (Proposal 11) and the corresponding text in paragraph A.1.2.3.3 of the proposed ACJ 25.21(g) (Proposal 26.)

As a result of the change of paragraph numbering in Proposal 10, a commenter noted that JAR 25.107(c)(3) should be amended to reference JAR 25.143(h). This comment is accepted.

Proposal 11

One commenter proposed that, for clarity, the text "(as defined in JAR 25.201(d))" contained in the current JAR 25.207(f) should also be included in the proposed JAR 25.207(e). The comment is agreed in principle but it is considered that this text need only be given once, on the first occasion it appears, so the FStG prefers to move the text to JAR 25.207(e).

As a result of a comment accepted for JAR 25.143(j)(1) and (2) (Proposal 10), for consistency, JAR 25.207(h)(1) and (2) and the corresponding text in paragraph A.1.2.3.3 of the proposed ACJ 25.21(g) (Proposal 26) should be amended to start "If activation of normal operation…".

At the RST meeting in March 2003, a comment was received that the proposed JAR 25.207(h)(2) and its associated advisory material are in conflict. This comment is accepted and the FStG reviewed the proposals. It concluded that the advisory material reflected the final intent of the FTHWG and that a corresponding change to the rule was overlooked. The FStG developed revised texts for the requirement and the ACJ that better reflected the FTHWG's proposals.

Another comment was received supporting the ALPA position documented in the Appendix to the NPA on the proposed JAR 25.207(h)(1) and the appropriate advisory material contained in ACJ 25.21(g) (a non-consensus issue.) However, several other commenters expressed their support for the position taken in the NPA. The comment is further addressed under Proposal 26.

Proposal 13

One commenter suggested that reference should be made to M_{FC}, or another Mach limitation, and also proposed the deletion of the 300 kts CAS criterion, such that the upper speed for stability characteristics in icing conditions would be the lower of V_{FC} or another speed at which the airframe will be free of ice accretion, as substantiated by the applicant. These comments are not accepted. The requirement is expressed in terms of speed, not Mach number, as it is the dynamic pressure that provides the mechanism for ice shedding, and the reference to 300 kts CAS serves to limit what could otherwise be an excessively stringent requirement.

Another commenter suggested making proposed JAR 25.253(c)(3) more specific as to why the ice should detach from the airframe. He proposed to add "due to self-induced ice shedding" to the end of the sentence. The FStG accepts that an explanation would assist clarity but considers that "due to the effects of increased dynamic pressure" is more precise.

Additionally, NPA 25B-333 has been accepted as a Final Rule during the disposition of the comments on NPA 25B,E,F-332. The NPA 25B-333 Final Rule includes a change to JAR 25.253(b), the definition of V_{FC}/M_{FC}, to reflect a re-numbering of JAR 25.177 in the same NPA. Although not raised as a comment, this change should be reflected in the Final Rule resulting from this NPA.

Proposal 16

One commenter supported the non-consensus position taken by ALPA in the FTHWG report on the proposed Appendix C, Part II, paragraph (a) regarding possible airspeed and configuration changes following ice accretion in a specific condition. ALPA's arguments are reproduced in the Appendix to the NPA. However, the FStG supports the majority position in the FTHWG, that the proposed text is sufficient to cover operational scenarios and that the concerns expressed by the commenter arise from ice accretions obtained in undefined icing conditions, possibly outside Appendix C. These icing conditions are being addressed by the Ice Protection Harmonisation Working Group (IPHWG) and are outside the Terms of Reference of the FTHWG.

One commenter proposed the addition of the word "occurring" following the comma in paragraph (a)(1) of Appendix C as clarification. This comment is accepted.

Proposal 26, ACJ 25.21(g)

One commenter proposed a revised text for paragraph A.1.2.1.3 of Appendix 1 to the proposed ACJ 25.21(g) to add clarification regarding the maximum height of the ice shape. Although this was discussed in the FTHWG, the final report contains no such clarification as the FTHWG considered that this was an interface issue with the IPHWG that would require further work. Hence, the FStG does not accept the comment but lately became aware that the IPHWG has developed a new text for the definition of holding ice that is expected to be included in the FAA NPRM corresponding to this NPA. It was considered that it is not legitimate to change the Final Rule to reflect this new text but that the earliest opportunity should be taken to ensure a consistent definition of holding ice.

Regarding Appendix I, A1.2.3.3, one commenter stated that it is possible that ice may accrete on the airframe with no indication on ice probes or detection systems. Additionally, it is sometimes difficult to detect ice accretions so that procedures that are based on visual observation should be considered very carefully. The commenter offered no suggestions for an improved text so the FStG can only note these comments.

As a result of a comment accepted for JAR 25.143(j)(1) and (2) (Proposal 10), for consistency, the corresponding text in paragraphs A.1.2.3.3 (a) - (e) of the proposed ACJ 25.21(g) should be amended to start "If activation of normal operation…".

Another commenter supported the non-consensus position taken by ALPA in the FTHWG report regarding the difficulties in recognising ice accretions and, in particular, the additional accretion times appropriate to ice protection systems that rely on pilot observation of ice accretion. ALPA's arguments for using 120 seconds, and not 30 seconds, are reproduced in an Appendix to the NPA. The commenter contends that no scientific or engineering rationale supporting 30 seconds, rather than 120 seconds, is given in the NPA. However, the FStG's view is that the 30 seconds should be considered as a standard for determination of a specific ice accretion associated with the most severe Appendix C icing conditions and does not directly represent a pilot response time in typical icing conditions. The proposals are thus not changed in this respect.

During the discussion on the comments, a query arose regarding the power setting to be used in the stall demonstrations of paragraph 6.17.2(d). For clarification, it was agreed to add a sentence after "stall speed determination" as follows:

"For power-on stalls, use the power setting as defined in JAR 25.201(a)(2) but with ice accretions on the aeroplane."

Additionally, during the development of the Final Rule, three non-significant changes to the ACJ text were identified for consistency:

Paragraph 4.4.1 Change "thrust" to "power or thrust"

Paragraph 4.7.a Change "power" to "power or thrust"

Paragraph 4.8.2.2 Change "icing" to "icing conditions".

4. Changes to the NPA Proposals

To accommodate the comments, further amend the proposed rules circulated in NPA 25B,E,F-332 as follows (changes to the NPA text indicated by bolding and strike-though):

Proposal 3, JAR 25.105(a)(2)(i).

"(a) The take-off speeds described in JAR 25.107, the accelerate-stop distance described in JAR 25.109, the take-off path described in JAR 25.111, the take-off distance and take-off run described in JAR 25.113, and the net take-off flight path described in JAR 25.115, must be in the selected configuration for take-off at each weight, altitude, and ambient temperature within the operational limits selected by the applicant –

(1) In non-icing conditions; and

(2) In icing conditions, if in the configuration of JAR 25.121(b) with the “Take-off Ice” accretion defined in Appendix C:

(i) The stall speed at maximum take-off weight ~~is increased~~ **exceeds that in non-icing conditions** by more than the greater of 3 knots CAS or 3% V_{SR}; or…"

(ii) The degradation of the gradient of climb determined in accordance with JAR 25.121(b) is greater than one-half of the applicable actual-to-net take-off flight path gradient reduction defined in JAR 25.115(b)."

Proposal 7, JAR 25.121(b)(2).

"(b) Take-off; landing gear retracted. …

(2) The requirements of sub-paragraph (b)(1) of this paragraph must be met:

(i) In non-icing conditions; and

(ii) In icing conditions with the "Take-off Ice" accretion defined in Appendix C, if in the configuration of JAR 25.121(b) with the "Take-off Ice" accretion:

(A) The stall speed at maximum take-off weight ~~is increased~~ **exceeds that in non-icing conditions** by more than the greater of 3 knots CAS or 3% V_{SR}; or

(B) The degradation of the gradient of climb determined in accordance with JAR 25.121(b) is greater than one-half of the applicable actual-to-net take-off flight path gradient reduction defined in JAR 25.115(b).

(c) Final take-off. …

(2) The requirements of sub-paragraph (c)(1) of this paragraph must be met:

(i) In non-icing conditions; and

(ii) In icing conditions with the "Final Take-off Ice" accretion defined in Appendix C, if in the configuration of JAR 25.121(b) with the "Take-off Ice" accretion:

(A) The stall speed at maximum take-off weight ~~is increased~~ **exceeds that in non-icing conditions** by more than the greater of 3 knots CAS or 3% V_{SR}; or

(B) The degradation of the gradient of climb determined in accordance with JAR 25.121(b) is greater than one-half of the applicable actual-to-net take-off flight path gradient reduction defined in JAR 25.115(b)."

Proposal 8, JAR 25.123(b)(2)(i)

"(b) The one-engine-inoperative net flight path data must represent the actual climb performance diminished by a gradient of climb of 1.1% for two-engined aeroplanes, 1.4% for three-engined aeroplanes, and 1.6% for four-engined aeroplanes~~.~~ -

(1) In non-icing conditions; and

(2) In icing conditions with the “En-route Ice” accretion defined in Appendix C, if:

(i) $1.18V_{SR}$ with the “En-route Ice ” accretion exceeds the en-route speed selected in non-icing conditions by **more than** the greater of 3 knots CAS or 3% V_{SR}, or

(ii) The degradation of the gradient of climb is greater than one-half of the applicable actual-to-net flight path reduction defined in sub-paragraph (b) of this paragraph."

Proposal 10, JAR 25.143

"(j) For flight in icing conditions prior to **activation of** normal operation of the ice protection system, the following apply:

(1) If **activation of** normal operation of any ice protection system is dependent upon visual recognition of a specified ice accretion on a reference surface, the requirements of JAR 25.143 are applicable with the ice accretion defined in Appendix C, Part II(e).

(2) If **activation of** normal operation of any ice protection system is dependent upon means of recognition other than that defined in sub-paragraph (j)(1) of this paragraph, it must be shown that the aeroplane is controllable in a pull-up manoeuvre up to 1.5g and there is no longitudinal control force reversal during a pushover manoeuvre down to 0.5g with the ice accretion defined in Appendix C, Part II(e)."

Amend the cross-reference in JAR 25.107(c)(3) to JAR 25.143(h).

Proposal 11, JAR 25.207

"(e) In icing conditions, when the speed is reduced at decelerations of up to 1 kt/sec, the stall warning margin in straight and turning flight must be sufficient to allow the pilot to prevent stalling **(as defined in JAR 25.201(d))** when recovery, using the same test technique as for the non-contaminated aeroplane, is initiated not less than 3 seconds after the onset of stall warning, with -

(1) The “Holding Ice” accretion described in Appendix C for the en-route, holding, approach, landing, and go-around high-lift configurations; and

(2) The more critical of the "Take-off Ice" and "Final Take-off Ice" accretions described in Appendix C for each high-lift configuration used in the take-off phase.

(f) The stall warning margin must be sufficient to allow the pilot to prevent stalling ~~(as defined in JAR 25.201(d))~~ when recovery is initiated not less than one second after the onset of stall warning in slow-down turns with at least 1.5g load factor normal to the flight path and airspeed deceleration rates of at least 2 knots per second, with the flaps and landing gear in any normal position, with the aeroplane trimmed for straight flight at a speed of 1.3 V_{SR}, and with the power or thrust necessary to maintain level flight at 1.3 V_{SR}. When demonstrating compliance with this sub-paragraph with ice accretions, the same test technique as for the aeroplane without ice accretions must be used for recovery.

(g) Stall warning must ....

(h) For flight in icing conditions prior to **activation of** normal operation of the ice protection system, the following apply:

(1) If **activation of** normal operation of any ice protection system is dependent upon visual recognition of a specified ice accretion on a reference surface, the requirements of this paragraph except sub-paragraphs (c) and (d) are applicable with the ice accretion defined in Appendix C, Part II(e).

(2) If **activation of** normal operation of any ice protection system is dependent upon means of recognition other than that defined in sub-paragraph (h)(1) of this paragraph**:**

(i) If stall warning is provided by the same means as for flight in non-icing conditions, when the speed is reduced at **rates not exceeding** 1 kt/sec, the stall warning margin in straight and turning flight must be sufficient to allow the pilot to prevent stalling, using the same test technique as for the non-contaminated aeroplane, **without encountering any adverse characteristics when recovery** is initiated not less than 1 second after the onset of stall warning, with the ice accretion defined in Appendix C, Part II(e).

(ii) If stall warning is provided by a different means than for flight in non-icing conditions, when the speed is reduced at rates not exceeding 1 kt/sec, the stall warning in straight and turning flight must be sufficient to allow the pilot to prevent stalling, using the same test technique as for the non-contaminated aeroplane, without encountering any adverse characteristics when recovery is initiated not less than 3 seconds after the onset of stall warning, with the ice accretion defined in Appendix C, Part II(e). Additionally, compliance with JAR 25.203 must be shown using the demonstration means prescribed by JAR 25.201, except that the 3 kts/sec airspeed deceleration rates of JAR 25.201(c)(2) need not be demonstrated."

Proposal 13, JAR 25.253(b) and(c)

"(b) *Maximum speed for stability characteristics, V_{FC}/M_{FC}.* V_{FC}/M_{FC} is the maximum speed at which the requirements of JAR 25.143(g), 25.147(e), 25.175(b)(1), 25.177**(a) through (c)**, and 25.181 must be met with wing-flaps and landing gear retracted. Except as noted in JAR 25.253(c), it may not be less than a speed midway between V_{MO}/M_{MO} and V_{DF}/M_{DF}, except that, for altitudes where Mach number is the limiting factor, M_{FC} need not exceed the Mach number at which effective speed warning occurs.

(c) The maximum speed for stability characteristics with the ice accretions defined in Appendix C, at which the requirements of JAR 25.143(g), 25.147(e), 25.175(b)(1), 25.177 and 25.181 must be met, is the lower of:

(1) 300 knots CAS,

(2) $V_{FC,}$ or

(3) A speed at which it is demonstrated that the airframe will be free of ice accretion **due to the effects of increased dynamic pressure**."

Proposal 16, JAR-25 Appendix C, Part II, paragraph (a)(1)

"(1) Take-off Ice is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, **occurring** between lift-off and 400 ft above the take-off surface, assuming accretion starts at lift-off in the take-off maximum icing conditions of Part I, paragraph (c) of this Appendix. "

Proposal 26, ACJ 25.21(g)

Paragraph 4.4.1 Change "thrust" to "**power or** thrust"

Paragraph 4.7.a Change "power" to "power **or thrust**"

Paragraph 4.8.2.2 Change "icing" to "icing **conditions**"

Add a sentence after "stall speed determination" in paragraph 6.17.2(d) as follows:

"For power-on stalls, use the power setting as defined in JAR 25.201(a)(2) but with ice accretions on the aeroplane."

Reword paragraph 6.18.3.2.b as follows:

b. At decelerations of up to 1 knot per second, reduce the speed to stall warning plus 1 second, and demonstrate **that stalling can be prevented** using the same test technique as for the non-contaminated aeroplane, without encountering any adverse characteristics **(e.g., a rapid roll-off)**. **As required by JAR 25.207(h)(2)(ii), w**here stall warning is provided by a different means than for the aeroplane without ice accretion, ~~and~~ the stall characteristics ~~are~~ **must** ~~demonstrated to~~ be satisfactory~~,~~ **and** the delay **must**~~should~~ be at least 3 seconds."

Further amend the introductory text of A.1.2.3.3 (a) – (e) to read "If **activation of** normal operation…"

5. Conclusion

Based on the comments received, it is proposed that the NPA be adopted as published for comment but with additional amendments, as given in section 4 above.