Federal Aviation Administration
Aviation Rulemaking Advisory Committee

Transport Airplane and Engine Issue Area
Flight Test Harmonization Working Group

Task 3 – Flight Characteristics in Icing Conditions

Task Assignment

Aviation Rulemaking Advisory Committee; Transport Airplane and Engine Issues

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of new task assignment for the Aviation Rulemaking Advisory Committee.

SUMMARY: Notice is given of new task assignments for the Flight Test Working Group of the Aviation Rulemaking Advisory Committee (ARAC). This notice informs the public of the activities of the ARAC.

FOR FURTHER INFORMATION CONTACT: Michael H. Borfitz, Assistant Executive Director, Aviation Rulemaking Advisory Committee, Transport Airplane and Engine Issues, FAA Engine & Propeller Directorate, 12 New England Executive Park, Burlington, Massachusetts 01803; telephone (617) 238–7110, fax (617) 238–7199.

SUPPLEMENTARY INFORMATION: On January 22, 1991 (56 FR 2190), the Federal Aviation Administration (FAA) established the Aviation Rulemaking Advisory Committee (ARAC). The committee provides advice and recommendations to the FAA Administrator, through the Associate Administrator for Regulation and Certification, on the full range of the FAA's rulemaking activities with respect to aviation-related issues.

In order to develop such advice and recommendations, the ARAC may choose to establish working groups to which specific tasks are assigned. Such working groups are comprised of experts from those organizations having an interest in the assigned task. A working group member need not be a representative of the full committee. One of the working groups established by the ARAC is the Flight Test Working Group.

The FAA announced at the Joint Aviation Authorities (JAA)-Federal Aviation Administration (FAA) Harmonization Conference in Toronto, Canada June 2–5, 1992, that it would consolidate within the ARAC structure an ongoing objective to "harmonize" the Joint Aviation Requirements (JAR) and the Federal Aviation Regulations (FAR).

Task

The Flight Test Working Group's tasks are as follows:

Task 1—Gate Requirements for High Lift Devices: Recommend to the ARAC simplified and clarified requirements related to gated positions on the control used by the pilot select the position of an airplane's high lift devices.

Task 2—Flight Characteristics in Icing Conditions: Recommend to the ARAC new or revised requirements and compliance methods related to airplane performance and handling characteristics in icing conditions.

Reports

For each task listed above, the Flight Test Working Group should develop and present to the ARAC:

1. A recommended work plan for completion of the task, including the rationale supporting such plan, for consideration at the meeting of the ARAC to consider transport airplane and engine issues held following publication of this notice;

2. A detailed conceptual presentation on the proposed recommendation(s), prior to proceeding with the work stated in item 3. below;

3. A draft Notice of Proposed Rulemaking (NPRM), with supporting economic and other required analyses, and/or any other related guidance material or collateral documents the working group determines to be appropriate; or, if new or revised requirements of compliance methods are not recommended, a draft report stating the rationale for not making such recommendations; and

4. A status report at each meeting of the ARAC held to consider transport airplane and engine issues.

Participation in Working Group Task

An individual who has expertise in the subject matter and wishes to become a member of the working group should write to the person listed under the caption **FOR FURTHER INFORMATION CONTACT** expressing that desire, describing his or her interest in the task and stating the expertise he or she would bring to the working group. The request will be reviewed with the assistant chairman and working group leader, and the individual will be advised whether or not the request can be accommodated.

The Secretary of Transportation has determined that the information and use of the Aviation Rulemaking Advisory Committee are necessary in the public interest in connection with the performance of duties imposed on the FAA by law. Meetings of the Aviation Rulemaking Advisory Committee will be open to the public, except as authorized by section 10(d) of the Federal Advisory Committee Act. Meetings of the working group will not be open to the public, except to the extent that individuals with an interest and expertise are selected to participate. No public announcement of working group meetings will be made.

Issued in Washington, DC, on June 3, 1994.

Chris A. Christie,

Executive Director, Aviation Rulemaking Advisory Committee.

[FR Doc. 94–14145 Filed 6–9–94; 8:45 am]

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Recommendation Letter

400 Main Street
East Hartford, Connecticut 06108

Pratt & Whitney
A United Technologies Company

April 4, 2000

Federal Aviation Administration
800 Independence Avenue, SW
Washington, DC 20591

Attention: Mr. Thomas McSweeny, Association Administrator for Regulation and Certification

Subject: ARAC Recommendations

Reference: ARAC Tasking, Federal Register, November 19, 1999

Dear Tom,

The Transport Airplane and Engine Issues Group is pleased to submit the following "Fast Track" reports as recommendation to the FAA in accordance with the reference tasking. These reports have been prepared by the Flight Test Harmonization Working Group.

- Task 3 25.1419 / Ice Protection ANM-94-464-A
- 25.1501(c), 25.1583(k), 25X1591 ANM-00-079-A
- 25.107(e) (l) (iv) — ANM-91-464-A

Sincerely yours,

Craig R. Bolt

Craig R. Bolt
Assistance Chair, TAEIG

Attachments

Copy: Kris Carpenter - FAA-NWR
*Bob Park - Boeing
*Effie Upshaw - FAA Washington, DC

*letter only

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Acknowledgement Letter

U.S. Department
of Transportation

**Federal Aviation
Administration**

800 Independence Ave. S.W.
Washington, D.C. 20591

MAY 3 2004

Mr. Craig R. Bolt
Manager, Product Development and Validation
Pratt & Whitney
Mail Stop 162-12
East Hartford, CT 06108

Dear Mr. Bolt:

In an effort to clean up pending Aviation Rulemaking Advisory Committee (ARAC) recommendations on Transport Airplane and Engine Issues, the recommendations from the following working groups have been forwarded to the proper Federal Aviation Administration offices for review and decision. We consider your submittal of these recommendations as completion of the ARAC tasks. Therefore, we have closed the tasks and placed the recommendations on the ARAC website at http://www.faa.gov/avr/arm/arac/index.cfm

Date	**Task**	**Working Group**
December 1999	Interaction of Systems and Structure Part 33 Static Parts	Loads and Dynamics Harmonization Working Group
March 2000	Part 35/JARP: Airworthiness Standards Propellers	Engine Harmonization Working Group
April 2000	Flight Characteristics in Icing conditions	Flight Test Harmonization Working Group #3 ANM-94-464-A
May 2000	Thrust Reversing Systems	Powerplant Installation Harmonization Working Group
September 2000	Lightning Protection Requirements	Electromagnetic Effects Harmonization Working Group
July 2001	Main Deck Class B Cargo Compartments	Cargo Standards Harmonization Working Group
April 2002	Design Standard for Flight Guidance	Flight/Guidance Systems Harmonization Working Group

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I wish to thank the ARAC and the working groups for the resources they spent in developing these recommendations. We will continue to keep you apprised of our efforts on the ARAC recommendations at the regular ARAC meetings.

Sincerely,

Anthony F. Fazio
Executive Director, Aviation Rulemaking
Advisory Committee

Recommendation

ARAC FTHWG Report

<u>Flight in Icing Requirements</u>

1 - What is the underlying safety issue addressed by the FAR/JAR?

Section 25.1419 broadly addresses safe airplane operation in the continuous maximum and intermittent maximum icing conditions of appendix C. However, existing Part 25, Subpart B does not contain any specific flight test requirements to ensure the ability of airplanes to safely operate in these icing conditions. The proposed regulations and advisory material developed by the FTHWG provides harmonized FAR 25/JAR-25 airplane performance and handling characteristics certification requirements to ensure safe airplane operation in the appendix C icing conditions.

2 - What are the current FAR and JAR standards?

The only pertinent regulatory text in current FAR 25 and JAR-25 is contained in a Subpart F requirement (§ 25.1419) related to ice protection systems.

<u>Current FAR text</u>: **If certification with ice protection provisions is desired, the airplane must be able to safely operate in the continuous maximum and intermittent maximum icing conditions of appendix C.**

<u>Current JAR text</u>: **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.**

In addition, the JAA has applied Notice of Proposed Amendment (NPA) 25F-219 to certification projects over the last ten years. [NPA 25F-219 presents Draft Advisory Material Joint (AMJ) 25.1419 entitled "Flight in Icing Conditions - Acceptable Handling Characteristics and Performance Effects."]

3 - What are the differences in the standards and what do these differences result in?:

The FAR 25 standard is poorly worded since it makes the demonstration of an airplane's ability to safely operate in icing conditions contingent solely upon the desire of the applicant to certificate an ice protection system. The JAR-25.1419 requirement is correctly worded, relating the demonstration of safe operation in icing conditions to the applicant's desire to have the airplane certificated for flight in icing. Despite the differences in wording, the regulations have been applied in a similar manner over the years. The greatest difference has occurred within the last ten years with the JAA's application of NPA 25F-219 to all certification projects. This NPA contains significant new material for airplane performance and handling characteristics in icing conditions. Comments provided to JAA regarding this NPA strongly argued for developing harmonized FAA-JAA requirements for flight in icing conditions. Finally, a problem that exists in the FAA use of § 25.1419 for icing certifications is that no standardized criteria have been developed and applied to define what is meant by "to safely operate" in terms of performance and handling characteristics.

4 - What, if any, are the differences in the means of compliance?

Considerable differences exist in the means of compliance with FAR 25 and JAR-25 certification requirements for flight in icing. As noted above, this has largely been due to the application of the advisory material contained in NPA 25F-219, which defines "to safely operate" in terms of airplane performance and handling characteristics.

5 – What is the proposed action?

The proposed action is to adopt new rulemaking and advisory material developed by the FTHWG. Specifically, the FTHWG has developed a set of Subpart B performance and handling characteristics requirements for flight in the icing conditions of Appendix C that are based on the material contained in JAA NPA 25F-219. The FTHWG proposal also adopts the introductory wording of JAR-25.1419 and adds the definition of ice accretions appropriate to various phases of flight in Appendix C.

6 - What should the harmonized standard be?

The harmonized standards should be those developed by the FTHWG, which are provided as Attachment 1. Note that this activity predates the Fast Track program, and therefore the attachment includes preamble material.

7 - How does this proposed standard address the underlying safety issue (identified under #1)?

The proposed standards provide a comprehensive set of regulatory criteria, including definition of ice accretions in addition to specific performance and handling characteristics requirements, to ensure safe operation of transport category airplanes in icing conditions.

8 - Relative to the current FAR, does the proposed standard increase, decrease, or maintain the same level of safety? Explain.

Relative to the current FAR, the proposed standard increases the level of safety. The current FAR states a very general safety objective (i.e., the airplane must be able to safely operate) that is open to interpretation; the proposed standard defines specific requirements that must be met to obtain certification for flight in icing conditions.

9 - Relative to current industry practice, does the proposed standard increase, decrease, or maintain the same level of safety? Explain.

Relative to current industry practice, the proposed standards represent an increase in the level of safety. Due to the JAA's application of NPA 25F-219 over the last ten years, current industry practice results in a level of safety that is very close to that intended by the proposed standards; the proposed standards, however, are stated in terms of legally-based regulatory requirements whereas NPA 25F-219 is essentially applied as interpretive advisory material.

10 - What other options have been considered and why were they not selected?

The only other options investigated by the FTHWG were: (1) Produce advisory material based on JAA NPA 25-219 and the public comments received against it, and (2) Introduce a paragraph in FAR/JAR 25.21 (Compliance) that would require compliance with certain Subpart B flight requirements in icing conditions and require the airplane to be capable of safe operation in icing conditions for the remaining aspects of Subpart B. The first option was rejected because of industry objections to Subpart B flight requirements being presented in advisory material that would be tied to a Subpart F rule. The second option was later rejected by FAA legal counsel because it presented intended safety objectives in the advisory material that could not be enforced.

11 - Who would be affected by the proposed change?

Airplane manufacturers will be affected by the proposed regulatory changes. Since it is currently not the intent to apply the proposed standards retroactively, airplane operators will not be affected in the short term. For future airplane types that comply with the standards being proposed for flight in icing conditions, operators may or may not be affected depending on the extent of design changes that may be incorporated by the manufacturers to ensure satisfactory handling qualities and mitigate any potential performance losses.

12 - To ensure harmonization, what current advisory material (e.g., ACJ, AMJ, AC, policy letters) needs to be included in the rule text or preamble?

As previously noted, the JAA's Draft AMJ 25.1419 provided the basis for development of the proposed standards; that document will be cancelled upon issuance of the final rule. Proposed advisory material in the form of an FAA AC and a JAA ACJ will complement the proposed regulatory changes. Some elements of the advisory material associated with the proposed regulatory changes were excerpted from the FAA's Advisory Circular 25-7, "Flight Test Guide for Certification of Transport Category Airplanes."

13 - Is existing FAA advisory material adequate? If not, what advisory material should be adopted?

Existing FAA advisory material is not adequate. A comprehensive package of advisory material in the form of an FAA AC and a JAA ACJ has been developed by the FTHWG in conjunction with the proposed regulatory standards. The proposed advisory material presents a suggested means of compliance with the new flight requirements of Subpart B for icing conditions and guidance for determining the appropriate ice accretions. The harmonized advisory material provided as Attachment 2 should be adopted.

14 - How does the proposed standard compare to the current ICAO standard?

The proposed standard exceeds the applicable ICAO standards.

15 - Does the proposed standard affect other HWG's?

The proposed standards do not directly affect other HWGs. However, the Ice Protection HWG is developing requirements for ice detection and protection systems and the Flight Guidance System HWG has been requested to develop requirements for the certification of autopilot systems for use in icing conditions. These working groups have been coordinating, as necessary, to ensure that the effects of one group's work does not detrimentally affect work of the other groups.

16 - What is the cost impact of complying with the proposed standard?

The change in cost relative to the current practice of joint FAA/JAA certification is not anticipated to be a great increase since manufacturers are already addressing the majority of the proposed standards through the JAA's application of NPA 25F-219. However, if the change in cost was to be determined relative to what would be required to comply with existing FAA standards for flight in icing, the change could conceivably be considerable.

17 - Does the HWG want to review the draft NPRM at "Phase 4" prior to publication in the Federal Register?

Yes.

18 – In light of the information provided in this report, does the HWG consider that the "Fast Track" process is appropriate for this rulemaking project, or is the project too complex or controversial for the Fast Track Process. Explain.

The "Fast Track" process is not appropriate to this rulemaking project. This project was begun in October 1994 and, after much debate and deliberation, resulted in the completion of a FTHWG Draft NPRM and advisory material in November 1999 that still contains two non-consensus items. Everything in the rulemaking package represents new certification requirements that do not lend themselves to the "Fast Track" process.

NPRM 00-XX/PNPA 25B-2XX

Paragraphs affected: FAR 25/JAR-25 Sub-Part B
FAR/JAR 25.1419
FAR/JAR Appendix C

PERFORMANCE AND HANDLING QUALITIES IN ICING CONDITIONS

Introduction/Summary[1]

This NPA/NPRM is based on text developed by the Flight Test Harmonization Working Group (FTHWG), a group of European and North American airworthiness authorities' and industry flight specialists, and pilot representatives working to harmonize Subpart B of JAR 25, FAR 25 and Transport Canada's Part 525. As an element of the Harmonization Work Program, the FTHWG reports to the JAA and to the Transport Airplane and Engine Issues Group (TAEIG). The TAEIG, in turn, 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 rulemaking activities.

The harmonized requirements and associated guidance material of this NPA supersede the European Joint Aviation Authorities' (JAA) NPA 25F-219, Issue 2, as published for consultation on April 23, 1993. The task for the FTHWG was to review NPA 25F-219 and the comments received following public consultation on the NPA and to recommend new or revised requirements and compliance methods related to airplane performance and handling characteristics in icing conditions.

The FTHWG proposes to amend FAR 25/JAR-25 to revise the requirements related to ice protection systems and introduce requirements to evaluate airplane performance and handling characteristics in the icing conditions of Appendix C to FAR 25/JAR-25. Harmonized 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, most of them having two positions supported by an almost equal number of member organizations. Consensus was eventually reached on all but one of these requirements – the pass/fail criteria for the zero-g pushover maneuver used to investigate an airplane's susceptibility to ice-contaminated tailplane stall. It was therefore decided to present the majority position in the Draft NPA/NPRM with countering minority positions presented and dispositioned in the preamble. Note that one member organization also submitted two "minority positions" relative to the proposed advisory material clarifying what the "critical" ice accretion is for the various phases of flight and the delay time appropriate for determining an ice accretion that would exist on unprotected and protected surfaces before normal ice protection system operation.

JAA NPA 25F-219 will be withdrawn on adoption of these proposals.

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[1] This section will most likely require slightly different wording for the NPA and NPRM due to format differences that exist in the FAA and JAA systems.

Background

The FAA, JAA and Transport Canada currently have various documents addressing handling and performance in icing conditions. These documents have been amended over the years to add requirements 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. Consequently, it was recognized that little material existed addressing satisfactory standards for flight characteristics (i.e. performance and handling qualities) for operation in icing conditions, and what did exist was not standardized among the airworthiness authorities.

The JAA took a major step in developing a comprehensive set of criteria for certificating transport category airplanes for flight in icing conditions with the publication of NPA 25F-219 in the late 1980s; 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 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 push-over maneuver to zero "g" was developed to evaluate an airplane's susceptibility to this phenomenon. A further task was to develop policy on airplane performance and handling qualities criteria for flight in icing conditions, which was based on identification of existing practices and a review of the clear air flight test requirements. The intention was to formalize and harmonize 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 turboprop airplanes 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 has now been 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 airplane performance and handling characteristics in icing conditions. Following discussion of NPA 25F-219 and the proposed AC 25-7 material in the JAA Flight Studies Group (FSG), the subject was raised in 1994 as a FAA/JAA harmonization item and the Flight Test Harmonization Working Group was tasked with reviewing NPA 25F-219 and the comments received during the public consultation. The FTHWG considered whether this issue should be addressed by requirements or solely by advisory material. The consensus was that new requirements in Subpart B were required.

There was also debate in the working group as to whether full compliance with Subpart B was required for flight in icing conditions. The final agreement was to require compliance with selected requirements. Hence, the FTHWG took a different approach to that in the NPA: where NPA 25F-219 Issue 2 proposed Advisory Material to 25.1419, this NPA/NPRM proposes rule changes to Subpart B to identify specific performance and handling qualities requirements which must be met, in full or in part, in icing conditions. The remaining flight requirements are considered to be not applicable for flight in icing conditions.

The primary impetus for developing the proposed Subpart B regulations rather than advisory material came from U.S. legal requirements imposed on the FAA by the Administrative Procedures Act. The path originally taken by the FTHWG would have added a paragraph to FAR/JAR 25.21 (Proof of compliance) specifying the Subpart B regulations that had to be complied with and stating the airplane must be able to operate safely in the icing conditions of Appendix C for all other aspects of airplane performance and handling characteristics; advisory material would have interpreted what was meant by "to operate safely" for the non-Subpart B aspects of flight. Under the Administrative Procedures Act, the requirement to show an airplane can "safely operate" would be defined as an "interpretive" rule that would not have the force of law, thus being subject to challenge. The general guideline provided to the FTHWG was that a regulation must establish a requirement or standard that is sufficiently clear to those required to comply with it so that they have a reasonable understanding of what is expected of them without having to resort to material not published in the rule; the regulation must be able to stand on its own. Similarly, the FTHWG was provided guidelines for developing advisory material; it may not impose or lessen a burden on anyone, nor may it have a mandatory effect. Consequently, the FTHWG restructured the material to incorporate what was originally proposed as interpretive advisory material into Subpart B regulations. The proposed regulations amend many existing regulations to include specific criteria related to certification for flight in icing conditions.

The Subpart B requirements for icing conditions were developed with the intent of making certification for flight in icing mandatory by removing the existing conditional statements that preface both FAR and JAR 25.1419. (For reference, FAR 25.1419 requires the airplane be able to safely operate in the icing conditions of Appendix C if an ice protection system is installed while JAR-25.1419 ties the same requirement to the applicant's desire to have the airplane certificated for flight in icing conditions.) The FTHWG's first approach was to revise FAR and JAR 25.1419 to make certification for flight in icing mandatory thus avoiding conflict with the mandatory nature of the proposed Subpart B icing requirements. This approach was later abandoned for several reasons, the final proposal being for the FAA to adopt the wording of JAR-25.1419, which relates compliance with the icing regulatory requirements to an applicant's desire to certificate the airplane for flight in icing conditions. A detailed description of the FAR/JAR 25.1419 issues is provided in the following "Discussion of Proposals" section.

In developing the following proposals, the FTHWG retained the two basic premises the JAA employed when preparing NPA 25F-219: 1) The probability of a transport category airplane operating in icing conditions is one, and 2) All transport category airplanes must show compliance with the same requirements for flight in icing conditions. Similarly, the FTHWG proposals also retain the 1g stall basis for stall speed determination and operating speed factors. The harmonized 1g stall regulatory changes were published for public comments in JAA NPA 25B-215 and FAA NPRM 95-17. The comments received have been reviewed and the final version of these rules were published as Amendment 25-xx on mmddyy and as part of Change 15 to JAR-25 on mmddyy.

The specific requirements that are proposed for certification for flight in icing conditions were determined by a comprehensive review of FAR/JAR 25 Subpart B requirements taking into consideration what aspects were considered most important to ensure safe flight in icing conditions. A second part of this development process was a review of what type and amount of flight testing had been accomplished in previous certifications for the full range of transport category airplanes (i.e., low to high gross weights, straight wing and swept wing, pneumatic de-ice and thermal anti-ice systems, and turbopropeller and turbojet propulsion). This broad review of existing icing certification data was aimed at identifying: 1) any design-specific trends in test requirements, and 2) any safety-related shortcomings that should be addressed by this rulemaking activity.

This review resulted in the concept behind the following proposals being that, whilst degradation in performance in icing conditions may be allowable to a point, in general terms there can be no degradation in handling qualities below the minimum required by Subpart B. There are a few exceptions to this and they are detailed in the following proposals.

Discussion of the Proposals

The FTHWG proposes to harmonize on the introductory wording of existing JAR 25.1419, which relates the need to demonstrate the ability of an airplane to safely operate in the icing conditions of Appendix C to the applicant's desire to have the airplane certificated for flight in icing conditions. The FTHWG also proposes to define a set of FAR/JAR Subpart B airplane performance and handling characteristics standards that must be met by transport category airplanes with the ice accretion appropriate to the phase of flight being investigated; compliance with these requirements, to be specified in FAR/JAR 25.21, "Compliance," will demonstrate the ability of an airplane to safely operate in the icing conditions of Appendix C. In addition, the FTHWG proposes to amend Appendix C of FAR/JAR 25 to define the ice shapes appropriate to each phase of flight.

As a preface to the following discussions of the individual regulatory proposals, it is worthwhile to understand the underlying philosophy that was employed in the development of the criteria the FTHWG considers necessary to show a transport category airplane can be safely operated in icing conditions. The regulatory requirements that follow were primarily determined by a paragraph by paragraph review of the existing FAR/JAR 25 subpart B regulations with consideration given to those aspects deemed critical enough that they should be re-investigated with ice accretions on the airplane. This determination was based on the aforementioned review of incidents and accidents attributed to ice accretion and engineering judgment of what flight aspects are critical for all airplanes.

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, ice accretions. Where it was recognized 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 proposal adopts a modified version of the concept utilized by the JAA that permits some tolerance on performance (for the airplane without ice) before requiring that performance be recomputed specifically for operation in icing conditions. JAA Draft AMJ 25.1419 retained the performance threshold criteria introduced by the French DGAC in Special Condition B-(6) for certification of the ATR-72 whereby the need to recalculate performance for a given phase of flight is predicated on the increase in the 1g stall speed due to ice accretion for the associated airplane configuration. That criteria requires the performance to be recalculated for operation in icing conditions, using the 1g stall speed determined with ice, if the 1g stall speed increases by more than the greater of five knots or five percent of the 1g stall speed for the airplane without ice. Since performance degradation was not implicated as a causal factor in any of the icing-related accidents, and since it is accepted that transport category airplanes have used operating speeds in icing conditions that have been determined for the airplane without ice accretion, the FTHWG proposal acknowledges the fact that the FAR/JAR 25 operating speed factors are adequate to permit some amount of tolerance for the negative effects of ice accretion; in particular, the increase in stall speed with ice that reduces the operating speed margin. The FTHWG proposal, however, introduces a smaller stall speed tolerance value than the 5 kts/5%$V_{S\ 1\text{-}G}$ criteria of Draft AMJ 25.1419 and also introduces a similar tolerance to the relevant "operating" speed for all phases of flight beyond the FAR/JAR 25 takeoff path; these tolerances will be further discussed in the material associated with each proposed regulation.

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 regulations for the airplane with ice accretions. Operating speeds for icing conditions may also have to be increased in order to show compliance with the maneuver capability requirements of FAR/JAR 25.143 that were introduced by the 1g stall rule.

The following 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 favor 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 recognizes that the widely used descriptor "ice accumulations" would have served the same purpose.

<u>FAR/JAR 25.21</u> – Paragraph (g) has been added to specify the requirements that must be met in icing conditions if certification for flight in icing is desired. As noted in the general discussion of the proposals, 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 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 paragraph (g)(1) were determined to be beyond what was necessary to determine an airplane's ability to be safely operated in icing conditions.

FAR/JAR 25.21(g)(1) - The objective of the proposed requirements of 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) with the ice protection systems operating normally. FAR/JAR 25.21(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 with regard to showing compliance with the requirements for non-icing conditions; these tolerances are stated in the individual performance regulations. Furthermore, the icing conditions in which compliance must be shown with the proposed requirements are defined as those of FAR/JAR 25, Appendix C. Discussions were held relative to incorporating material related to testing in Supercooled Large Droplet (SLD) icing environments; it was generally felt that such action would be premature since another HWG was tasked with reviewing available data and redefining, if necessary, the icing atmosphere for aircraft certification. An important element of paragraph (g)(1) is the closing text that defines the operation of the airplane to be in accordance with Airplane Flight Manual (AFM) operating limitations and operating procedures, which apart from prescribing the operating conditions, also provides an avenue to include limitations and operating procedures that are specific to operating in icing conditions in the AFM.

FAR/JAR 25.21(g)(2) – Paragraph (g)(2) is proposed to ensure that airplanes will have adequate handling characteristics in the period between the airplane 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 airplane handling characteristics due to its insidious nature and expanse of coverage. A definition of such an ice accretion is proposed to be added to Part 2 of FAR/JAR 25, Appendix C. The proposed advisory material provides guidance for further defining this ice accretion based on the means of detection.

FAR/JAR 25.21(g)(3) – Paragraph (g)(3) is proposed to prevent the use of different load, weight, and center of gravity limits for flight in icing. The basis of these requirements is that operation in icing conditions should be essentially transparent to the flightcrew 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 with regard to reducing operational complexity and flightcrew workload.

FAR/JAR 25.21 Proof of compliance

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

(1) Unless otherwise prescribed, each requirement of this Subpart, except FAR/JAR 25.121(a), 25.123(c), 25.143(b)(1) and (2), 25.149, 25.201(c)(2), 25.207(c) and (d), 25.239 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 airplane in accordance with the operating limitations and operating procedures established by the applicant and contained in the Airplane Flight Manual.

(2) The airplane must meet the requirements of FAR/JAR 25.143(j) and 25.207(h) with the ice accretion prior to normal operation of the ice protection system specified in Appendix C, Part 2(c).

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

- FAR/JAR 25.103 Stalling Speed – The assumed stall speed basis for the proposed flight in icing requirements is the 1g stall criteria as published for public comment in NPRM 95-17/NPA 25B-215 and subsequently modified during the harmonized disposition of comments received (Note: Publication of the final 1g stall rule is anticipated to occur in late 1999.) The proposed requirements for icing conditions require stall speed to be determined with ice for each airplane configuration; this is conveyed by the revision to FAR/JAR 25.103(b)(3), which adds ice accretion as a configuration variable related to the performance standard for which it will be used. 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.

FAR/JAR 25.103 Stalling Speed

(a) The reference stall speed V_{SR} is a calibrated airspeed defined by the applicant. V_{SR} may not be less than a 1-g stall speed. V_{SR} is expressed as:

$$V_{SR} \geq V_{CLMAX}/\sqrt{(n_{zw})}$$

where -

V_{CLMAX} = Calibrated airspeed obtained when the load factor-corrected lift coefficient ($n_{ZW}W/(qS)$) is first a maximum during the maneuver prescribed in sub-paragraph (c) of this paragraph. In addition, when the maneuver is limited by a device that abruptly pushes the nose down at a selected angle of attack (e.g. a stick pusher), V_{CLMAX} may not be less than the speed existing at the instant the device operates;

n_{ZW} = Load factor normal to the flight path at V_{CLMAX};

W = Airplane gross weight;

S = Aerodynamic reference wing area; and

q = Dynamic pressure.

(b) V_{CLMAX} is determined with:

(1) Engines idling, or, if that resultant thrust causes an appreciable decrease in stall speed, not more than zero thrust at the stall speed;
(2) Propeller pitch controls (if applicable) in the take-off position;
(3) The airplane in other respects (such as flaps, landing gear **and ice accretions**) in the condition existing in the test or performance standard in which V_{SR} is being used;
(4) The weight used when V_{SR} is being used as a factor to determine compliance with a required performance standard;
(5) The center of gravity position that results in the highest value of reference stall speed; and
(6) The airplane trimmed for straight flight at a speed selected by the applicant, but not less than 1.13 V_{SR} and not greater than 1.3 V_{SR}.

(c) Starting from the stabilized trim condition, apply the longitudinal control to decelerate the airplane so that the speed reduction does not exceed one knot per second.

(d) In addition to the requirements of sub-paragraph (a) of this paragraph, when a device that abruptly pushes the nose down at a selected angle of attack (e.g. a stick pusher) is installed, the reference stall speed, V_{SR}, may not be less than 2 knots or 2%, whichever is greater, above the speed at which the device operates.

FAR/JAR 25.105 Takeoff – FAR/JAR 25.105(a) was amended (and restructured accordingly) to require takeoff performance to be considered for flight in the icing conditions of FAR/JAR 25, Appendix C. In conjunction with the changes to paragraph (a), Appendix C was also amended to define an icing atmosphere appropriate for takeoff conditions.

The proposed changes to paragraph (a) specify the conditions under which takeoff performance must be determined for icing conditions and the ice accretion to be used. As noted in the associated advisory material, the critical surfaces of the airplane are assumed to be clear of ice and snow at the beginning of the takeoff as required by existing operating rules (Ref.: FAR 91.527(a), 121.629(b) and (c), and JAR-Ops 1-345). The proposed requirements assume ice accretion begins at liftoff, which is consistent with operating rules that prohibit flight crews from conducting takeoffs in airplanes with frost, snow or ice adhering to certain airplane surfaces or when the takeoff would not be in compliance with an approved ground de-icing/anti-icing program.

The JAA predecessor to this NPA/NPRM, Draft AMJ 25.1419, which has been applied to numerous certification projects, acknowledged the fact that transport category airplane service history showed some tolerance with regard to the effects of ice on airplane performance. Draft AMJ 25.1419 permitted the stall speed to increase by the greater of 5 knots or 5% of the 1g stall speed (V_{SR}) before takeoff path performance had to be recalculated using the stall speeds determined for the airplane with ice accretions. Several commenters expressed concern with the size of this allowable increase in stall speed, noting the considerable reductions in maneuver capability and stall margin, particularly for the takeoff climb with landing gear retracted (commonly referred to "second segment climb"). This NPA/NPRM retains the tolerance philosophy of Draft AMJ 25.1419 but introduces a smaller and more operationally viable stall speed tolerance. Takeoff path performance must be determined specifically for icing conditions if the uncontaminated 1g stall speed increases by the greater of 3 knots or 3%V_{SR} with the "Takeoff ice" accretion defined in Part 2 of Appendix C (as proposed to be added by this NPA/NPRM).

In addition to the stall speed increase, which allowed a reduction in the margin between stall and the operating speeds for the non-contaminated airplane, Draft AMJ 25.1419 also placed a limit on the increase in drag due to ice accretion before takeoff performance had to be recomputed specifically for operation in icing conditions; Draft AMJ 25.1419 established that limit as a 5% increase in drag. Since climb performance is expressed in terms of a gradient for a given weight, altitude, and temperature (WAT), and since the gradient for a given WAT condition is a function of thrust, lift, and drag, all of which are dependent on airspeed, the FTHWG determined that it would be more appropriate to express the acceptable tolerance of climb performance in terms of <u>climb gradient reduction due to ice</u> rather than just the effect of ice on the drag component alone. The AFM takeoff climb performance is presented in terms of "net" climb gradient, which is computed as the actual climb gradient reduced by specific values prescribed in FAR/JAR 25.115(b). Since operational takeoff performance determinations base obstacle clearance on the "net" takeoff flight path, the actual takeoff flight path will have increasing obstacle clearance as the distance from the starting point of the takeoff 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 determined that half of the takeoff climb gradient reduction would be an appropriate tolerance on takeoff performance with ice. If the effect of ice exceeds one-half this gradient reduction, the takeoff flight path performance must be recomputed specifically for icing.

Though the "Takeoff ice" accretion is defined as the most critical ice accretion from liftoff to 400 feet above the takeoff surface, it is considered to be a representative performance parameter for the entire takeoff path (which ends at 1,500 feet above the takeoff surface) based on the fact that the landing gear retracted takeoff climb, which comprises the majority of the climb segment for "Takeoff ice" accretion, is generally the most limiting case in the takeoff path. Similarly, the one-half of the takeoff flight path reduction tolerance is related to FAR/JAR 25.121(b), which prescribes the configuration and conditions for the landing gear retracted takeoff climb (second segment), thus again using the limiting takeoff climb case to cover the entire takeoff flight path. An added conservatism inherent to the takeoff path performance arises from the requirement of FAR/JAR 25.111(d)(3) for that performance to be determined without ground effect.

FAR/JAR 25.105 Takeoff

(a) The takeoff speeds described in FAR/JAR 25.107, the accelerate-stop distance described in FAR/JAR 25.109, the takeoff path described in FAR/JAR 25.111, the takeoff distance and takeoff run described in FAR/JAR 25.113, **and the net takeoff flight path described in FAR/JAR 25.115**, must be determined in the selected configuration for takeoff 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 FAR/JAR 25.121(b) with the "Take-off ice" accretion defined in Appendix C:

(i) The stall speed at maximum takeoff weight is increased 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 FAR/JAR 25.121(b) is greater than one-half of the applicable actual-to-net takeoff flight path gradient reduction defined in FAR/JAR 25.115(b).

(b) No takeoff made to determine the data required by this section may require exceptional piloting skill or alertness.

(c) The takeoff data must be based on—

(1) In the case of land planes and amphibians:

(i) Smooth, dry and wet, hard-surfaced runways; and

(ii) At the option of the applicant, grooved or porous friction course wet, hard-surfaced runways.

(2) Smooth water, in the case of seaplanes and amphibians; and

(3) Smooth, dry snow, in the case of skiplanes.

(d) The takeoff data must include, within the established operational limits of the airplane, the following operational correction factors:

(1) Not more than 50 percent of nominal wind components along the takeoff path opposite to the direction of takeoff, and not less than 150 percent of nominal wind components along the takeoff path in the direction of takeoff.

(2) Effective runway gradients.

<u>FAR/JAR 25.107 Takeoff speeds</u> – FAR/JAR 25.107(g) is added to note that the minimum control and minimum unstick speeds, determined as limits on takeoff speeds for the airplane without ice, may be used as limits for determining takeoff speeds for the airplane with ice accretions.

The minimum unstick speed (V_{MU}) is defined in FAR/JAR 25.107(d) as the ". . .airspeed at and above which the airplane can safely lift off the ground and continue the takeoff" and is used as a limitation on the lift-off speed, which in turn effects all other takeoff speeds. Since the FTHWG determined that it is reasonable to assume that ice accretion does not begin until lift-off, the use of the non-icing conditions V_{MU} is justified for use in determining takeoff speeds for icing conditions.

The ground minimum control speed (V_{MCG}) is applied as a minimum limit to the engine failure speed (V_{EF}) in FAR/JAR 25.107(a)(1), which in turn determines the speed V_1 (at which the pilot is either continuing the takeoff or is initiating the first action to abort the takeoff) to ensure adequate directional control for the continued takeoff case should the critical engine fail during the groundborne acceleration run. As with V_{MU}, this occurs prior to lift-off where ice accretion is assumed to begin thus justifying the use of the V_{MCG} determined in non-icing conditions for determining takeoff speeds for icing conditions.

The air minimum control speed (commonly referred to as V_{MCA}) is defined in FAR/JAR 25.149(b) as the airspeed at which it is possible to maintain control of the airplane, with no more than 5 degrees of bank, when the critical engine is suddenly made inoperative. Multiples of V_{MCA} are used in FAR/JAR 25.107 to define minimum limits for the rotation speed (V_R) and the takeoff safety speed (V_2). Again, since V_R occurs before lift-off, 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.

The case for V_2 is different - in the event of an engine failure, the airborne portion of the takeoff path from 35 feet to 400 feet above the takeoff surface will 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 takeoff speeds. FAR/JAR 25.111(c)(4) limits airplane configuration changes during this segment to landing gear retraction and propeller feathering. JAR 25 further limits this to automatic propeller feathering and the FAA applies the same limitation through advisory material contained in AC 25.7A. The impact of this limitation is that ice protection systems are typically not activated until the airplane is more than 400 feet above the takeoff surface, 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 airplanes do not have any ice protection on the vertical stabilizer, a situation that could lead to reduced directional control due to ice accretion in the takeoff path that in turn could increase the air minimum control speed. To alleviate these concerns, the FTHWG proposes to amend FAR/JAR 25.143 with a requirement to show that the airplane is safely controllable and maneuverable at the minimum V_2 for takeoff with the critical engine inoperative and with the critical ice accretion appropriate to the phase of flight as defined in proposed additions to Appendix C.

FAR/JAR 25.107 Takeoff speeds

(a) V_1 must be established in relation to V_{EF} as follows:
  (1) V_{EF} is the calibrated airspeed at which the critical engine is assumed to fail. V_{EF} must be selected by the applicant, but may not be less than V_{MCG} determined under FAR/JAR 25.149(e).
  (2) V_1, in terms of calibrated airspeed, is the takeoff decision speed selected by the applicant; however, V_1 may not be less than V_{EF} plus the speed gained with the critical engine inoperative during the time interval between the instant at which the critical engine is failed, and the instant at which the pilot recognizes and reacts to the engine failure, as indicated by the pilot's initiation of the first action (e.g. applying brakes, reducing thrust, deploying speed brakes) to stop the airplane during accelerate-stop tests.

(b) V_{2MIN}, in terms of calibrated airspeed, may not be less than—
  (1) 1.2 V_S for—
    (i) Two-engine and three-engine turbopropeller and reciprocating engine powered airplanes; and
    (ii) Turbojet powered airplanes without provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed;
  (2) 1.15 V_S for—

(I) Turbopropeller and reciprocating engine powered airplanes with more than three engines; and

(ii) Turbojet powered airplanes with provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed; and

(3) 1.10 times V_{MC} established under FAR/JAR 25.149.

(c) V_2, in terms of calibrated airspeed, must be selected by the applicant to provide at least the gradient of climb required by FAR/JAR 25.121(b) but may not be less than—

(1) V_{2MIN}, and

(2) V_R plus the speed increment attained (in accordance with FAR/JAR 25.111 ©(2)) before reaching a height of 35 feet above the takeoff surface.

(d) V_{MU} is the calibrated airspeed at and above which the airplane can safely lift off the ground, and continue the takeoff. V_{MU} speeds must be selected by the applicant throughout the range of thrust-to-weight ratios to be certificated. These speeds may be established from free air data if these data are verified by ground takeoff tests.

(e) V_R, in terms of calibrated airspeed, must be selected in accordance with the conditions of subparagraphs (e)(1) through (4) of this section:

(1) V_R may not be less than—

(i) V_1;

(ii) 105 percent of V_{MC};

(iii)The speed (determined in accordance with FAR/JAR 25.111©(2)) that allows reaching V_2 before reaching a height of 35 feet above the takeoff surface; or

(iv)A speed that, if the airplane is rotated at its maximum practicable rate, will result in a V_{LOF} of not less than 110 percent of V_{MU} in the all-engines-operating condition and not less than 105 percent of V_{MU} determined at the thrust-to-weight ratio corresponding to the one-engine-inoperative condition, (except that in the particular case that lift-off is limited by the geometry of the aeroplane, or by elevator power, the above margins may be reduced to 108% in the all-engines-operating case and 104% in the one-engine-inoperative condition.")[JAR-25 ONLY]

(2) For any given set of conditions (such as weight, configuration, and temperature), a single value of V_R, obtained in accordance with this paragraph, must be used to show compliance with both the one-engine-inoperative and the all-engines-operating takeoff provisions.

(3) It must be shown that the one-engine-inoperative takeoff distance, using a rotation speed of 5 knots less than V_R established in accordance with subparagraphs (e)(1) and (2) of this section, does not exceed the corresponding one-engine-inoperative takeoff distance using the established V_R. The takeoff distances must be determined in accordance with FAR 25.113 (JAR-25.113(a)(1)).

(4) Reasonably expected variations in service from the established takeoff procedures for the operation of the airplane (such as over-rotation of the airplane and out-of-trim conditions) may not result in unsafe flight characteristics or in marked increases in the scheduled takeoff distances established in accordance with FAR/JAR 25.113(a).

(f) V_{LOF} is the calibrated airspeed at which the airplane first becomes airborne.

(g) V_{FTO}, in terms of calibrated airspeed, must be selected by the applicant to provide at least the gradient of climb required by § 25.121(c), but may not be less than—
(1) 1.18 V_{SR}; and
(2) A speed that provides the maneuvering capability specified in § 25.143(g).

(h) In determining the takeoff 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.

FAR/JAR 25.111 Takeoff path – FAR/JAR 25.111 defines the takeoff path and describes the applicable airplane configuration and performance. The FTHWG proposes to amend FAR/JAR 25.111(c) by adding a new subparagraph (5) that specifies which proposed Appendix C, Part 2, ice accretion is to be used for determining the airplane drag in specified airborne segments of the takeoff path. Subparagraph (5) is stated in a conditional sense, relating back to the discriminant criteria of proposed FAR/JAR 25.105(a)(2) that determine whether or not takeoff path performance must be recalculated for flight in icing conditions. It should be emphasized again that the criteria of subparagraph (5) are only applicable to the airborne portions of the takeoff path since it is assumed ice accretion does not begin until lift-off. Additionally, if takeoff path performance is required to be determined for icing conditions by the proposed criteria of FAR/JAR 25.105(a)(2), the takeoff speeds of FAR/JAR 25.107 determined for icing conditions must be used for determining the airplane drag with the ice accretion specified in subparagraph (5) for the particular takeoff path segment. Additionally, the structure of FAR/JAR 25.111(c)(4) has been revised to improve the order of the requirements but the content remains unchanged other than the addition of the connective "and."

FAR/JAR 25.111 Takeoff path

(a) The takeoff path extends from a standing start to a point in the takeoff at which the airplane is 1,500 feet above the takeoff surface, or at which the transition from the takeoff to the en route configuration is completed and a speed is reached at which compliance with FAR/JAR 25.121(c) is shown, whichever point is higher. In addition—
(1) The takeoff path must be based on the procedures prescribed in FAR/JAR 25.101(f);
(2) The airplane must be accelerated on the ground to V_{EF}, at which point the critical engine must be made inoperative and remain inoperative for the rest of the takeoff; and
(3) After reaching V_{EF}, the airplane must be accelerated to V_2.

(b) During the acceleration to speed V_2, the nose gear may be raised off the ground at a speed not less than V_R. However, landing gear retraction may not be begun until the airplane is airborne.

(c) During the takeoff path determination in accordance with paragraphs (a) and (b) of this section—
(1) The slope of the airborne part of the takeoff path must be positive at each point;

(2) The airplane must reach V_2 before it is 35 feet above the takeoff surface and must continue at a speed as close as practical to, but not less than V_2, until it is 400 feet above the takeoff surface;

(3) At each point along the takeoff path, starting at the point at which the airplane reaches 400 feet above the takeoff surface, the available gradient of climb may not be less than—

(i) 1.2 percent for two-engine airplanes;

(ii) 1.5 percent for three-engine airplanes; and

(iii) 1.7 percent for four-engine airplanes;

(4) **The airplane configuration may not be changed, except for gear retraction and propeller feathering,** and no change in power or thrust that requires action by the pilot may be made until the airplane is 400 feet above the takeoff surface; **and**

(5) **If FAR/JAR 25.105(a)(2) requires the takeoff path to be determined for flight in icing conditions, the airborne part of the takeoff must be based on the airplane drag:**

(i) With the "Take-off ice" accretion defined in Appendix C from a height of 35 feet above the takeoff surface up to the point where the airplane is 400 feet above the takeoff surface; and

(ii) With the "Final Take-off ice" accretion defined in Appendix C from the point where the airplane is 400 feet above the takeoff surface to the end of the takeoff path.

(d) The takeoff path must be determined by a continuous demonstrated takeoff or by synthesis from segments. If the takeoff path is determined by the segmental method—

(1) The segments must be clearly defined and must be related to the distinct changes in the configuration, power or thrust, and speed;

(2) The weight of the airplane, the configuration, and the power or thrust must be constant throughout each segment and must correspond to the most critical condition prevailing in the segment;

(3) The flight path must be based on the airplane's performance without ground effect; and

(4) The takeoff path data must be checked by continuous demonstrated takeoffs up to the point at which the airplane is out of ground effect and its speed is stabilized, to ensure that the path is conservative relative to the continuous path. The airplane is considered to be out of the ground effect when it reaches a height equal to its wing span.

(e) For airplanes equipped with standby power rocket engines, the takeoff path may be determined in accordance with Section II of Appendix E.

<u>FAR/JAR 25.119 Landing climb</u> – FAR/JAR 25.119 is amended by reformatting with introductory text to specify the airplane configuration, thrust setting and gradient requirements, and subparagraphs (a) and (b) revised to require all-engines-operating landing climb performance to be determined for both non-icing conditions and icing conditions. Subparagraphs (a) and (b) each contain a reference to the appropriate paragraph of FAR/JAR 25.125 for the landing climb speed applicable to the conditions. FAR/JAR 25.119(b) also identifies the Appendix C, Part 2, ice accretion to be used in calculating landing climb performance for icing conditions. It should be noted that there are no conditional performance parameters (i.e., increase in V_{SR} or decrease in

climb gradient due to ice) in the proposed changes to FAR/JAR 25.119 - landing climb performance is required to be determined for all transport category airplanes, which codifies what has been standard FAA practice for almost 40 years.

The FTHWG also proposes to amend FAR/JAR 25.119 to harmonize the landing speed requirements. The FTHWG proposes to remove JAR 25.119(b) (per 1g stall rule), which defines the landing climb speed and permits it to be as low as $1.13V_{SR}$ with a further reduction to $1.08V_{SR}$ for four-engined airplanes that have a significant reduction in stall speed due to power application. The FTHWG also proposes to amend FAR 25.119 by specifying the landing climb speed to be "V_{REF}" as opposed to the current wording, which states "not more than V_{REF}." The additional limitation of JAR 25.119(b) for the landing climb speed to be not less than V_{MCL} will be implicitly retained since V_{MCL} is also specified as a limitation on V_{REF} in FAR/JAR 25.125. The FTHWG considers these changes to be appropriate since the landing climb performance is applicable for balked landings, and since the normal procedure for a balked landing is to establish a positive rate of climb before retracting the landing gear and then accelerate the airplane to permit changing the airplane configuration to further reduce drag, it does not seem logical to permit the speed to be reduced below V_{REF} during the landing climb. The FTHWG believes that the small loss of performance that propeller-driven airplanes may suffer without the lower climb speed limit of JAR 25.119(b), due to slightly less net thrust available, will be outweighed by the benefits of standardization. Additionally, the FTHWG is not aware of any close-in obstacle clearance limitations for balked landings that would require the use of a reduced climb speed to increase the climb gradient.

FAR/JAR 25.119 Landing climb: All-engines-operating

In the landing configuration, the steady gradient of climb may not be less than 3.2 percent, with 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;

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

(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 25.125 (b)(2)(B).

<u>FAR/JAR 25.121 Climb: One-engine-inoperative</u> – FAR/JAR 25.121(b) and (c) are reformatted and amended to specify the conditions under which the climb performance described by those subparagraphs is required to be determined for icing conditions in addition to non-icing conditions. Since the climb segments of FAR/JAR 25.121(b) and (c) are part of the takeoff path described in FAR/JAR 25.111, the stall speed and gradient discriminants of proposed FAR/JAR 25.105(a)(2) are applicable and restated in FAR/JAR 25.121(b)(2) and (c)(2) for the landing gear retracted and final takeoff climb segments, respectively. (See the proposal to amend FAR/JAR 25.105 for a detailed discussion of the reasons for selecting these criteria as discriminants.) FAR/JAR 25.121(b)(2)(ii) and (c)(2)(ii) also specify which Appendix C, Part 2 ice accretion is to

be used for determining the climb performance in icing conditions for those takeoff climb segments. It should be emphasized that if the climb speed of either of the climb segments described by FAR/JAR 25.121(b) and (c) is required to be increased for icing conditions due to the stall speed of the landing gear retracted takeoff climb configuration increasing by the greater of 3 knots or 3% V_{SR}, the airplane drag used in the computation of climb performance for icing conditions must be computed at the appropriate icing conditions climb speed.

FAR/JAR 25.121(d) has been reformatted to accommodate the addition of a requirement to determine approach climb performance in icing conditions with the "Holding ice" accretion of proposed Appendix C, Part 2. Proposed FAR/JAR 25.121(d)(2)(ii) requires approach climb performance to be determined with the "Holding ice" accretion described in proposed Appendix C, Part 2. Proposed FAR/JAR 25.121(d)(2)(ii) also specifies the criteria for determining the approach climb speed for icing conditions which, unlike the speeds used in the takeoff path, is not based on the relationship between the stall speed for the airplane with and without ice accretion. Instead, the criteria for determining whether the climb speed needs to be redetermined for icing conditions is 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 and the same operating speed factor as used for non-icing conditions does not exceed the climb speed for non-icing conditions by more than the greater of 3 knots CAS or 3% V_{SR}, the non-icing speeds may be used for calculating approach climb performance for icing conditions. Since the approach climb speed will be in the range of 1.2 to 1.4V_{SR}, which will result in operating speeds greater than 100 knots for the majority of FAR/JAR 25 airplanes, this approach represents a more liberal criteria than the 3 kts./3%V_{SR} discriminant used for takeoff path speeds (e.g., if approach climb speed is 1.25V_{SR} and V_{SR}=100 knots (low), 3% of the approach speed is 3.75 knots). The FTHWG considers this small alleviation to be acceptable on the basis that though the one-engine-inoperative approach climb gradient requirement determines the maximum landing weight for most transport category airplanes, it is not related to an operational go-around. If it is necessary to increase the approach climb speed for icing conditions, the airplane drag used in the computation of climb performance for icing conditions must be computed at that speed.

FAR/JAR 25.121 Climb: One-engine-inoperative

(a) *Takeoff; landing gear extended.* In the critical takeoff configuration existing along the flight path (between the points at which the airplane reaches V_{LOF} and at which the landing gear is fully retracted) and in the configuration used in FAR/JAR 25.111 but without ground effect, the steady gradient of climb must be positive for two-engine airplanes, and not less than 0.3 percent for three-engine airplanes or 0.5 percent for four-engine airplanes, at V_{LOF} and with—
  (1) The critical engine inoperative and the remaining engines at the power or thrust available when retraction of the landing gear is begun in accordance with FAR/JAR 25.111 unless there is a more critical power operating condition existing later along the flight path but before the point at which the landing gear is fully retracted;
  (2) The weight equal to the weight existing when retraction of the landing gear is begun, determined under FAR/JAR 25.111;

(b) *Takeoff; landing gear retracted.* In the takeoff configuration existing at the point of the flight path at which the landing gear is fully retracted, and in the configuration used in FAR/JAR 25.111 but without ground effect:

(1) The steady gradient of climb may not be less than 2.4 percent for two-engine airplanes, 2.7 percent for three-engine airplanes, and 3.0 percent for four-engine airplanes, at V_2 with:

(i) The critical engine inoperative, the remaining engines at the takeoff power or thrust available at the time the landing gear is fully retracted, determined under FAR/JAR 25.111, unless there is a more critical power operating condition existing later along the flight path but before the point where the airplane reaches a height of 400 feet above the takeoff surface; and

(ii) The weight equal to the weight existing when the airplane's landing gear is fully retracted, determined under FAR/JAR 25.111.

(2) The requirements of paragraph (b)(1) of this section 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 FAR/JAR 25.121(b) with the "Take-off ice" accretion :

(A) The stall speed at maximum takeoff weight is increased 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 FAR/JAR 25.121(b) is greater than one-half of the applicable actual-to-net takeoff flight path gradient reduction defined in FAR/JAR 25.115(b).

(c) *Final takeoff.* In the en route configuration at the end of the takeoff path determined in accordance with FAR/JAR 25.111:

(1) The steady gradient of climb may not be less than 1.2 percent for two-engine airplanes, 1.5 percent for three-engine airplanes, and 1.7 percent for four-engine airplanes, 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 takeoff path, determined under FAR/JAR 25.111.

(2) The requirements of paragraph (c)(1) of this section 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 FAR/JAR 25.121(b) with the "Take-off ice" accretion:

(A) The stall speed at maximum takeoff weight is increased 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 FAR/JAR 25.121(b) is greater than one-half of the applicable actual-to-net takeoff flight path gradient reduction defined in FAR/JAR 25.115(b).

(d) *Approach.* In the approach configuration corresponding to the normal all-engines-operating procedure in which V_S for this configuration does not exceed 110 percent of the V_S for the related landing configuration:

(1) The steady gradient of climb may not be less than 2.1 percent for two-engine airplanes, 2.4 percent for three-engine airplanes, and 2.7 percent for four-engine airplanes, 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 paragraph (d)(1) of this section 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 paragraph (d)(1)(iii) of this section, does not exceed that speed by more than the greater of 3 knots CAS or 3%.

<u>FAR/JAR 25.123 En route flight paths</u> – FAR/JAR 25.123(a) has been amended by adding a minimum speed limitation of $1.18V_{SR}$, which is also the minimum limit on the final takeoff speed (in the same configuration) of FAR/JAR 25.121(c). This addition ensures that the airplane will not experience a decrease in kinetic energy when transitioning from the final takeoff to en route climb segment and reflects the inherent limit speed for showing compliance to the maneuver capability requirements introduced by the 1g stall rule (Ref.: FAR/JAR 25.143(h)).

The icing-related amendments to FAR/JAR 25.123 only affect the paragraphs dealing with one-engine-inoperative performance; it is assumed that failure of a second engine would give flightcrews considerable cause to avoid or depart icing conditions.

FAR/JAR 25.123(a) has been amended to state the conditions under which en route fight path performance must be determined for icing conditions and the proposed Appendix C, Part 2 ice accretion to be used; these criteria are presented in FAR/JAR 25.123(b)(2). Similar to the preceding takeoff 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 determined for icing conditions.

Similar to the takeoff path, 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 FAR/JAR 25.123(b). FAR/JAR 25.123 uses an operating speed discriminant similar to the approach climb of FAR/JAR 25.121(d), only in this case a speed of $1.18V_{SR}$ determined with the "En-route ice" accretion of proposed Appendix C, Part 2 is compared with the en route climb speed selected for non-icing conditions. The basis of this operating speed increase criteria is the fact that propeller-driven airplanes will generally use the minimum allowable operating speeds due to the inverse relationship between thrust and airspeed whereas turbojet-powered airplanes will use a higher speed selected to maximize climb performance. The result of this difference in operating speeds is that turbojets will typically have an approximate 12% V_{SR} margin above the minimum speed at which compliance can be shown with the maneuver capability requirements of FAR/JAR 25.143(h) while the propeller driven airplanes will have no margin. Additionally, due to their slower operating speeds, the propeller-driven airplanes will probably be subjected to increased exposure to icing conditions. The proposed criteria acknowledges the fact that two classes of transport category airplanes exist with significantly different criteria for determining their operating speeds, protecting one class from the negative effects of ice while not unduly penalizing 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 airplanes should be treated the same, the FTHWG believes 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 airplane drag used in the computation of climb performance for icing conditions must be computed at that speed.

FAR/JAR 25.123 En route flight paths

(a) For the en route configuration, the flight paths prescribed in paragraphs (b) and (c) of this section must be determined at each weight, altitude, and ambient temperature, within the operating limits established for the airplane. 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 speed not less than V_{FTO}, with—
- (1) The most unfavorable center of gravity;
- (2) The critical engines inoperative;
- (3) The remaining engines at the available maximum continuous power or thrust;
- (4) The means for controlling the engine-cooling air supply in the position that provides adequate cooling in the hot-day condition;

(b) The one-engine-inoperative net flight path data must represent the actual climb performance diminished by a gradient of climb of 1.1 percent for two-engine airplanes, 1.4 percent for three-engine airplanes, and 1.6 percent for four-engine airplanes-
- **(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 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 paragraph (b) of this section.

(c) For three- or four-engine airplanes, the two-engine-inoperative net flight path data must represent the actual climb performance diminished by a gradient of climb of 0.3 percent for three-engine airplanes, and 0.5 percent for four-engine airplanes.

FAR/JAR 25.125 Landing – FAR/JAR 25.125(a) has been amended to state the conditions under which the landing distance must be determined for icing conditions and the proposed Appendix C, Part 2 ice accretion to be used. Specifically, if V_{REF} determined with the "Landing ice" accretion is greater than V_{REF} in non-icing conditions by more than 5 knots CAS, the landing distance for icing conditions must be determined with the "Landing ice" accretion and at the appropriate V_{REF}, as defined in new FAR/JAR 25.125(b)(2)(B).

The "5 knots CAS" increase criteria has its origin in: 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 airplane can be safely controlled and landed when the airspeed at 50 feet is V_{REF} - 5 knots; 2) Transport category airplanes are typically operated with speed additives to provide gust margins that may or may not be bled off before crossing the threshold; and similarly 3) Many transport category airplanes have been operated with a 5 knot speed additive during final approach to cover for inadvertent speed loss, that has often been carried to the 50 foot point without any indication of a landing distance-related safety problem. In conjunction with the third reason for using a 5 knot discriminant, it should be noted that many of the transport category airplanes with the 5 knot additive are operated under FAR Part 121, which requires that the airplane can be landed and brought to a complete stop in 60% of the available field length, whereas another segment of transport category airplanes are operated under FAR Part 91 and may or may not be operated with this same landing field length margin. 4) A 5 knot increase above the non-contaminated airplane landing reference speed equates to approximately 3% of the 1g stall speed (slightly more than 3% for larger airplanes) for the same configuration, which is consistent with the allowable stall speed tolerance for the takeoff path airplane configurations with ice. In consideration of the information presented above, the FTHWG considers a 5 knot increase in V_{REF} due to ice accretion to be acceptable.

A second constraint on V_{REF} for icing conditions is that it must provide the maneuvering capability required by FAR/JAR 25.143(g) with the "Landing ice" accretion; this entails demonstrating a constant speed 40° banked turn without encountering stall warning.

Existing FAR/JAR 25.125(a)(2), which has been reformatted as proposed FAR/JAR 25.125(b)(2)(A), also requires V_{REF} for non-icing conditions to be not less than the Landing Minimum Control Speed, V_{MCL}, to ensure adequate directional control 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 takeoff 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 takeoff case, this is not explicitly stated but is obvious since proposed FAR/JAR 25.125(b)(2)(B) 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 maneuverability 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 FAR/JAR 25.143(c)(2) and (3) require the applicant to show the airplane will be safely controllable and maneuverable during an approach and go-around, and an approach and landing, with the critical engine inoperative; in the interest of flight test safety, these maneuvers may be accomplished with a simulated engine failure, as noted in the associated advisory material. Consequently, the FTHWG considers the use of the non-icing conditions V_{MCL} to be acceptable as a limitation on V_{REF} for icing conditions.

FAR/JAR 25.125 Landing

(a) The horizontal distance necessary to land and to come to a complete stop (or to a speed of approximately 3 knots for water landings) from a point 50 feet 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 airplane) :

(1) In non-icing conditions

(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 5 knots CAS.

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

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

(2) A stabilized approach, with a calibrated airspeed of not less than V_{REF}, must be maintained down to the 50 foot height.

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

(i) $1.23V_{SR0}$;

(ii) V_{MCL} established under JAR 25.149(f); and

(iii) a speed that provides the maneuvering capability specified in FAR/JAR 25.143(h).

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

(i) the speed determined in paragraph (b)(2)(A) of this section;

(ii) 1.23 V_{SR0} with the landing ice accretion if that speed exceeds V_{REF} selected in non-icing condition by more than 5 knots CAS

(iii) a speed that provides the maneuvering capability specified in FAR/JAR 25.143(h).

(3) Changes in configuration, power or thrust, and speed, must be made in accordance with the established procedures for service operation.

(4) The landing must be made without excessive vertical acceleration, tendency to bounce, nose over, ground loop, porpoise, or water loop.

(5) The landings may not require exceptional piloting skill or alertness.

(c) For landplanes and amphibians, the landing distance on land must be determined on a level, smooth, dry, hard-surfaced runway. In addition—

(1) The pressures on the wheel braking systems may not exceed those specified by the brake manufacturer;

(2) The brakes may not be used so as to cause excessive wear of brakes or tires; and

(3) Means other than wheel brakes may be used if that means—

(i) Is safe and reliable;

(ii) Is used so that consistent results can be expected in service; and

(iii) Is such that exceptional skill is not required to control the airplane.

(d) For seaplanes and amphibians, the landing distance on water must be determined on smooth water.

(e) For skiplanes, the landing distance on snow must be determined on smooth, dry, snow.

(f) The landing distance data must include correction factors for not more than 50 percent of the nominal wind components along the landing path opposite to the direction of landing, and not less than 150 percent of the nominal wind components along the landing path in the direction of landing.

(g) If any device is used that depends on the operation of any engine, and if the landing distance would be noticeably increased when a landing is made with that engine inoperative, the landing distance must be determined with that engine inoperative unless the use of compensating means will result in a landing distance not more than that with each engine operating.

FAR/JAR 25.143 Controllability and Maneuverability - General – As noted in discussions related to takeoff and landing speeds, FAR/JAR 25.143 is amended with the addition of a new paragraph (c) that requires the applicant to show the airplane is safely controllable and maneuverable in three one-engine-inoperative low speed maneuvers with the appropriate ice accretion; these requirements were added to ensure that use of the minimum control speeds determined for non-icing conditions will not result in controllability and maneuverability problems when used as minimum operating speed limits for icing conditions.

FAR/JAR 25.143 is also amended with the addition of paragraph (i), which contains a general icing-related application requirement in subparagraph (1) and a specific icing conditions test in subparagraph (2).

FAR/JAR 25.143(i)(1) states, in part, that "...controllability may be demonstrated with the ice accretion described in Appendix C that is most critical for the particular flight phase." Implicit in this statement is a requirement for compliance to be shown with all of FAR/JAR 25.143 (except paragraphs (b)(1) and (2) that are exempted by proposed FAR/JAR 25.21(g)), with an allowance being made for the applicant to minimize 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. Subparagraph (1) also adds a requirement for "Sandpaper ice" to be considered in determining the "critical" ice accretion for airplanes with unpowered elevator controls. The thin, rough, layer of ice that is defined as "Sandpaper ice" in the proposed Appendix C, Part 2 has been shown in many cases to have a more detrimental effect on handling characteristics than larger shapes for airplanes with unpowered control systems, in some cases resulting in control surface hinge moment reversals that require the application of extremely high pilot control forces to recover from resulting upsets.

FAR/JAR 25.143(i)(2) adds a requirement that is intended to investigate an airplane's susceptibility to ice-contaminated tailplane stall (ICTS). Several incidents and accidents have been attributed to ICTS, which can be characterized as an actual stalled airflow condition existing, or an elevator hinge moment reversal due to separated flow, on the lower surface of the horizontal stabilizer. ICTS incidents and accidents have typically occurred during landing approaches, with some form of ice accretion on the horizontal stabilizer (tailplane), when selecting increased flap deflections and/or decreasing pitch attitude abruptly, resulting in angle of attack (AoA) increases and required download (lift) increases on the tailplane. The degraded airflow conditions caused by ice accretion result in a reduced tailplane stall AoA and lift capability that is manifested by longitudinal control push force lightening and/or reversal. A flight test method to conservatively determine susceptibility to ICTS by increasing the AoA on an ice contaminated tailplane by inducing a nose down pitch rate has been created involving a pushover to zero-g. The pass/fail criteria proposed for this test is that a longitudinal control push force be required to some 'g' level and that the airplane must remain controllable to zero-g. Some criteria have also included demonstration of a sideslip maneuver with an ice-contaminated tailplane since this has been shown as a more critical ICTS triggering mechanism for some airplanes.

The proposal presented in FAR/JAR 25.143(i)(2) for investigating an airplane's susceptibility to ICTS does not represent a consensus position within the FTHWG; it represents the majority position as determined by a vote of the ARAC member organizations that participated in developing the proposals of this NPRM. As such, alternative proposals for regulatory language with associated justifications are provided in the following paragraphs. Dispositions of the alternative positions are also presented and appropriately identified.

FAR/JAR 25.143 is also amended by the addition of subparagraph (j) to specify tests for ensuring that the airplane has adequate controllability with the ice accretions that exist on the unprotected and protected surfaces prior to normal activation of the ice protection system. In developing these controllability criteria, the FTHWG gave consideration to the temporary nature of this ice accretion and further classified the temporary nature 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 advisory material for Appendix C, Part 2(c) provides guidance for determining the appropriate ice accretion for this testing based on the means of ice detection.

Alternative 1

23 April 1999

Flight Test Harmonization Working Group - Flight In Icing Conditions

JAA/FAA/ALPA Minority Position: Zero-g pushover maneuver and Longitudinal Characteristics During Sideslip Maneuvers

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 or thereabouts, the practice of many Authorities has been to require testing to lower load factors and NPA 25F-219 requires a push force throughout the maneuver to zero g. The FTHWG is agreed that testing should be performed to zero g. However, it is the JAA/FAA/ALPA Minority contention in the FTHWG that a push force should be required to zero g. The Majority position 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/FAR 25.143(f), 25.255(b)(2) and the ACJ/AC material to 25.143(f)) do not allow force reversals. Furthermore, a survey of JAA/FAA/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.

The Majority position on this item goes some way to addressing the cause of past accidents. However, the method proposed by the Majority of determining the acceptability of a control force reversal is subjective and will lead to inconsistent evaluations. The JAA/FAA/ALPA Minority position is 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 airplane and the criteria recognizes 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 airplane's controllability and provides a readily understood criteria of acceptability. Any lesser standard does not give confidence that the problem has been fully addressed or resolved.

Whilst 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 25.143 has been agreed to achieve this, the JAA/FAA/ALPA Minority believe that a specific requirement, as proposed in 25.143(i)(3), is appropriate.

FAA Flight Test Pilot comment on FAA, JAA, ALPA Pushover Position

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/FAR 25.143(f), 25.255(b)(2) and the ACJ/AC material to 25.143(f)) do not allow force reversals. Furthermore, a survey of JAA/FAA/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 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.

(This 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 JAR 25.143.)

In a survey, several FAA Flight Test Pilots stated that the procedure and criteria in this paragraph, even though an attempt was made to be quantitative, is still too vague and will lead to differing interpretations across projects and flight test teams. They 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.

Majority Disposition of FAA, JAA, ALPA Pushover Position

Historically, the pushover test was usually performed to 0.5g rather than zero g. As practiced by Transport Canada, this demonstration was done with a high pitch rate and hence there was significant overshoot of the 0.5g level down to around .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 rather 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 or thereabouts, the practice of many Authorities has been to require testing to lower load factors. This evolved until the introduction of NPA 25F-219 which not only requires testing to zero g but also requires a push force throughout the maneuver to zero g. The FTHWG Majority argued that a zero g pushover is an improbable condition, going well beyond any operational maneuver, which does not properly represent gusts, pitch rate, elevator position, and other factors which 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, the Majority eventually accepted use of the pushover maneuver, within limits, as a compromise means of showing that an adequate safety margin exists. However, it is the Majority position that requiring a push force to zero g is excessive.

The Flight Test Guide, AC 25-7A, 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 0g. 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 which should not be exceeded. Between the OFE and the LFE, it is understood that handling qualities may be degraded, but the airplane must remain controllable and it must be possible to avoid exceeding the limit load factor (see FAR/JAR 25.143(b)). The Majority position is consistent with these concepts.

The Minority cite existing regulations which do not allow force reversals for the en-route configuration (e.g. FAR/JAR 25.143(f), 25.255(b)(2)). In practice, the certification tests for these rules do not cover the full structural limit flight envelope, but rather 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 -1g, ACJ No. 2 to JAR 25.143(f) states, "assessment of the characteristics in the normal flight envelope involving normal accelerations from 1g to 0g, will normally be sufficient." With flaps up, 0g is the midpoint between the limit load factor and the trim point. The corresponding points for flaps down are 0g for the limit load factor and 0.5g for the midpoint assessment of characteristics. The Majority are concerned 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 which meet the Minority criterion still require a significant pull force to recover. The Majority position sets a 50 pound limit on the total control force to recover promptly. This ensures that the 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 is controllable with one hand. The 50 pound limit is a readily understood criterion of acceptability which 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 Minority position would legislate against 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 0g and 0.5g which is easily controllable. The Minority 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. 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 section 25.143(i)(1) requires sandpaper ice be considered if the elevator is unpowered regardless of the ice protection system. Many of the business jets are equipped with anti-ice systems which 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 which 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 zero at about 0.4g to 25 lb. at 0g.

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 Majority proposed test criteria would identify those airplanes with the hazardous characteristics.

Results of the NASA 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 0g with flaps 10 and 100 pounds was required with flaps 20. Hence, the Majority criteria provide an adequate safety margin and would have identified the aircraft as unacceptable before it ever got to the flaps 40 configuration which lost control.

The Majority position is the right balance between cost and benefit. It is adequate to ensure against uncontrollable tailplane stalls. The Majority criteria, combined with measures to ensure proper operation of the ice protection systems, would have prevented the ICTS accidents. The

Minority position would impose an unnecessary burden on some manufacturers and their customers.

Alternative 2

Draft 2
29 April 1999

Flight Test Harmonization Working Group - Flight In Icing

Minority Position (Transport Canada): Zero 'g' Pushover Maneuver and Longitudinal Characteristics During Sideslip Maneuvers

Zero 'g' Pushover Maneuver

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.

Transport Canada advisory material dating back to the mid 1980's specified that +/- 0.5 'g' longitudinal control had to be demonstrated. In practice, the demonstration was done in a fairly abrupt maneuver which generated a significantly higher transient pitch rate than that associated with the steady normal acceleration. The minimum normal acceleration obtained was usually around 0.25 'g' 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 1 'g' condition. The majority position recognizes this controllability issue by limiting the amount of pull force required to promptly recover the airplane from a 0.0 'g' condition to 50 lbf pull force. In addition, recognizing that positive stability is also important, the majority position requires a push force down to 0.5 'g'.

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

Based on this data and Transport Canada's past practice, the majority proposal 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/JAR 25. Hence Transport Canada considers that if the requirement is only going to specify a 'g' level, then 0.5 'g' for positive stability is inadequate. A value of 0.25 'g' is considered to be a compromise proposal between 0.5 'g' which is the majority position and 0.0 'g' which is the minority position held by the FAA/JAA/ALPA.

Transport Canada considers the majority proposal is acceptable with the following change:

> *"...It must be shown that a push force is required throughout the maneuver down to 0.25 'g' load factor..."*

Majority Disposition of Transport Canada Pushover Position

The Transport Canada position offers a compromise between the other two positions by specifying 0.25g for the push force requirement. The spirit of compromise is appreciated, however, it still entails some economic impact and has the disadvantage that 0.25g is not related to existing definitions of flight envelopes.

The Transport Canada position recognizes the importance of pitch rate. The Majority appreciate that pitch rate is a significant factor. An abrupt nose-down control input is required to reach zero g. The Majority believe that testing to zero g ensures 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.

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2 Longitudinal Characteristics During Sideslip Maneuvers

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 it was proposed by the FAA that pushover maneuvers be conducted while in sideslips. Transport Canada considered that this requirement was excessive but recognizing the concern, supported an additional requirement which 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 concurs with the minority FAA/JAA/ALPA position and 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."

Majority Disposition of TC Position on Longitudinal Characteristics During Sideslips

The FTHWG agreed that longitudinal control forces in sideslips could be important. FAA/ JAA/ ALPA and Transport Canada consider there should be a rule concerning this. The Majority consider this aspect is best included in advisory material to alert evaluation pilots to a possible concern. The consensus position had been reached on proposed language for the advisory material. When these same words were proposed as a rule it was the Majority opinion that they do not adequately define unacceptable characteristics and could be misinterpreted. At this time there does not appear to be sufficient data to establish criteria that are specific enough to stand as a rule.

FAR/JAR 25.143 Controllability and Maneuverability - General

(a) The airplane must be safely controllable and maneuverable during-
(1) Takeoff;
(2) Climb;
(3) Level flight;
(4) Descent; and
(5) Landing.

(b) It must be possible to make a smooth transition from one flight condition to any other flight condition without exceptional piloting skill, alertness, or strength, and without danger of exceeding the airplane limit-load factor under any probable operating conditions, including-
(1) The sudden failure of the critical engine;
(2) For airplanes with three or more engines, the sudden failure of the second critical engine when the airplane is in the en route, approach, or landing configuration and is trimmed with the critical engine inoperative; and
(3) Configuration changes, including deployment or retraction of deceleration devices.

(c) It must be shown that the airplane is safely controllable and maneuverable 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;
(3) During an approach and landing.

(d) The following table prescribes, for conventional wheel type controls, the maximum control forces permitted during the testing required by paragraphs (a) through (c) of this section:

Values in pounds of force as applied to the control wheel or rudder pedals.	Pitch	Roll	Yaw
For short term application for pitch and roll control – two hands available for control	75	50	-
For short term application for pitch and roll control – one hand available for control	50	25	-
For short term application for yaw control	-	-	150
For long term application	10	5	20

(e) Approved operating procedures or conventional operating practices must be followed when demonstrating compliance with the control force limitations for short term application that are prescribed in paragraph (c) of this section. The airplane must be in trim, or as near to being in trim as practical, in the preceding steady flight condition. For the takeoff condition, the airplane must be trimmed according to the approved operating procedures.

(f) When demonstrating compliance with the control force limitations for long term application that are prescribed in paragraph (d) this section, the airplane must be in trim, or as near to being in trim as practical.

(g) When maneuvering at a constant airspeed or Mach number (up V_{FC}/M_{FC}), the stick forces and the gradient of the stick versus maneuvering load factor must lie within satisfactory limits. The stick forces must not be so great as to make excessive demands on the pilot's strength when maneuvering the airplane, and must not be so low that the airplane can easily be overstressed inadvertently. Changes of gradient that occur with changes of load factor must not cause undue difficulty maintaining control of the airplane, and local gradients must not be so low as to result in a danger of overcontrolling.

(h) The maneuvering capabilities in a constant speed coordinated turn at forward center of gravity, as specified in the following table, must be free of stall warning or other characteristics that might interfere with normal maneuvering:

CONFIGURATION	SPEED	MANEUVERING BANK ANGLE IN A COORDINATED TURN	THRUST/POWER SETTING
TAKEOFF	V_2	30°	ASYMMETRIC WAT-LIMITED.[1]
TAKEOFF	V_2 + XX[2]	40°	ALL-ENGINES-OPERATING CLIMB.[3]
ENROUTE	V_{FTO}	40°	ASYMMETRIC WAT-LIMITED.[1]
LANDING	V_{REF}	40°	SYMMETRIC FOR -3° FLIGHT PATH ANGLE

(1) A combination of weight, altitude and temperature (WAT) such that the thrust or power setting produces the minimum climb gradient specified in § 25.121 for the flight condition.
(2) Airspeed approved for all-engines-operating initial climb.
(3) That thrust or power setting which, in the event of failure of the critical engine and without any crew action to adjust the thrust or power of the remaining engines, would result in the thrust or power specified for the take-off condition at V_2, or any lesser thrust or power setting that is used for all-engines-operating initial climb procedures.

(i) When demonstrating compliance with FAR/JAR 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 airplanes with unpowered elevator controls, "Sandpaper ice" must be considered in determining the critical ice accretion; and

(2) The airplane must be controllable in a pushover maneuver 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 maneuver down to 0.5g. It must be possible to promptly recover from the maneuver without exceeding 50 pounds pull control force.

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

(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 FAR/JAR 25.143 are applicable with the ice accretion defined in Appendix C, Part 2(c).

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

FAR/JAR 25.207 Stall warning – FAR/JAR 25.207(b) is amended to require stall warning to be provided by the same means in icing conditions as it is in non-icing conditions. Another approach that was considered by the FTHWG was 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. This approach was not adopted for several reasons, the most overriding being the human factors aspects that would result from pilots being trained to recognize stall warning by two different means. Considering that one of the premises the FTHWG assumed in developing the proposed regulatory changes and guidance material is that the probability of icing conditions is one, adequate stall warning should be provided and it is logical that it should be provided by the same means as for non-icing conditions, in the same sense that current FAR/JAR 25.207(b) requires stall warning to be provided by a warning device for all airplane flap/landing gear configurations if it is used to provide stall warning.

A new paragraph FAR/JAR 25.207(e) specifies the stall warning criteria that must be met in icing conditions, including the Appendix C ice accretion applicable to the airplane high-lift configuration. The proposed criteria require an investigation of stall warning margin for straight and turning flight with an entry rate of 1 kt/sec. The stall warning settings established for the airplane 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. In developing this criteria, the FTHWG took into consideration the types of transport category airplanes that have been in icing-related accidents as a result of stalling one or both wings; that subgroup of airplanes 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 airplanes, while having a lesser impact on the subgroup of transport category airplanes that have demonstrated safe flight in icing conditions. Since all modern transport category airplanes use some type of artificial stall warning system (i.e., stick shaker or combined aural and visual warning), and since three seconds is considered adequate for a trained pilot response, the FTHWG considers this icing-specific stall warning definition to be acceptable.

The FTHWG considered requiring an investigation of stall warning in icing conditions at entry rates greater than 1 kt./sec. (as required for non-icing conditions) with a one second delay before pilot action to recover, the reduced delay being associated with the assumption that a high entry rate would most likely be associated with maneuvers such as collision avoidance. The FTHWG did not propose such criteria 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 making the slow entry rate with longer delay time the critical case.

The FTHWG determined the "Holding ice" accretion to be appropriate for investigating the stall warning margin for those high-lift configurations used from the actual holding maneuver through the descent to either a landing or go-around. The "Holding ice" accretion of proposed Appendix C, Part 2, is representative of the ice accretion that has traditionally been employed by the FAA in icing certifications; it is the result of up to a 45 minute hold in the Continuous Maximum Icing conditions defined in Appendix C, Part 1, that is 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 en-route, approach, landing, and go-around configurations, the proposed Appendix C, Part 2, definitions of the ice accretions appropriate to the en-route and landing configurations permit the use of "Holding ice" in lieu of defining additional shapes.

Proposed FAR/JAR 25.207(e)(2) permits the use of the more critical of the "Takeoff ice" or "Final takeoff ice" accretion to be used in evaluating the stall warning margin for the takeoff configuration. The takeoff configuration is treated separately due to the different icing atmosphere defined for takeoff (see Appendix C, Part 1) and due to a more limited exposure time. As noted in proposed Appendix C, Part 2, the "Holding ice" accretion may also be used in lieu of the "Takeoff ice" and "Final takeoff 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 airplane handling characteristics may not be the large, craggy, multi-horned shape that one would intuitively expect but may instead be a thin, rough layer of ice that initially accretes.

FAR/JAR 25.207(f) is amended to clarify that the pilot should use the same stall recovery techniques for the airplane with ice accretions as used for demonstrating compliance with FAR/JAR 25.207 in non-icing conditions. This requirement is based on human factors' considerations for minimizing 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.

Although the stall warning criteria of FAR/JAR 25.207(c) and (d) for non-icing conditions are exempted for icing conditions in new FAR/JAR 25.21(g), a specific reference to FAR/JAR 25.207(e), which specifies the stall warning criteria for icing conditions, is contained in the sentence that has been added to FAR/JAR 25.207(b) to address the means of stall warning in icing conditions. Since FAR/JAR 25.207(e) prescribes the Appendix C ice accretions that must be used in evaluating stall warning for operation in icing conditions, the requirements of FAR/JAR 25.207(h)(2), which permit a different means of stall warning for evaluating the airplane with the ice accretion prior to normal ice protection system operation, represent the specific application of a stand-alone requirement and do not contradict other stall warning requirements proposed for icing conditions.

FAR/JAR 25.207 is amended by the addition of subparagraph (h) to specify the stall warning margins that must exist with the ice accretions that exist on the unprotected and protected surfaces prior to normal activation of the ice protection system. In developing these stall warning criteria, the FTHWG gave consideration to the temporary nature of this ice accretion 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. The FTHWG had particular concern for airplanes where the means of ice detection is visual recognition of a specified ice accretion on a reference surface; as a result FAR/JAR 25.207(h)(1) requires the stall warning for these airplanes to be the same as that provided for operation in icing conditions (i.e., FAR/JAR 25.207 except paragraphs (c) and (d)). For airplanes that use other means of ice detection, FAR/JAR 25.207(h)(2) provides distinct stall warning criteria that also take into account the temporary nature of the ice accretion prior to normal ice protection system operation. As previously stated, due to the self-contained nature of FAR/JAR 25.207(h)(2), the stall warning requirements of that paragraph do not conflict with other stall warning requirements established for other phases of flight in icing conditions. The advisory material for proposed Appendix C, Part 2(c) provides guidance for determining the appropriate ice accretion for this testing based on the means of ice detection.

FAR/JAR 25.207 Stall warning

(a) Stall warning with sufficient margin to prevent inadvertent stalling with the flaps and landing gear in any normal position must be clear and distinctive to the pilot in straight and turning flight.

(b) The warning must be furnished either through the inherent aerodynamic qualities of the airplane 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 airplane configurations prescribed in paragraph (a) of this section at the speed prescribed in paragraph (c) of this section. **For flight in icing conditions, the stall warning prescribed in paragraph (e) of this section must be provided by the same means as the stall warning for flight in non-icing conditions.**

(c) When the speed is reduced at rates not exceeding one knot per second, stall warning must begin, in each normal configuration, at a speed, V_{SW}, exceeding the speed at which the stall is identified in accordance with § 25.201(d) by not less than five knots or five percent CAS, whichever is greater. Once initiated, stall warning must continue until the angle of attack is reduced to approximately that at which stall warning began.

(d) In addition to the requirement of paragraph (c) of this section, when the speed is reduced at rates not exceeding one knot per second, in straight flight with engines idling and at the center-of-gravity position specified in § 25.103(b)(5), V_{SW}, in each normal configuration, must exceed V_{SR} by not less than three knots or three percent CAS, whichever is greater.

(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 when recovery, using the same test technique as for the non-contaminated airplane, 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 must be sufficient to allow the pilot to prevent stalling (as defined in § 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 airplane 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 paragraph with ice accretions, the same test technique as for the airplane without ice accretions must be used for recovery.**

(g) Stall warning must also be provided in each abnormal configuration of the high lift devices that is likely to be used in flight following system failures (including all configurations covered by Airplane Flight Manual procedures).

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

(1) If normal operation of any ice protection system is dependant upon visual recognition of a specified ice accretion on a reference surface, the requirements of 25.207 except (c) and (d) are applicable with the ice accretion defined in Appendix C, Part 2(c).

(2) If normal operation of any ice protection system is dependent upon means of recognition other than that defined in paragraph (h)(1) of this section, 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 when recovery, using the same test technique as for the non-contaminated airplane, is initiated not less than 1 second after the onset of stall warning, with the ice accretion defined in Appendix C, Part 2(c).

FAR/JAR 25.237 Wind velocities – FAR/JAR 25.237(a) is amended with the addition of a requirement to determine a landing crosswind component for landplanes and amphibians in icing conditions. This is in addition to the existing requirement for non-icing conditions, with appropriate editorial changes to retain correct paragraph structure and specifically denote "non-icing" and "icing" conditions. FAR/JAR 25.237(a) is also amended to state that the crosswind component established for takeoff without ice accretions may be used for takeoffs conducted in icing conditions. A review of certification data for existing transport category airplanes showed that directional control was not detrimentally affected by ice accretions on the leading edge of the vertical stabilizer. 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 airplane through descent and landing. Since the FTHWG has defined and justified in-flight icing conditions as not beginning until lift-off, and since the amount of ice accretion during the takeoff phase will be less than the "Landing ice" accretion of Appendix C, Part 2, the FTHWG does not consider it necessary to demonstrate a separate crosswind velocity for takeoff with an ice accretion.

FAR/JAR 25.237 Wind velocities

(a) For landplanes and amphibians, **the following applies**:

(1) A 90-degree cross component of wind velocity, demonstrated to be safe for takeoff and landing, must be established for dry runways and must be at least 20 knots or 0.2 V_{S0}, whichever is greater, except that it need not exceed 25 knots.

(2) The crosswind component for takeoff 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.

(b) For seaplanes and amphibians, the following applies:

(1) A 90-degree cross component of wind velocity, up to which takeoff and landing is safe under all water conditions that may reasonably be expected in normal operation, must be established and must be at least 20 knots or 0.2 Vs0, whichever is greater, except that it need not exceed 25 knots.

(2) A wind velocity, for which taxiing is safe in any direction under all water conditions that may reasonably be expected in normal operation, must be established and must be at least 20 knots or 0.2 V_{S0}, whichever is greater, except that it need not exceed 25 knots.

FAR/JAR 25.253 High-speed characteristics – FAR/JAR 25.253 is amended to add a new paragraph (c) that provides a definition of the *Maximum speed for stability characteristics, V_{FC}/M_{FC}*, specifically for icing conditions. A review of certification data showed that none of the flight tests for which V_{FC}/M_{FC} is an upper bound had been conducted above 300 knots CAS with artificial ice accretions. One reason for not exceeding 300 knots 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 airfoil leading edges at high speeds. The FTHWG considers these to be reasonable justifications for specifying a maximum value for V_{FC} of 300 knots CAS for showing compliance with the referenced handling characteristics requirements with ice accretions. Since the group of airplanes defined as "transport category" encompasses a number of configurations with differing propulsive means, the proposed FAR/JAR 25.253(c) recognizes that not all transport category airplanes will have a V_{FC}/M_{FC} as high as 300 knots CAS; consequently, an allowance is provided for V_{FC} with ice accretions to be the lower of 300 knots CAS, V_{FC} without ice accretions (from FAR/JAR 25.253(b)), or any lower airspeed at which the applicant can demonstrate the airplane will be free of ice accretions.

FAR/JAR 25.253 High-speed characteristics

(a) Speed increase and recovery characteristics. The following speed increase and recovery characteristics must be met:

(1) Operating conditions and characteristics likely to cause inadvertent speed increases (including upsets in pitch and roll) must be simulated with the airplane trimmed at likely cruise speed up to

V_{MO}/M_{MO}. These conditions and characteristics include gust upsets, inadvertent control movements, low stick force gradient in relation to friction, passenger movement, leveling off from climb, descent from Mach to airspeed limit altitudes.

(2) Allowing for pilot reaction time after effective inherent or artificial speed warning occurs, it must be shown that the airplane can be recovered to a normal altitude and its speed reduced to V_{MO}/M_{MO}, without-

(I) Exceptional piloting strength or skill;

(ii) Exceeding V_D/M_D, V_{DF}/M_{DF}, or the structural limitations; and

(iii) Buffeting that would impair the pilot's ability to read the instruments or control the airplane for recovery.

(3) With the airplane trimmed at any speed up to V_{MO}/M_{MO}, there must be no reversal of the response to control input about any axis at any speed up to V_{DF}/M_{DF}. Any tendency to pitch, roll, or yaw must be mild and readily controllable, using normal piloting techniques. When the airplane is trimmed at V_{MO}/M_{MO}, the slope of the elevator control force versus speed curve need not be stable at speeds greater than V_{FC}/M_{FC}, but there must be a push force at all speeds up to V_{DF}/M_{DF} and there must be no sudden or excessive reduction of control force as V_{DF}/M_{DF} is reached. (Adequate roll capability to assure a prompt recovery from a laterally upset condition must be available.)$^{\text{JAR-25 ONLY}}$

((4) Reserved.)$^{\text{JAR-25 ONLY}}$

((5) *Trim change due to airbrake selection.* With the aeroplane trimmed at VMO/MMO, extension of the airbrakes at speeds above VMO/MMO, over the available range of movements of the pilots control must not result in an excessive positive load factor with the stick free, and any nose-down pitching moment must be small.)$^{\text{JAR-25 ONLY}}$

(b) *Maximum speed for stability characteristics, V_{FC}/M_{FC},* V_{FC}/M_{FC} is the maximum speed at which the requirements of FAR/JAR 25.143**(g)**, 25.147(e), 25.175(b)(1), 25.177, and 25.181 must be met with flaps and landing gear retracted. **Except as noted in FAR/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 25.143(g), 25.147(e), 25. 175(b)(1), 25.177 and 25.181 must be met, is the lower of 300 knots CAS or V_{FC} or any lower speed at which it is demonstrated that the airframe will be free of ice accretion.

<u>FAR/JAR 25.1419 Ice protection</u> – FAR 25.1419 is amended to adopt the conditional statement of JAR-25.1419 in the introductory conditional statement. Current FAR 25.1419 bases the need for showing an airplane can operate safely in the icing conditions of Appendix C on the presence of ice protection systems, the introductory phrase reading, "If certification with ice protection provisions is desired. . .." Current JAR-25.1419 bases the need for showing an airplane can operate safely in the icing conditions of Appendix C on the desire of the applicant to certificate the airplane for flight in icing conditions, the introductory phrase reading, "If certification for flight in icing conditions is desired. . .." The introductory paragraph of both FAR and JAR

25.1419 is also amended to remove redundant text from the second sentence that refers to the "continuous maximum and intermittent maximum conditions of appendix C," which is already specified in the first sentence.

The initial approach taken by the FTHWG was to remove the optional nature of airworthiness certification for flight in icing conditions that currently exists in both FAR 25 and JAR-25. The basis for that approach was that in today's operating environment, with an emphasis on flexibility and minimizing interruptions to scheduled service, it is almost inconceivable that a manufacturer would propose a transport category airplane that is not intended to operate in icing conditions. Though not objecting to this proposal or the logic behind it, industry representatives 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 icing program was complete. This type of approval has been used to permit manufacturers to deliver airplanes to customers for non-revenue flying such as demonstrations, flight crew training, and familiarization – mandatory certification for flight in icing conditions would eliminate this flexibility. The favored option of the FTHWG was to grant this alleviation by adding appropriate text to the regulatory preamble; this approach was rejected by FAA legal counsel on the basis that the preamble material for a rule should not conflict with the regulatory content. A second option discussed by the FTHWG was to add a sub-paragraph to FAR/JAR 25.1419 that would explicitly state that the Type Certificate could be granted prior to completing the icing program provided the manufacturer submitted a plan for its completion prior to delivery of the first airplane or issuance of a standard Certificate of Airworthiness, whichever occurs later (similar to FAR/JAR 25.1529 requirements for Continued airworthiness); various iterations of this proposal were discussed in the FTHWG and, though legally acceptable, it was rejected due to subtle differences in the manner that the member civil aviation authorities define and grant operational approval. Consequently, this NPA/NPRM proposes to amend FAR 25.1419 only to replace the current conditional statement, "If certification with ice protection provisions is desired. . .," with the text used in JAR-25.1419; "If certification for flight in icing conditions is desired. . .." This change was made for two reasons: 1) A literal reading of the current FAR 25.1419 wording implies the applicant does not have to show the airplane can be safely operated in icing conditions unless an ice protection system is installed, and 2) the JAR-25.1419 text will retain the optional nature of certification for flight in icing conditions, which in turn will permit the type certification of airplanes before the icing program is complete with an appropriate limitation against flight in icing conditions.

FAR/JAR 25.1419 Ice protection

If certification for flight in icing conditions is desired, the airplane must be able to safely operate in the continuous maximum and intermittent maximum icing conditions of appendix C. **To establish this** –

(a) An analysis must be performed to establish that the ice protection for the various components of the airplane is adequate, taking into account the various airplane operational configurations; and

(b) To verify the ice protection analysis, to check for icing anomalies, and to demonstrate that the ice protection system and its components are effective, the airplane or its components must be flight tested in the various operational configurations, in measured natural atmospheric icing conditions and, as found necessary, by one or more of the following means:
(1) Laboratory dry air or simulated icing tests, or a combination of both, of the components or models of the components.
(2) Flight dry air tests of the ice protection system as a whole, or of its individual components.
(4) Flight tests of the airplane or its components in measured simulated icing conditions.

(c) Caution information, such as an amber caution light or equivalent, must be provided to alert the flightcrew when the anti-ice or de-ice system is not functioning normally.

(d) For turbine engine powered airplanes, the ice protection provisions of this section are considered to be applicable primarily to the airframe. For the powerplant installation, certain additional provisions of Subpart E of this part may be found applicable.

<u>FAR/JAR 25, Appendix C</u> - FAR/JAR 25, Appendix C is amended to: 1) Create two subsections, one to define the icing atmospheric conditions and another to define ice accretions, 2) Add a definition of the "takeoff" icing atmospheric conditions, and 3) Define the limiting conditions for determining the ice accretions appropriate to each phase of flight.

New proposed Part 1 of Appendix C contains the existing definitions of atmospheric icing conditions and adds a definition of the icing atmosphere to be used in determining ice accretions for the takeoff phase of flight. One of the early industry objections to adopting the JAA NPA 25F-219 material for the takeoff 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 Appendix C Continuous Maximum Icing conditions (0.80 grams per cubic meter (g/m^3)) will only be found near the top of cloud layers that are greater than 4,000 feet deep with the freezing point near the top of the cloud layer. The FAA meteorologists also stated that the amount of water vapor 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 vapor, air, etc.) in that space. This fact would permit a universal definition of a takeoff icing atmosphere that would be equally applicable to all of an airplane's approved takeoff field elevations.

For determining the takeoff ice shapes, changes in the LWC must be considered in the segment of the flight path from the takeoff surface to 1,500 feet above ground level (AGL), though the lowest cloud base is generally above 100 feet AGL. Theory and experiment have shown that the LWC is smallest (usually less than 0.10 g/m^3) at cloud base and generally increases with distance above cloud base. The ice accretion on an airplane would be due to the gradually increasing LWC and normally decreasing air temperature as the airplane climbs from the runway to 1,500 feet AGL. Although measured data at low altitudes AGL are sparse, the FAA Technical Center's database on inflight icing conditions contains data for 99^{th} percentile LWC limits as low as 2,500 feet AGL. When scaled to 1,500 feet 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 1,500 ft. 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 takeoff 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 1,500 feet AGL, the airplane would be exposed to an atmosphere with a uniform LWC of approximately 0.30 g/m^3.

Based on the information discussed above, the FTHWG proposes to define the takeoff maximum icing conditions atmosphere as having a constant LWC of 0.35 g/m^3, which will provide a conservative estimate of actual conditions. The two other necessary characteristics to describe the takeoff icing atmosphere are a water droplet mean effective diameter (MED) (more correctly referred to in current terminology as median-volumetric diameter (MVD))and an ambient temperature. An MED value of 20μ was determined to be appropriate to such low level icing conditions by both industry and FAA icing specialists.

Selection of the ambient temperature for takeoff 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 takeoff 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 takeoff maximum icing conditions was added as paragraph (c) of Part 1. The new Appendix C definition of takeoff icing conditions also notes that the takeoff maximum icing conditions exist from ground level to 1,500 feet above the takeoff surface to coincide with the definition of the takeoff path of FAR/JAR 25.111.

New proposed Part 2(a) of Appendix C contains definitions of the ice accretions appropriate to each phase of flight, along with any limiting conditions (e.g., altitude limits for "Takeoff ice" accretion); further considerations for the development of artificial and natural ice accretions are contained in the advisory material associated with these proposed regulatory changes. Each Subpart B flight requirement that must be met in icing conditions specifies which of these ice accretion is to be used in showing compliance. In order to reduce the number of artificial ice accretions that must be manufactured, proposed Part 2 also permits the use of an 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 takeoff phase will generally have a large effect on performance).

One FTHWG member did not consider the combination of the proposed regulatory changes and associated advisory material to provide a definitive enough description of the ice accretions to be considered, particularly with regard to the variables to be considered in determining the critical ice shape for a particular flight phase; that member's views are expressed in the following position paper:

Flight Test Harmonization Working Group - Flight In Icing Conditions

ALPA Minority Position: Ice Accretions

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 requirement is intended to insure that the full range of possible accretion locations for atmospheric conditions defined by this appendix are considered. The primary parameter of concern is location of the ice accretion on the airfoil. The majority position is that "flight conditions (e.g. configuration, speed, angle of attack, and altitude)" will provide for the most critical accretion. The proposed change merely insures the objective stated by the majority is in fact achieved.

In NASA research accomplished following the 1994, ATR-72 accident at Roselawn, Indiana 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 airfoil 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 airfoil aerodynamics of a simulated ice shape depending upon its location on the negative pressure side of the airfoil.

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 airfoil. 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 which accumulates prior to normal system operation, changing the location of ice on the suction side of the airfoil 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.

The NTSB, in their report on the EMB 120 accident at Monroe, Michigan 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.

Majority Disposition of ALPA Position on Ice Accretions

The rules and guidance material drafted by the flight test harmonization working group consider ice accretions for all phases of flight and all configurations of high lift devices. The rules require that the effects of the ice accretion during the phases of flight with high lift devices extended be accounted for. The 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 minority position determined the effect on lift and drag of a spoiler-like protuberance located at various chord locations of a two dimensional airfoil. These data do not support the minority 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 airfoil with high lift devices extended.

The effect of a protuberance on a two-dimensional airfoil 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 reference were also considered by the FTHWG when it discussed ice accreted in conditions outside of Appendix C. The majority of the FTHWG decided not to include these accretions because the only icing design envelope available is Appendix C, and also because of the IPHWG tasking.

New Part 2(b) of Appendix C addresses specific concerns related to determining the ice accretions appropriate to the takeoff phase. As noted in the discussion of the Subpart B takeoff proposals, the FTHWG assumed the candidate airplanes would be in compliance with operating rules that prohibit pilots from conducting takeoffs with any frost, snow or ice adhering to certain airplane surfaces or require the airplane to be operated in accordance with an approved ground de-icing/anti-icing program, resulting in the airplanes being free of frost, snow, and ice up to the point of lift-off. Part 2(b) also clarifies that no crew action to activate the ice protection system is assumed until the airplane is 400 feet above the takeoff surface; this is consistent with the existing requirement of FAR/JAR 25.111(c)(4) that limits the number of configuration changes requiring crew action before reaching 400 feet above the takeoff surface (i.e., end of the second segment).

New Part 2(c) of Appendix C defines an ice accretion prior to normal ice protection system operation that must be considered. Further guidance is provided to define this ice accretion in Appendix 1 of the associated advisory material. This ice accretion prior to normal ice protection system operation is necessary since transport category airplanes will be required to fly with some amount of ice accretion, even with a fully operational ice protection system; this is equally 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 is to be determined as an exposure to the continuous maximum icing conditions of Appendix C, Part 1, that includes: 1) the time for recognition, 2) a delay time appropriate to the means of ice detection, and 3) the time for the ice protection system to perform its intended function after manual or automatic activation. Considerable discussion was dedicated to defining the delay time appropriate to the various means of "visual" detection. The advisory material describes two methods of visual detection: 1) recognition that some prescribed amount of ice has accreted on a reference surface, and 2) recognition of the first sign of ice accretion on a reference surface. A delay time of 30 seconds exposure to continuous maximum icing conditions was agreed to by the majority of the FTHWG members for both of these cases (and for crew recognition of visible moisture and temperature conditions conducive to icing). One member disagreed with the use of a 30 second time delay for a visual means of ice detection that relied on the flightcrew to recognize the first indication of an ice accretion on a reference surface and submitted the following position paper:

Aviation Rulemaking Advisory Committee
Transport Airplane and Engines Issues Group

Flight Test Harmonization Working Group - Flight In Icing Conditions

ALPA Minority Position: Delay Ice

1) Conditions (a) (specified amount prior to activation) and (b) (activation at first indication) of Paragraph A1.2.3 of the associated advisory material are really the same situation with a smaller amount required for condition (b). There is no technical reason for the difference in 143 & 207 requirements for (a) and (b). Since checking outside the cockpit (not even close to a primary IMC visual scan pattern) in all visibility's and lighting conditions is required for both (a) & (b) they should have the same basic maneuver and stall protections.

2) The 30 second & 10 second times are now clearly pilot reaction times. I can accept a 10 seconds reaction time following indication from an ice detection system if the indication meets appropriate warning system criteria. 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. I believe this was discussed at either FTHWG #15 or #16; was its omission an oversight or is there perhaps an existing requirement for such indications?

3) I can accept the reduced maneuver and stall requirements for conditions (c) through (e), even though the 30 second reaction time is a stretch for me in condition (c) - we expect pilots 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, I can not accept 30 seconds for the pilot delay with indications outside the cockpit. I would reluctantly accept the 2 minutes as originally proposed because of the precedent in 33.77; although I am certain that any human factor study would 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 insuring that no more than something around 20 seconds passes between checks of the representative surface. Many flights operate for extended periods without ice accumulations 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 TSB report on the Air Canada RJ accident in Fredericton, clearly shows these workload issues.
In an email that was copied to many of you, one FTHWG industry member said, "If the height of ice is an important factor for drag increase, it is not the major factor for handling qualities." If so, the additional ice accreted during the more representative recognition time would not have a

major effect. Thus, there is no reason not to require it. Additionally, as the chairman of the IPHWG briefed the TAEIG on June 30, a significant number of Ice Protection Harmonization Working Group (IPHWG) members feel our rule eliminates the need for the operational rule nearly finalized by the IPHWG. The IPHWG rule (driven by incident/accident data analysis) responds to the critical problem of operations with ice accumulations prior to system operation. The 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).

Majority Disposition of ALPA Position on Delay Ice

1. The test requirements for conditions (a) (specified amount prior to activation) and (b) (activation at first indication) are different because it is assumed the flightcrew will recognize the existence of icing conditions and be vigilant in monitoring the reference surface for the first indication of ice accretion. Hence condition (b) would be expected to have a smaller amount of ice accretion and that accretion would exist for a shorter time period than that of condition (a). This is the logic used in prescribing the less stringent flight test requirements for condition (b).

2. Airworthiness authorities would apply appropriate criteria, as they do with other systems requiring pilot action, in determining the applicability of the prescribed 10 second delay time to the method of indication used by the ice detector system (this would be covered by the general requirement of FAR/JAR 25.1301(a) for installed equipment to "Be of a kind and design appropriate to its intended function.

3. The pertinent point of the third paragraph is whether 30 seconds is an acceptable delay time for visual means of ice detection requiring the pilot to look outside the cockpit. The 30 second time delay is just that and provides a reasonable time period for the pilot to activate the ice protection system – the ice accretion prior to normal ice protection system operation is determined as the amount of ice that will accrete during the "recognition" (or detection) time combined with the further ice accretion that will occur during the 30 second delay time plus the ice that will accrete in the time between activation of the ice protection system and the point at which it performs its intended function, all in the continuous maximum icing conditions of Appendix C, Part 1.

Appendix C to Part 25:

Part 1 - Atmospheric icing conditions
(a) ...
(b) ...
(c)Takeoff maximum icing. The maximum intensity of atmospheric icing conditions for takeoff (takeoff maximum icing) is defined by the cloud liquid water content of 0.35 g/m3,

the mean effective diameter of the cloud droplets of 20 micron, the ambient air temperature at ground level of -9 degrees C. The takeoff maximum icing conditions extend from ground level to a height of 1500 ft above the level of the takeoff surface.

Part 2 - Airframe ice accretions for showing compliance with subpart B

(a) Ice accretions - General

FAR/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 1 of this Appendix, and the flight conditions (e.g. configuration, speed, angle of attack, and altitude). The following ice accretions must be determined:

(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, between liftoff and 400 ft above the takeoff surface, assuming accretion starts at liftoff in the Takeoff Maximum icing conditions of Part 1, paragraph (c) of this Appendix.

(2) "Final Take-off ice" is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, between 400 ft and 1500 ft above the take-off surface, assuming accretion starts at liftoff in the Takeoff Maximum icing conditions of Part 1, paragraph (c) of this Appendix.

(3) "En-route 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 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.

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

- **The more critical of "Take-off ice" and "Final Take-off ice" may be used throughout the take-off phase.**

- **"Holding ice" may be used for the en-route, holding, approach, landing and go-around flight phases.**
- **"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"**

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.

(b) Ice accretions for the take-off phase

For both unprotected and protected parts, the ice accretion may be determined by calculation, assuming the Takeoff Maximum icing conditions defined in Appendix C, and:

- **that airfoils, control surfaces and, if applicable, propellers are free from frost, snow, or ice at the start of the take-off, and -**
- **the ice accretion starts at liftoff,**
- **the critical ratio of thrust/power-to-weight,**
- **failure of the critical engine occurs at V_{EF}, and**
- **crew activation of the ice protection system 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 airplane is 400 ft above the take-off surface.**

(c) 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.

Economic Impact

(To be added)

Proposed Advisory Material

(Referenced and provided under separate cover.)

Revision (03/01/00): Inserted § 25.107(g) to be consistent with 1g stall rule definition of V_{FTO}. Existing § 25.107(g) became § 25.107(h).

Revised speed reference in § 25.121(c) from "at not less than 1.18 V_{SR}" to "at V_{FTO}" to be consistent with 1g stall rule.
Revised speed reference in § 25.123 from "1.18 V_{SR}" to "V_{FTO}" to be consistent with 1g stall rule.
Revised preamble material for § 25.207 discussing use of artificial stall warning for all configurations to better reflect regulatory wording.

Attachment 2
FTHWG Report
January 2000

PROPOSAL
FOR
FAA ADVISORY CIRCULAR/JAA ADVISORY CIRCULAR JOINT RELATED TO JAR/FAR 25.21(g)

HANDLING CHARACTERISTICS AND PERFORMANCE IN APPENDIX C ICING CONDITIONS

Minority positions are referenced in a 'text box' like this.

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0 INTRODUCTION

This Advisory Circular {Advisory Circular Joint} provides guidance information on acceptable means of compliance related to performance and handling characteristics requirements of subpart B as affected by flight in the icing conditions defined in Appendix C of FAR 25 {JAR-25}. Like all Advisory Circular {Advisory Circular Joint} material, this guidance information is not mandatory and does not constitute regulations. It is derived, in large part, from previous experience in finding compliance with the airworthiness requirements and describes methods and procedures found to be acceptable by that experience. Where mandatory terms such as "shall" and "must" are used in this Advisory Circular {Advisory Circular Joint}, these terms apply only to applicants who seek to demonstrate compliance by use of the specific methods described herein, while that method of compliance is itself not mandatory.

The guidance information is presented in three chapters plus three appendices.

Chapter 1 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 airplane in the atmospheric conditions of FAR 25 {JAR-25}, Appendix C.

Chapter 2 describes acceptable methods and procedures that an applicant may use to show that an airplane meets these requirements. Depending on the design features of a specific airplane as discussed in Appendix 3 of this AC, its similarity to other types or models, and the service history of those types or models, some judgment will often be necessary for determining that any particular method or procedure is adequate for showing compliance with a particular requirement. These factors are also discussed in Chapter 2. Any alternate method or procedure proposed by the applicant should be given due consideration. Applicants are encouraged to develop more efficient and less costly methods of achieving the objectives of the applicable requirements of FAR 25 {JAR-25}.

Chapter 3 provides an acceptable flight test program where flight testing is selected by the applicant and agreed to by the Authority as being the primary means of compliance.

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

1 REQUIREMENTS GUIDANCE

1.1 General

Chapter 1 provides guidance for showing compliance with Subpart B requirements for flight in icing conditions.

Operating rules for large and turbine-powered multiengine airplanes (e.g. FAR 91.527, FAR 121.629, and JAR-OPS1.345) require that the airplane 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.

Appendix C to FAR/JAR 25 defines the ice accretions to be used in showing compliance with FAR/JAR 25.21(g) and (h).. Appendix 1 of this AC provides details on ice accretions including accounting for delay in the operation of the ice protection system and consideration of ice detection systems.

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.

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

1.2 Proof of Compliance (FAR/JAR 25.21(g))

Demonstration of compliance with certification requirements for flight in icing conditions may be accomplished by any of the means discussed in paragraph 2.1.

Certification experience has shown that airplanes of conventional design do not require additional detailed substantiation of compliance with the requirements of FAR/JAR 25.23, 25.25, 25.27, 25.29, 25.31, 25.231, 25.233, 25.235, 25.253(a) and (b), and 25.255 for flight in icing conditions or with ice accretions.

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.

1.3 Propeller Speed and Pitch Limits (FAR/JAR 25.33)

Certification experience has shown that it may be necessary to impose additional propeller speed limits for operations in icing conditions.

1.4 Performance - General (FAR/JAR 25.101)

1.4.1 The propulsive thrust available for each flight condition must be appropriate to the airplane operating limitations and normal procedures for flight in icing conditions. In general, it is acceptable to determine the propulsive thrust available by suitable analysis, substantiated when required by appropriate flight tests (e.g., when determining the thrust available after 8 seconds for FAR/JAR 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.

1.4.2 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.

1.4.3 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 analysis.

1.4.4 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.

1.4.5 Performance associated with flight in icing conditions is applicable after exiting icing conditions until the ice protection systems are selected "off" and the airplane critical surfaces are free of ice accretion.

1.5 Stalling speed (FAR/JAR 25.103)

Certification experience has shown that for airplanes of conventional design it is not necessary to make a separate determination of the effects of Mach number on stall speeds for the airplane with ice accretions.

1.6 Failure Conditions (FAR/JAR 25.1309)

1.6.1 The failure modes of the ice protection system and the resulting effects on airplane handling and performance should be analyzed in accordance with FAR/JAR 25.1309. In determining the probability of a failure condition, it should be assumed that the probability of entering icing conditions is one.

1.6.2 For probable failure conditions that are not annunciated to the crew, the guidance in this Advisory Circular for a normal condition is applicable with the Failure Ice configuration.

1.6.3 For probable failure conditions that are annunciated and the associated procedure does not require the airplane to exit icing conditions, the guidance in this Advisory Circular for a normal condition is applicable with the Failure Ice configuration.

1.6.4 For probable failure conditions that are annunciated to the crew, and the associated operating procedure requires the airplane to leave the icing conditions as soon as practicable, it should be shown that the airplane is capable of continued safe flight and landing with the "Failure ice" accretion defined in Appendix C. 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.

1.6.5 For failure conditions that are improbable but not extremely improbable, the analysis and substantiation of continued safe flight and landing, in accordance with FAR/JAR 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.

1.7 Flight-related Systems

In general, systems aspects are covered by the applicable systems and equipment requirements in other Subparts of FAR/JAR 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 thrust/power settings. This may result in a minimum power 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 may also be affected.

(d) Ice blockage of unprotected inlets and vents which 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.

(j) Automatic flight control systems operation.

(l) Installed thrust. This includes operation of ice protection systems when establishing acceptable thrust setting procedures, control, stability, lapse rates, rotor speed margins, temperature margins, Automatic Takeoff Thrust Control System (ATTCS) operation, and thrust lever angle functions.

1.8 Airplane Flight Manual (JAR/FAR 25.1581)

1.8.1 Limitations

(a) Where limitations are required to ensure safe operation in icing conditionsthese limitations shall be stated in the AFM.

(b) The Limitations section of the AFM should include, as applicable, a statement similar to the following: "In icing conditions the airplane 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."

1.8.2 Operating Procedures

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

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

(c) 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, should also be included.

1.8.3 Performance Information

Performance information, derived in accordance with Subpart B, must be provided in the AFM for all relevant phases of flight.

2 ACCEPTABLE MEANS OF COMPLIANCE - GENERAL

2.1 General

Chapter 2 describes acceptable methods and procedures that an applicant may use to show that an airplane meets the performance and handling requirements of subpart B in the atmospheric conditions of Appendix C to FAR/JAR-25.

Compliance with FAR/JAR 25.21(g) should be shown by one or more of the methods listed in this section, as agreed to with the Certification Authority.

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

The design features included in Appendix 3 should be considered when determining the extent of the substantiation program.

Appropriate means for showing compliance include:

<u>Flight Testing</u>
Flight testing in dry air using artificial ice shapes or with ice shapes created in natural icing conditions.

<u>Wind Tunnel Testing and Analysis</u>
An analysis of results from wind tunnel tests with artificial ice shapes.

<u>Engineering Simulator Testing and Analysis</u>
An analysis of results from engineering simulator tests.

<u>Engineering Analysis</u>
An analysis which may include the results from executing an agreed computer code.

<u>Ancestor Airplane Analysis</u>
An analysis of results from a closely related ancestor airplane.

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.

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

2.2 Flight Testing

2.2.1 General

The extent of the flight test program should consider the results obtained with the non-contaminated airplane and the design features of the airplane as discussed in Appendix 3 of this AC.

It is not necessary to repeat an extensive performance and flight characteristics test program on an airplane with ice accretion. A suitable program, which is sufficient to demonstrate compliance with the requirements, can be established from experience with airplanes of similar size, review of the ice protection system design, control system design, wing design, horizontal and vertical stabilizer design, performance characteristics and handling characteristics of the non-contaminated airplane. In particular it is not necessary to investigate all weight and center of gravity combinations when results from the non-contaminated airplane clearly indicate the most critical combination to be tested. It is not necessary to investigate the flight characteristics of the aircraft at high altitude (i.e. above the upper limit specified in Appendix C). An acceptable flight test program is given in Chapter 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.

2.2.2 Flight Testing Using Approved Artificial Ice Shapes

The performance and handling tests may be based on flight testing in dry air with agreed artificial ice shapes.

Additional limited flight tests should be conducted in natural icing conditions, which are discussed in 2.2.3.

2.2.3 Flight Testing In Natural Icing Conditions

(a) 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.

(b) Where flight testing with artificial ice shapes is the primary means of compliance, additional limited flight tests should be conducted in measured 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. For some derivative airplanes with similar aerodynamic characteristics as the ancestor, it may not be necessary to carry out additional flight test in measured natural icing conditions if such tests have been already performed with the ancestor.

2.3 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 2 of Appendix C to FAR Part 25 may be used to substantiate the performance and handling characteristics.

2.4 Engineering Simulator Testing and Analysis

The results of an engineering simulator analysis of an airplane that includes the effects of the ice accretions as defined in Part 2 of Appendix C to FAR Part 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 judgment.

2.5 Engineering Analysis

An engineering analysis that includes the effects of the ice accretions as defined in Part 2 of Appendix C to FAR Part 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 judgment.

2.6 Ancestor Airplane Analysis

An ancestor airplane analysis that includes the effect of the ice accretions as defined in Part 2 of Appendix C to FAR Part 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 airplane.

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

3 ACCEPTABLE MEANS OF COMPLIANCE - FLIGHT TEST PROGRAM

3.1 General

Chapter 3 provides an acceptable flight test program where flight testing is selected by the applicant and agreed to by the Authority as being the primary means for showing compliance.

Where an alternate means of compliance is proposed for a specific paragraph in Chapter 3 it should enable compliance to be shown with at least the same degree of confidence as flight test would provide (see FAR/JAR 25.21(a)(1)).

This test program 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.

3.2 Stalling Speed (FAR/JAR 25.103)

3.2.1 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.

3.2.2 The following represents an acceptable test program subject to the provisions outlined above:

(a) Forward center of gravity position appropriate to the configuration

(b) Normal stall test altitude

(c) Trim at an initial speed of 1.13 to 1.30 V_{SR}. Decrease speed until an acceptable stall identification is obtained.

(1) High lift devices retracted configuration, "Final Take-off ice"

(2) High lift devices retracted configuration, "En-route ice"

(3) Holding configuration, "Holding ice"

(4) Lowest lift take-off configuration, "Holding ice"

(5) Highest lift take-off configuration, "Take-off ice"

(6) Highest lift landing configuration, "Holding ice"

3.3 Accelerate-stop Distance (FAR/JAR 25.109)

The effect of any increase in V_1 due to take-off in icing conditions may be determined by a suitable analysis.

3.4 Take-off Path (FAR/JAR 25.111)

If V_{SR} in the configuration defined by FAR/JAR 25.121(b) with the "Takeoff ice" accretion defined in Appendix C exceeds V_{SR} for the same configuration without ice accretions by more than the greater of 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.

3.5 Landing Climb: All-engines-operating (FAR/JAR 25.119)

The following represents an acceptable test program:

(a) "Holding ice"

(b) Forward center of gravity position appropriate to the configuration

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

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

3.6 Climb: One-engine-inoperative (FAR/JAR 25.121)

The following represents an acceptable test program:

(a) Forward center of gravity position appropriate to the configuration

(b) Stabilize 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.

(1) High lift devices retracted configuration, final take-off climb speed, "Final Take-off ice"

(2) Lowest lift take-off configuration, landing gear retracted, V_2 climb speed, "Take-off ice"

(3) Approach configuration appropriate to the highest lift landing configuration, landing gear retracted, approach climb speed, "Holding ice".

3.7 En-route Flight Path (FAR/JAR 25.123)

The following represents an acceptable test program:

(a) "En-route ice"

(b) Forward center of gravity position appropriate to the configuration

(c) En-route configuration and climb speed

(d) Stabilize 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.

3.8 Landing (FAR/JAR 25.125)

The effect of landing speed increase on the landing distance may be determined by a suitable analysis.

3.9 Controllability and Maneuverability - General (FAR/JAR 25.143 and 25.177)

3.9.1 A qualitative and quantitative evaluation is usually necessary to evaluate the airplane's controllability and maneuverability. In the case of marginal compliance, or the force limits or stick force per g limits of FAR /JAR 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 as the "Holding ice" is usually the most critical.

3.9.2 The following represents an acceptable test program for general controllability and maneuverability subject to the provisions outlined above:

(a) Holding ice

(b) Medium to light weight, aft center of gravity position, symmetric fuel loading

(c) Trim at specified speed. Conduct 30 degrees banked turns left and right with rapid reversals. Conduct 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}). Deploy and retract deceleration devices at the specified speed.

(1) High lift devices retracted configuration: 1.3 V_{SR}, V_{MO} or 250 KIAS whichever is less.

(2) Lowest lift take-off configuration : 1.3 V_{SR} and V_{FE} or 250 knots IAS whichever is less.

(3) Highest lift landing configuration : V_{REF} and V_{FE} or 250 knots IAS whichever is less.

(d) Lowest lift take-off configuration: 1.13 V_{SR} or $V_{2\,MIN}$, one engine inoperative (simulated), 30 degrees banked turns left and right with normal turn reversals and, in wings-level flight, a 5 knot speed decrease and increase

(e) Approach and go-around with all engines operating using the recommended procedure

(f) Approach and go-around with one engine inoperative (simulated) using the recommended procedure

(g) Approach and landing using the recommended procedure.. In addition satisfactory controllability should be demonstrated during a landing with V_{REF} minus 5 knots. These tests should be done at heavy weight and forward center of gravity.

(h) Approach and landing with one engine inoperative (simulated) using the recommended procedure.

3.9.3 The following represents an acceptable test program for compliance with controllability requirements in low g maneuvers and in sideslips.

For pushover maneuvers, it should be shown that the airplane 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 maneuver without exceeding 50 pounds pull control force.

Minority Positions

FAA, JAA, ALPA (zero-g pushover disagreement):

For pushover maneuvers, a push force should be maintained down to zero g or the lowest load factor obtainable if limited by elevator power.

Transport Canada

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 maneuver without exceeding 50 pounds pull control force.

[For details of Minority Positions, refer to the Draft NPRM.]

For sideslips, changes in longitudinal control force to maintain speed with increasing sideslip should be progressive with no reversals or sudden discontinuities (see paragraph 3.15.1).

(a) "Holding ice". For airplane with unpowered elevators these tests should also be performed with "Sandpaper ice"

(b) Medium to light weight, the most critical of aft or forward center of gravity position, symmetric fuel loading

(c) With the airplane in trim, or as nearly as possible in trim, at the specified trim speed, perform a continuous maneuver (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.

(1) Highest lift landing configuration at idle thrust, and the more critical of:

- Trim speed 1.23 V_{SR}, target speed not more than 1.23 V_{SR}, or

- Trim speed V_{FE}, target speed not less than V_{FE} - 20 knots.

(2) Highest lift landing configuration at go-around thrust, and the more critical of:

- Trim speed 1.23 V_{SR}, target speed not more than 1.23 V_{SR}, or:

- Trim speed V_{FE}, target speed not less than V_{FE} - 20 knots.

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

3.9.4 The following represents an acceptable test program for compliance with controllability requirements with the ice accretion prior to normal operation of the ice protection system.

(a) Where the ice protection system is activated as described in A1.2.3(a), paragraphs 3.9.1, 3.9.2 and 3.9.3 are applicable with the ice accretion prior to normal system operation.

(b) Where the ice protection system is activated as described in A1.2.3 (b), (c), (d) or (e), it is acceptable to demonstrate adequate controllability with the ice accretion prior to normal system operation, as follows:

With the airplane in the prescribed configuration, trim at the specified speed. Conduct pull up to 1.5g and pushover to 0.5g without longitudinal control force reversal.

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

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

3.10 Longitudinal Control (FAR/JAR 25.145)

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

3.10.2 The following represents an acceptable test program for compliance with FAR/JAR 25.145(a):

(a) Holding ice

(b) Medium to light weight, aft center of gravity position, symmetric fuel loading

(c) Trim 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.

(1) High lift devices retracted configuration, maximum continuous thrust

(2) Maximum lift landing configuration, maximum continuous thrust.

3.11 Directional and Lateral Control (FAR/JAR 25.147)

Qualitative evaluations should be combined with the other testing. The results from the non-contaminated airplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, these cases should be repeated.

3.12 Trim (FAR/JAR 25.161)

Qualitative evaluations should be combined with the other testing. The results from the non-contaminated airplane tests should be reviewed to determine whether there are any cases where there was marginal compliance. If so, these cases should be repeated.

3.13 Stability - General (FAR/JAR 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.

3.14 Demonstration of Static Longitudinal Stability (FAR/JAR 25.175)

3.14.1 Each of the following cases should be tested. In general, it is not necessary to test the cruise configuration at low speed (FAR/JAR 25.175(b)(2)) or the cruise configuration with landing gear extended (FAR /JAR25.175(b)(3)), nor is it necessary to test at high altitude. Although the maximum speed for substantiation of stability characteristics is the lower of 300 knots CAS or V_{FC}, the maximum speed for demonstration can be limited to 280 knots CAS provided that the stick force gradient can be satisfactorily extrapolated to 300 knots CAS or V_{FC} (e.g. there is no gradient decrease with increasing speed).

3.14.2 The following represents an acceptable test program.

(a) "Holding ice"

(b) High landing weight, aft center of gravity position, symmetric fuel loading

(c) Trim at initial specified speed and other conditions as stated in the requirement.

(1) Climb with high lift devices retracted, Trim at 1.3 V_{SR}

(2) Cruise with high lift devices retracted, Trim at V_{MO} or 250 knots CAS, whichever is lower

(3) Approach with the high lift devices in the approach position appropriate to the highest lift landing configuration, trim at 1.3 V_{SR}

(4) Landing with the highest lift landing configuration, trim at 1.3V_{SR}.

3.15 Static Directional and Lateral Stability (FAR/JAR 25.177)

3.15.1 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 3.19).

3.15.2 The following represents an acceptable test program for static directional and lateral stability:

(a) "Holding ice"

(b) Medium to light weight, aft center of gravity position, symmetric fuel loading

(c) Trim at specified speed. Conduct steady heading sideslips to full rudder authority or 180 lb. rudder pedal force or full lateral control authority (whichever comes first).

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

(2) Lowest lift take-off configuration: Trim at the all-engines-operating initial climb speed

(3) Highest lift landing configuration: Trim at V_{REF}.

3.16 Dynamic Stability (FAR/JAR 25.181)

Provided that there are no marginal compliance aspects with the non-contaminated airplane, 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.

3.17 Stall Demonstration (FAR/JAR 25.201)

3.17.1 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 program which encompasses all weights, center 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 airplane, a reduced test matrix can be established. However, if the stall characteristics with ice accretion show a significant difference from the non-contaminated airplane, or testing indicates marginal compliance, or a stall identification system (e.g. stick pusher) is required to be reset for icing conditions, additional tests may be necessary.

3.17.2 The following represents an acceptable test program 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 center of gravity position, symmetric fuel loading

(c) Normal stall test altitude

(d) Trim at same initial stall speed factor used for stall speed determination. Decrease speed to stall identification and recover using the same test technique as for the non-contaminated airplane.

(1) High lift devices retracted configuration: Straight/Power Off, Straight/Power On, Turning/Power Off, Turning/Power On

(2) Lowest lift take-off configuration: Straight/Power On, Turning/Power Off

(3) Highest lift take-off configuration: Straight/Power Off, Turning/Power On

(4) Highest lift landing configuration: Straight/Power Off, Straight/Power On, Turning/Power Off, Turning/Power On.

3.18 Stall Warning (FAR/JAR 25.207)

3.18.1 Stall warning should be assessed in conjunction with stall speed testing and stall characteristics testing (§ 25.103 and § 25.203 and paragraphs 3.2 and 3.17 of this AC/ACJ) and in tests with faster entry rates.

3.18.2 The following represents an acceptable test program for stall warning in slow down turns of at least 1.5g and at entry rates of at least 2 knot/sec:

(a) "Holding ice"

(b) Medium to light weight, aft center of gravity position, symmetric fuel loading

(c) Normal stall test altitude

(d) Trim at the same initial stall speed factor used for stall speed determination. Increase speed as necessary prior to establishing at least 1.5g and a deceleration of at least 2 knot/sec. Decrease speed until 1 sec after stall warning and recover using the same test technique as for the non-contaminated airplane.

(1) High lift devices retracted configuration: Power On

(2) Lowest lift take-off configuration: Power Off

(3) Highest lift landing configuration: Power Off

3.18.3 The following represents an acceptable test program for evaluating stall warning margin with the ice accretion prior to normal operation of the ice protection system.

(a) Where the ice protection system is activated as described in A1.2.3(a), paragraphs 3.18.1 and 3.18.2 are applicable with the ice accretion prior to normal system operation.

(b) Where the ice protection system is activated as described in A1.2.3 (b), (c), (d) or (e), it is acceptable to demonstrate adequate stall warning with the ice accretion prior to normal system operation, as follows:

In the configurations prescribed in paragraphs (b)(1) and (2), below, trim the airplane at 1.3 V_{SR}. At decelerations of up to 1 knot per second, reduce the speed to stall warning plus 1 second and demonstrate prompt recovery, using the same test technique as for the non-contaminated airplane, without encountering any adverse characteristics. Where stall warning is provided by a different means than for the aircraft without ice accretion and the stall characteristics are demonstrated to be satisfactory, the delay should be at least 3 seconds.

(1) High lift devices retracted configuration: Straight/Power Off

(2) Landing configuration: Straight/Power off.

3.19 Wind Velocities (FAR/JAR 25.237)

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

3.19.2 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 airplane, and the flight characteristics (e.g. control forces and deflections) are similar, then the non-contaminated airplane crosswind component is considered valid.

3.19.3 If the results of the comparison of 3.19.2 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:

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

where V_{CW} is the crosswind component, V_{REF} is the landing reference speed appropriate to a minimum landing weight, and the sideslip angle is that demonstrated at V_{REF} (see paragraph 3.15).

3.20 Vibration and Buffeting (FAR/JAR 25.251)

3.20.1 Qualitative evaluations should be combined with the other testing including speeds up to the maximum speed obtained in the longitudinal stability tests (see paragraph 3.14).

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

3.20.3 An airplane 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.

3.21 Natural Icing Conditions

3.21.1 General

Whether the flight test has been performed with artificial ice shapes or in natural icing conditions, additional limited flight test 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.

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 maneuvers as soon as possible after exiting the icing cloud to minimize the atmospheric influences on ice shedding.

During any of the maneuvers specified in 3.21.2, the behavior of the airplane should be consistent with that obtained with artificial ice shapes. There should be no unusual control responses or uncommanded airplane motions. Additionally, during the level turns and bank-to-bank rolls, there should be no buffeting or stall warning.

3.21.2 Ice accretion/Maneuvers

(a) Holding scenario

The maneuvers specified in the table below should be carried out with the following ice accretions representative of normal operation of the ice protection system:

- on unprotected parts: A thickness of 3 inches on those parts of the airfoil where the collection efficiency is highest should be the objective. (A thickness of 2 inches is normally a minimum value unless a lesser value is agreed.)

- on protected parts: The ice accretion thickness should be that resulting from normal operation of the ice protection system.

For airplanes with control surfaces which 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.

Configuration	c.g.	Trim speed	Maneuver
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)	1.4 V_S or 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

(b) Approach/Landing Scenario

The maneuvers specified in the table below should be carried out with successive accretions in different configurations on unprotected surfaces such that the final ice accretion represents the sum of the amounts accreted in each configuration: -

Ice accretion thickness (*)	Configuration	c.g.	Trim speed	Maneuver
first 0.5 in	Flaps up, gear up	Optional (aft range)	Holding	No specific test

additional 0.25 in	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
additional 0.25 in	Further intermediate flaps, gear up (as applicable)	Optional (aft range)	1.4 V_S or 1.3 V_{SR}	Bank-to-bank rapid roll, 30° - 30°, speed brake extension and retraction (if approved), deceleration to stall warning
additional 0.25 in	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 airfoil with the highest collection efficiency.

3.21.3 For airplanes 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 3.9.3 should be repeated with a thin accretion of natural ice.

3.21.4 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.

3.22 Failure Conditions (FAR/JAR 25.1309)

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

3.22.2 In addition to a general qualitative evaluation, the following test program (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 airplane to exit the icing condition:

(a) The critical ice accretion on the unprotected surfaces (and on the normally protected surfaces that are still functioning following the segmental failure of a cyclical de-ice system), appropriate to normal ice protection system operation during the holding flight phase, plus the critical ice accretion on the normally protected surfaces that are no longer protected as a result of the failure condition.

(b) Medium to light weight, aft center of gravity position, symmetric fuel loading

(c) Trim at specified speed. Conduct 30 degrees banked turns left and right with normal reversals. Conduct pull up to 1.5g and pushover to 0.5g.

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

In addition deploy and retract deceleration devices

(2) Approach configuration, approach speed, thrust for level flight

(3) Landing configuration, landing speed, 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) Trim 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 airplane. Natural stall warning is acceptable for the failure case.

(1) High lift devices retracted configuration: Straight/Power Off

(2) Landing configuration: Straight/Power off.

(e) Approach and go-around with all engines operating using the recommended procedure

(f) 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.

3.22.3 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 3.22.2, or as agreed with the certification 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. airplane configuration, speed, angle of attack, altitude, and -
- the icing conditions of Appendix C, e.g., temperature, liquid water content, mean effective drop diameter.

Minority Positions

ALPA submitted a minority position that supports a more definitive description of the parameters that determine the "critical" ice accretion for each airplane configuration.

[For details of Minority Positions, refer to the Draft NPRM.]

A1.2 Operative Ice Protection System

A1.2.1 All flight phases except take-off

For unprotected parts, the ice accretion to be considered should be determined in accordance with FAR/JAR 25.1419.

Unprotected parts consist of the unprotected airfoil 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 airplanes which are characterized 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.

For Holding Ice, certification experience has shown that the amount of ice on the most critical unprotected main airfoil surface (e.g. wing, horizontal or vertical stabilizers) to be considered need not exceed a pinnacle height of typically 3 inches (75 mm) 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 3 inches (75 mm) should be assumed. The shape and texture of the ice are important and should be agreed with the certification authority.

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 which 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 deicing 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).

A1.2.2 Take-off phase

For both unprotected and protected parts, the ice accretion identified in Appendix C to FAR/JAR-25 for the take-off phase may be determined by calculation, assuming the Takeoff Maximum icing conditions defined in Appendix C, and:

- that airfoils, control surfaces and, if applicable, propellers are free from frost, snow, or ice at the start of the take-off, and -
- the ice accretion starts at liftoff,
- the critical ratio of thrust/power-to-weight,
- failure of the critical engine occurs at V_{EF}, and
- crew activation of the ice protection system 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 airplane is 400 ft above the take-off surface.

The ice accretions identified in Appendix C to FAR/JAR-25 for the take-off phase are:

- Take-off ice: The most critical ice accretion between liftoff and 400 ft above the takeoff surface, assuming accretion starts at liftoff in the icing environment.

- Final Take-off ice: The most critical ice accretion between 400 ft and 1500 ft above the take-off surface, assuming accretion starts at liftoff in the icing environment.

A1.2.3 Ice accretion prior to normal system operation

Ice protection systems are normally operated as anti-icing systems (i.e. designed to prevent ice accretion on the protected surface) or deicing systems (i.e. designed to remove ice from the protected surface). In some cases, systems may be operated as anti-icing or deicing 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.

The Airplane 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, to account for crew delay in either identifying the conditions and activating the ice protection systems ((a), (b) and (c) below), or activating the ice protection system following indication from an ice detection system ((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.

Minority Positions

ALPA submitted a minority position that questions the applicability of a 30 second delay time to an ice detection method that requires the pilot to look outside the cockpit..

[For details of Minority Positions, refer to the Draft NPRM.]

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

(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 crew delays in recognition of the ice accreted and operation of the system, determined as follows:

(1) the specified accretion, plus
(2) the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part 1(a), plus
(3) 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 crew delays in recognition of the ice accreted and operation of the system, determined as follows:

(1) the ice accretion corresponding to first indication on the reference surface, plus

(2) the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part 1(a), plus

(3) the ice accretion during the system response time.

(c) If 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 the icing conditions and operation of the system, determined as follows

(1) the ice accretion equivalent to thirty seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part 1(a), plus
(2) the ice accretion during the system response time.

(d) If 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, probable crew delays in activating the ice protection system and operation of the system, determined as follows

(1) the ice accretion corresponding to the time between entry into the icing conditions and indication from the ice detection system, plus

(2) the ice accretion equivalent to ten seconds of operation in the Continuous Maximum icing conditions of Appendix C, Part 1(a) plus

(3) the ice accretion during the system response time.

(e) If 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:

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

(2) 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

(a) .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.

(b) In the case where the failure condition is annunciated and the associated procedure does not require the airplane 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.

(c) In the case where the failure condition is annunciated and the associated procedure requires the airplane 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 certifying authority.

APPENDIX 2

ARTIFICIAL ICE SHAPES

A2.1 General

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.

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 under paragraph A2.3 as being representative of natural ice accretion.

"Sandpaper ice" is addressed in paragraph A2.3.

A2.2 Shape and Texture of Artificial Ice

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).

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

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

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"

"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 certifying authority. The spanwise and chordwise coverage should be consistent with the areas of ice accretion determined for the conditions of FAR/JAR-25 Appendix C except that, for the zero g pushover maneuver of paragraph 3.9.3, the "Sandpaper ice" may be restricted to the horizontal stabilizer if this can be shown to be conservative.

APPENDIX 3

DESIGN FEATURES

A3.1 Airplane Configuration and Ancestry

An important design feature of an overall airplane configuration that can affect performance, controllability and maneuverability is its size. In addition, the safety record of the airplane's closely-related ancestors may be taken into consideration.

A3.1.1 Size

The size of an airplane 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 airplane size increases.

A3.1.2 Ancestors

If a closely related ancestor airplane 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 maneuverability 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 airplane 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 airplanes.

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 stabilizer, 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 airplane handling and/or control characteristics rather than degraded performance.

A3.3.1 Tail Sizing

The effect on airplane 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 Stabilizer Design

Cambered aerofoils and trimmable stabilizers 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 Stabilizer Design

The effectiveness of the vertical stabilizer in icing conditions can be evaluated by comparison with closely-related ancestor airplanes.

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.

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.

A3.4.1 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.

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.

A3.4.2 Tail Ice Protection/Detection

An ice detection system may activate a tailplane de-icing system on airplanes that do not have visible cues for system operation.

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

U.S. Department
of Transportation
**Federal Aviation
Administration**

800 Independence Ave S W
Washington, D C 20591

MAY 3 2004

Mr. Craig R. Bolt
Manager, Product Development and Validation
Pratt & Whitney
Mail Stop 162-12
East Hartford, CT 06108

Dear Mr. Bolt:

In an effort to clean up pending Aviation Rulemaking Advisory Committee (ARAC) recommendations on Transport Airplane and Engine Issues, the recommendations from the following working groups have been forwarded to the proper Federal Aviation Administration offices for review and decision. We consider your submittal of these recommendations as completion of the ARAC tasks. Therefore, we have closed the tasks and placed the recommendations on the ARAC website at http://www.faa.gov/avr/arm/arac/index.cfm

Date	Task	Working Group
December 1999	Interaction of Systems and Structure Part 33 Static Parts	Loads and Dynamics Harmonization Working Group
March 2000	Part 35/JARP: Airworthiness Standards Propellers	Engine Harmonization Working Group
April 2000	Flight Characteristics in Icing conditions	Flight Test Harmonization Working Group #3 ANM-94-464-A
May 2000	Thrust Reversing Systems	Powerplant Installation Harmonization Working Group
September 2000	Lightning Protection Requirements	Electromagnetic Effects Harmonization Working Group
July 2001	Main Deck Class B Cargo Compartments	Cargo Standards Harmonization Working Group
April 2002	Design Standard for Flight Guidance	Flight/Guidance Systems Harmonization Working Group

21258

I wish to thank the ARAC and the working groups for the resources they spent in developing these recommendations. We will continue to keep you apprised of our efforts on the ARAC recommendations at the regular ARAC meetings.

Sincerely,

Anthony F. Fazio
Executive Director, Aviation Rulemaking
Advisory Committee

Wednesday,

August 8, 2007

Part III

Department of Transportation

Federal Aviation Administration

14 CFR Part 25

Airplane Performance and Handling Qualities in Icing Conditions; Final Rule

DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Part 25

[Docket No. FAA–2005–22840; Amendment No. 25–121]

RIN 2120–AI14

Airplane Performance and Handling Qualities in Icing Conditions

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Final rule.

SUMMARY: This action introduces new airworthiness standards to evaluate the performance and handling characteristics of transport category airplanes in icing conditions. This action will improve the level of safety for new airplane designs when operating in icing conditions, and harmonizes the U.S. and European airworthiness standards for flight in icing conditions.

DATES: This final rule becomes effective October 9, 2007.

FOR FURTHER INFORMATION CONTACT: Don Stimson, FAA, Airplane & Flight Crew Interface Branch, ANM–111, Transport Airplane Directorate, Aircraft Certification Service, 1601 Lind Avenue SW., Renton, Washington 98057–3356; telephone: (425) 227–1129; fax: (425) 227–1149, e-mail: *don.stimson@faa.gov.*

SUPPLEMENTARY INFORMATION:

Availability of Rulemaking Documents

You can get an electronic copy using the Internet by:

(1) Searching the Department of Transportation's electronic Docket Management System (DMS) Web page (*http://dms.dot.gov/search*);

(2) Visiting the FAA's Regulations and Policies Web page at *http://www.faa.gov/regulations_policies;* or

(3) Accessing the Government Printing Office's Web page at *http://www.gpoaccess.gov/fr/index.html.*

You can also get a copy by sending a request to the Federal Aviation Administration, Office of Rulemaking, ARM–1, 800 Independence Avenue SW., Washington, DC 20591, or by calling (202) 267–9680. Make sure to identify the docket number or amendment number of this rulemaking.

Anyone is able to search the electronic form of all comments received into any of our dockets by the name of the individual submitting the comment (or signing the comment, if submitted on behalf of an association, business, labor union, etc.). You may review DOT's complete Privacy Act statement in the **Federal Register** published on April 11, 2000 (Volume 65, Number 70; Pages 19477–78) or you may visit *http://dms.dot.gov.*

Small Business Regulatory Enforcement Fairness Act

The Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996 requires the FAA to comply with small entity requests for information or advice about compliance with statutes and regulations within its jurisdiction. If you are a small entity and you have a question regarding this document, you may contact a local FAA official, or the person listed under **FOR FURTHER INFORMATION CONTACT**. You can find out more about SBREFA on the Internet at *http://www.faa.gov/regulations_policies/rulemaking/sbre_act/*.

Authority for This Rulemaking

The FAA's authority to issue rules regarding aviation safety is found in Title 49 of the United States Code. Subtitle I, Section 106 describes the authority of the FAA Administrator. Subtitle VII, Aviation Programs, describes in more detail the scope of the agency's authority.

This rulemaking is promulgated under the authority described in Subtitle VII, Part A, Subpart III, Section 44701, ''General requirements.'' Under that section, the FAA is charged with promoting safe flight of civil aircraft in air commerce by prescribing minimum standards required in the interest of safety for the design and performance of aircraft. This regulation is within the scope of that authority because it prescribes new safety standards for the design of transport category airplanes.

I. Background

A. Statement of the Problem

Currently, § 25.1419, ''Ice protection,'' requires transport category airplanes with approved ice protection features be capable of operating safely within the icing conditions identified in appendix C of part 25. This section requires applicants to perform flight testing and conduct analyses to make this determination. Section 25.1419 only requires an applicant to demonstrate that the airplane can operate safely in icing conditions if the applicant is seeking to certificate ice protection features.

Although an airplane's performance capability and handling qualities are important in determining whether an airplane can operate safely, part 25 does not have specific requirements on airplane performance or handling qualities for flight in icing conditions. In addition, the FAA does not have a standard set of criteria defining what airplane performance capability and handling qualities are needed to be able to operate safely in icing conditions. Finally, § 25.1419 fails to address certification approval for flight in icing conditions for airplanes without ice protection features.

Service history shows that flight in icing conditions may be a safety risk for transport category airplanes. We found nine accidents since 1983 in the National Transportation Safety Board's accident database that may have been prevented if this rule had been in effect. In evaluating the potential for this rulemaking to avoid future accidents, we considered only past accidents involving tailplane stall or potential airframe ice accretion effects on drag or controllability. We did not consider accidents related to ground deicing since this amendment does not change the ground deicing requirements. We also limited our search to accidents involving aircraft certificated to the icing standards of part 25 (or its predecessor).

B. NTSB Recommendations

This amendment addresses the following National Transportation Safety Board (NTSB) safety recommendations related to airframe icing:[1]

1. NTSB Safety Recommendation A–91–087 [2] recommended requiring flight tests where ice is accumulated in those cruise and approach flap configurations in which extensive exposure to icing conditions can be expected, and requiring subsequent changes in configuration to include landing flaps. This safety recommendation resulted from an accident that was attributed to tailplane stall due to ice contamination.

This amendment requires applicants to investigate the susceptibility of airplanes to ice-contaminated tailplane stall during airworthiness certification. An accompanying Advisory Circular (AC) will provide detailed guidance on acceptable means of compliance, including flight tests in icing conditions where the airplane's configuration is changed from flaps and landing gear retracted to flaps and landing gear in the landing position.

[1] Refer to appendix 3 of the NPRM for more details on these safety recommendations (except for A–96–056, which was not discussed in the NPRM).

[2] ''Effect of Ice on Aircraft Handling Characteristics (1984 Trials),'' Jetstream 31—G–JSSD, British Aerospace Flight Test Report FTR.177/JM, dated May 13, 1985.

2. NTSB Safety Recommendation A–96–056 [3] recommended revising the icing certification testing regulation to ensure that airplanes are properly tested for all conditions in which they are authorized to operate, or are otherwise shown to be capable of safe flight into such conditions. Additionally, if safe operations cannot be demonstrated by the manufacturer, operational limitations should be imposed to prohibit flight in such conditions and flightcrews should be provided with the means to positively determine when they are in icing conditions that exceed the limits for aircraft certification.

This amendment partially addresses safety recommendation A–96–056 by revising the certification standards to ensure that transport category airplanes are properly tested for the critical icing conditions defined in appendix C of part 25. We are considering future rulemaking action to address icing conditions beyond those covered by appendix C of part 25, and to provide flightcrews with a means to positively determine when they are in icing conditions that exceed the limits for aircraft certification.

3. NTSB Safety Recommendation A–98–094 [4] recommended that manufacturers of all turbine-engine driven airplanes (including the EMB–120) provide minimum maneuvering airspeed information for all airplane configurations, phases, and conditions of flight (icing and non-icing conditions). Also, the NTSB recommended that minimum airspeeds should take into consideration the effects of various types, amounts, and locations of ice accumulations, including thin amounts of very rough ice, ice accumulated in supercooled large droplet icing conditions, and tailplane icing.

This amendment partially addresses safety recommendation A–98–094 by requiring the same maneuvering capability requirements at the minimum operating speeds in the most critical icing conditions defined in appendix C of part 25 as are currently required in non-icing conditions. We are considering future rulemaking action to address supercooled large droplet icing conditions.

4. NTSB Safety Recommendation A–98–096 is also a result of the same accident discussed under Safety Recommendation A–98–094, above. The NTSB recommended the FAA require, during type certification, that manufacturers and operators of all transport category airplanes certificated to operate in icing conditions install stall warning/protection systems that provide a cockpit warning (aural warning and/or stick shaker) before the onset of stall when the airplane is operating in icing conditions.

This amendment requires adequate stall warning margin to be shown with the most critical ice accretion for transport category airplanes approved to fly in icing conditions. Except for the short time before icing conditions are recognized and the ice protection system activated, this stall warning must be provided by the same means as for non-icing conditions. Although neither an aural stall warning or stick shaker is required under this amendment, all recently certificated transport category airplanes have used either a stick shaker or an aural warning to warn the pilot of an impending stall. We do not anticipate any future transport category airplane designs without a cockpit warning of an impending stall.

C. Summary of the NPRM

This amendment is based on the notice of proposed rulemaking (NPRM), Notice No. 05–10, which was published in the **Federal Register** on November 4, 2005 (70 FR 67278). In the NPRM, we proposed to revise the airworthiness standards for type certification of transport category airplanes to add a comprehensive set of new requirements for airplane performance and handling qualities for flight in icing conditions. We also proposed to add requirements that define the ice accretion (that is, the size, shape, location, and texture of the ice) that must be considered for each phase of flight.

These changes were proposed to ensure that minimum operating speeds determined during certification of all future transport category airplanes will provide adequate maneuver capability in icing conditions for all phases of flight and all airplane configurations. They would also harmonize the FAA's regulations with those expected to be adopted by the European Aviation Safety Agency (EASA). This harmonization would not only benefit the aviation industry economically, but also maintain the necessary high level of aviation safety.

II. Discussion of the Final Rule

A. General Summary

Twelve commenters responded to the NPRM: Four private citizens, Airbus Industrie (Airbus), the Air Line Pilots Association (ALPA), The Boeing Company (Boeing), Dassault Aviation (Dassault), the General Aviation Manufacturers Association (GAMA), the National Transportation Safety Board (NTSB), Raytheon Aircraft Company (Raytheon), and the United Kingdom Civil Aviation Authority (U.K. CAA).

Seven of these commenters explicitly expressed support for the rule, none opposed it. Many of the commenters suggested specific improvements or clarifications. Summaries of their comments and our responses (including explanations of changes to the final rule in response to the comments) are provided below.[5]

1. Engine Bleed Configuration for Showing Compliance With § 25.119

The proposed § 25.119 would require applicants to comply with the landing climb performance requirements in both icing and non-icing conditions. Raytheon stated that proposed § 25.119(b) is unclear as to whether the engine bleed configuration for showing compliance should include bleed extraction for operation of the airframe and engine ice protection systems (IPS). Raytheon pointed out that engine bleed extraction for operating the airframe and engine IPS could affect engine acceleration time, which would affect the thrust level used for showing compliance. Raytheon noted that the means of compliance in the proposed AC addresses this issue, but recommended that it be clarified within the rule.

While we agree that engine bleed extraction could affect the thrust level used to show compliance with § 25.119(b), we disagree that the rule needs to be revised to state the bleed configuration. For flight in icing conditions, § 25.21(g)(1) requires compliance to be shown assuming normal operation of the airplane and its IPS in accordance with the operating limitations and operating procedures established by the applicant and provided in the Airplane Flight Manual (AFM). The bleed configuration of the engines would be part of the AFM operating procedures that must be used to show compliance with § 25.119(b). As noted by Raytheon, the guidance provided in the AC accompanying this final rule reminds applicants that the

[3] National Transportation Safety Board, 1996. ''In-Flight Icing Encounter and Loss of Control, Simmons Airlines, d.b.a.American Eagle Flight 4184, Avions de Transport Regional (ATR) Model 72–212, N401AM, Roselawn, Indiana, October 31, 1994.'' Aircraft Accident Report NTSB/AAR–96/01. Washington, DC.

[4] National Transportation Safety Board, 1998. ''In-Flight Icing Encounter and Uncontrolled Collision With Terrain, Comair Flight 3272, Embraer EMB–120RT, N265CA, Monroe, Michigan, January 9, 1997.'' Aircraft Accident Report NTSB/AR–98/04. Washington, DC.

[5] The full text of each commenter's submission is available in the Docket.

engine bleed configuration should be considered when showing compliance with the requirements of this final rule.

2. Using the Landing Ice Accretion To Comply With § 25.121(d)(2)(ii)

Boeing proposed using the landing ice accretion for showing compliance with the approach climb gradient requirement in icing conditions, rather than the holding ice accretion as proposed in § 25.121(d)(2)(ii). Boeing recommended this change to harmonize with EASA's proposed rule.

We consider it inappropriate to use the landing ice accretion for compliance with § 25.121(d). Section 25.121(d) specifies the minimum climb capability, in terms of a climb gradient, that an airplane must be capable of achieving in the approach configuration with one engine inoperative. This requirement involves the approach phase of flight, which occurs before entering the landing phase. Depending on the IPS design and the procedures for its use, the landing ice accretion (which is defined as the ice accretion after exiting the holding phase and transitioning to the landing phase) may be smaller than the holding ice accretion. For example, there may be a procedure to use the IPS to remove the ice when transitioning to the landing phase so that the protected areas are clear of ice for landing. It would be inappropriate to allow any reduction in the ice accretion to be used for the approach climb gradient (in the approach phase) resulting from using the IPS in the landing phase.

We note that neither EASA's Notice of Proposed Amendment (NPA) covering the same icing-related safety issues (NPA 16/2004) nor our NPRM define an ice accretion specific to the approach phase of flight. Both proposals used holding ice for compliance in icing conditions because holding ice was considered to be conservative for this flight phase. Therefore, we believe that it is appropriate to define an additional ice accretion that would be specifically targeted at the approach phase of flight. We have added the following definition as paragraph (a)(5) in part II of appendix C:

''Approach ice is the critical ice accretion on the unprotected parts of the airplane, and any ice accretion on the protected parts appropriate to normal IPS operation following exit from the holding flight phase and transition to the most critical approach configuration.''

Section 25.121(d)(2)(ii) is also revised to refer to this definition. The definition of landing ice is revised to be the ice accretion after exiting from the approach phase (rather than after the holding phase as proposed) and redesignated as paragraph (a)(6).

Finally, applicants would still have the option to use a more conservative ice accretion in accordance with paragraph (b) of part II of appendix C. Therefore, applicants would have the option of using the holding ice accretion as proposed in the NPRM if it was more critical than the approach ice accretion.

3. V_{REF} Comparison at Maximum Landing Weight

Proposed § 25.125(a)(2) would require landing distances to be determined in icing conditions if the landing approach speed, V_{REF}, for icing conditions exceeds V_{REF} for non-icing conditions by more than 5 knots calibrated airspeed. Boeing proposed that the V_{REF} speed comparison for icing and non-icing conditions in proposed § 25.125(a)(2) be made at the maximum landing weight. This proposal would harmonize the FAA's rule with the expected EASA final rule. Boeing also stated that the proposed rule was deficient in that it did not specify the weight or weights at which this comparison must be made. The results of this comparison can depend on the weight at which the comparison is made.

We agree that this comparison should be made at the maximum landing weight and have revised § 25.125(a)(2) of the final rule accordingly. We consider this to be a clarifying change that will not impose an additional burden on applicants.

4. Landing Distance in Icing Conditions

As noted in the discussion of the previous comment, proposed § 25.125(a)(2) would require the landing distance to be determined in icing conditions if the landing approach speed, V_{REF}, for icing conditions exceeds the non-icing V_{REF} by more than 5 knots calibrated airspeed. An increase in V_{REF} for icing conditions is normally caused by an increase in stall speed in icing conditions because V_{REF} must be at least 1.23 times the stall speed.

Raytheon noted that a change in stall speed is not the only factor that might affect landing distance in icing conditions. For example, idle thrust might be adjusted by an engine control system designed to maintain sufficient bleed flow to support the demands of engine and airframe ice protection. Also, landing procedures for icing conditions might be different than for non-icing conditions. Raytheon suggested revising proposed § 25.125(a)(2) to require that the landing distance must also be determined in icing conditions if the thrust settings or landing procedures used in icing conditions would cause an increase in the landing distance.

One of the primary safety concerns addressed by proposed § 25.125 is to maintain a minimum speed margin above the stall speed for an approach and landing in icing conditions. This is achieved by increasing the landing approach speed (V_{REF}) if ice on the airplane results in a significant increase in stall speed. Under proposed § 25.125(b)(2)(ii)(B), a significant increase in stall speed relative to this requirement is one that results in an increase in V_{REF} of more than 5 knots calibrated airspeed, where V_{REF} is not less than 1.23 times the stall speed.

An increase in V_{REF} will increase the distance required by the airplane to land and come to a stop since the airplane will touch down at a higher speed. A significant increase in stall speed in the landing configuration due to ice has a secondary effect of increasing the required landing distance. We proposed in § 25.125(a)(2) that this increase in landing distance be taken into account. Proposed § 25.125(a)(2) resulted from the secondary effect of a significant increase in stall speed in the landing configuration due to ice, not to an evaluation of all of the possible reasons why the required landing distance may need to be longer in icing conditions. The commenter correctly points out that a longer landing distance may also be needed if higher thrust settings or different landing procedures are used in icing conditions.

In evaluating the potential costs and effects of the proposed change, we could not find any existing airplanes where, if the requirement proposed by the commenter had been in effect, it would have required an applicant to determine a longer landing distance in icing conditions. In nearly all cases, applicants have not used different thrust or power settings or different procedures for landing in icing conditions. Airplane manufacturers indicated that they did not anticipate this relationship to change for future designs.

When different thrust or power settings or procedures have been used for landing in icing conditions, V_{REF} has also increased by more than 5 knots. In these cases, applicants would be required by the proposed § 25.125(a) to determine the landing distance for icing conditions, and existing § 25.101(c) and (f) require applicants to include the effects of different power or thrust settings or landing procedures on this landing distance.

Therefore, we see no need to amend the proposed requirement as recommended by Raytheon.

5. Sandpaper Ice Accretion

Proposed appendix C, part II(a)(6) defined sandpaper ice as a thin, rough layer of ice. A private citizen notes the NPRM did not specifically state how sandpaper ice should be used or considered in showing compliance with any of the proposed airplane performance and handling qualities requirements. This commenter suggested amending proposed § 25.143(i)(1) to add that if normal operation of the horizontal tail IPS allows ice to form on the tail leading edge, sandpaper ice must also be considered in determining the critical ice accretion. (Proposed § 25.143(i)(1) would require applicants to demonstrate the airplane is safely controllable, per the applicable requirements of § 25.143, with the ice accretion defined in appendix C that is most critical for the particular flight phase.)

Appendix C, part II(a) requires applicants to use the most critical ice accretion to show compliance with the applicable subpart B airplane performance and handling requirements in icing conditions. The determination of the most critical ice accretion must consider the full range of atmospheric icing conditions of part I of appendix C as well as the characteristics of the IPS (per § 25.21(g)(1) and appendix C, part II(a)). This includes consideration of thin, rough layers of ice (known as sandpaper ice) as well as any other type of ice accretion that may occur in the applicable atmospheric icing conditions, taking into account the operating characteristics of the IPS and the flight phase.

Since the requirement to use the most critical ice accretion includes consideration of sandpaper ice and sandpaper ice is not referenced elsewhere in the rule, we have removed appendix C, part II(a)(6) from the final rule. The AC that we are issuing along with this final rule, or shortly thereafter, provides further information on the use of sandpaper ice in showing compliance. (This AC will be available in the Regulatory Guidance Library (RGL) when issued.)

6. Critical Ice Accretion for Showing Compliance With § 25.143(i)(1)

As noted in the discussion of the previous comment, proposed § 25.143(i)(1) would require applicants to demonstrate the airplane is safely controllable, per the applicable requirements of § 25.143, with the ice accretion defined in appendix C that is most critical for the particular flight phase. Raytheon stated that because ice accretion before normal system operation is addressed separately in § 25.143(j), the controllability demonstration required by § 25.143(i)(1) should be limited to only the most critical ice accretion defined in appendix C part II(a) rather than all of appendix C.

For purposes of the controllability demonstrations required by § 25.143(i)(1), appendix C, parts I and II(a), (b), (c), and (d) apply. Appendix C, part II(e) only applies to §§ 25.143(j) and 25.207(h), which are the only subpart B requirements pertaining to flight in icing conditions before activation of the IPS. We acknowledge that this limited applicability of appendix C, part II(e) is unclear in the language proposed, and we have revised the final rule to include a sentence that specifies this limitation.

7. Pushover Maneuver for Ice-Contaminated Tailplane Stall Evaluation

Raytheon stated that proposed § 25.143(i)(2), which states that a push force from the pilot must be required throughout a pushover maneuver down to zero g or full down elevator, is inconsistent with allowing a pull force for recovery from the maneuver. Raytheon noted that the FAA stated in the NPRM that a force reversal (that is, a push force becoming a pull force) is unacceptable, implying that the pilot should only be permitted to relax his or her push force to initiate recovery. The 50-pound limit for recovery in the proposed § 25.143(i)(2) appears to allow up to 50 pounds of force reversal to develop during the maneuver, including at the initiation of recovery from the maneuver. Raytheon stated that they object to the proposed requirement and continue to support the industry proposal for the pushover maneuver submitted to ARAC by the Flight Test Harmonization Working Group. The industry proposal specified there must be no force reversal down to 0.5 g (the limit of the operational flight envelope) and a prompt recovery from zero g (or full down elevator control if zero g cannot be obtained) with less than 50 pounds of stick force. Raytheon stated that the 50-pound pull force was not intended as a limit for the subsequent pull-up maneuver during recovery from the push-over test.

The FAA continues to disagree with the industry proposal, and Raytheon did not offer any new evidence or rationale that would lead us to reconsider our position. As stated in the NPRM, certification testing and service experience have shown that testing to only 0.5 g is inadequate, considering the relatively high frequency of experiencing 0.5 g in operations. Since the beginning of the 1980s, the practice of many certification authorities has been to require testing to lower load factors. The industry proposal for determining the acceptability of a control force reversal (as described in the NPRM) was subjective and would have led to inconsistent evaluations. Requiring a push force to zero g removes subjectivity in the assessment of the airplane's controllability and provides readily understood criteria of acceptability. Any lesser standard would not give confidence that the problem has been fully addressed.

We do not consider the requirement for a push force to be needed to reach zero g, coupled with allowing a pull force of up to 50 pounds during the recovery, to be inconsistent with our position that force reversals are unacceptable within the normal flight envelope. The pushover maneuver ends when zero g is reached (or when full down elevator is achieved if zero g cannot be reached). The recovery is a separate pull-up maneuver, initiated by the pilot, to regain the original flight path. It is acceptable for this maneuver to require a pull force, but the pull force must not exceed 50 pounds, which is the maximum pitch force permitted by the existing § 25.143(c) (renumbered as § 25.143(d) by this amendment) for short term application of force using one hand. No changes were made.

8. Pushover Maneuver Limited by Design Features Other Than Elevator Power

Airbus noted that proposed § 25.143(i)(2) would allow the required pushover maneuver to end before zero g is reached if the airplane is limited by elevator power. Airbus commented that safe design characteristics other than limited elevator power may also prevent an aircraft from reaching zero g during the pushover maneuver (e.g., flight envelope protections designed into fly-by-wire control systems). Airbus proposed revising the proposed rule to allow the pushover maneuver to end before reaching zero g for other safe design characteristics that prevent reaching zero g.

We agree with Airbus and have revised § 25.143(i)(2) to include consideration of other design characteristics of the flight control system that may prevent reaching zero g in the pushover maneuver.

9. Pitch Force Requirements During a Sideslip Maneuver

Raytheon stated that the proposed requirement for flight in icing conditions is more stringent than the requirements applicable to non-icing conditions. Proposed § 25.143(i)(3) would require that any changes in force that the pilot must apply to the pitch control to maintain speed with increasing sideslip angle must be steadily increasing with no force reversals. Raytheon notes the non-icing subpart B static lateral-directional stability requirements of § 25.177 do not specify that the pitch forces cannot reverse. For example, a push force at small sideslip angles that changes to a pull force as sideslip increases is acceptable.

Raytheon noted that it would not be unusual for an airplane to require an increase in pull force with increasing sideslip. If the tailplane or a portion of it developed aerodynamic separation as sideslip increases, then to maintain 1–g flight the elevator hinge moment would require further pull force that could be sudden or become excessive. Raytheon notes this undesirable characteristic would comply with proposed § 25.143(i)(3).

Raytheon and another commenter (a private citizen) proposed that the proposed rule be revised to eliminate the requirements that the pitch force be steadily increasing with increasing sideslip and that there be no reversal. Instead, these commenters suggested that the requirement should be limited to ensuring that there is no abrupt or uncontrollable pitching tendency.

The FAA agrees with the commenters that small, gradual changes in the pitch control force may not be objectionable or unsafe, and that the proposed requirement is unnecessarily more stringent than the requirements for non-icing conditions. The safety concern is sudden or large pitch force changes that would be difficult for the pilot to control. Therefore, we have changed § 25.143(i)(3) in the final rule to read as follows:

''Any changes in force that the pilot must apply to the pitch control to maintain speed with increasing sideslip angle must be steadily increasing with no force reversals, unless the change in control force is gradual and easily controllable by the pilot without using exceptional piloting skill, alertness, or strength.''

Under this new language, abrupt changes in the control force characteristic, unless so small as to be unnoticeable, would not be considered to meet the requirement that the force be steadily increasing. A gradual change in control force is a change that is not abrupt and does not have a steep gradient. It can be easily managed by a pilot of average skill, alertness, and strength. Control forces in excess of those permitted by § 25.143(d) would be considered excessive.

10. Stall Warning in Icing Conditions

Existing § 25.207(c) requires at least a 3 knot or 3% speed margin between the stall warning speed (V_{SW}) and the reference stall speed (V_{SR}). Existing § 25.207(d) requires at least a 5 knot or 5% speed margin between V_{SW} and the speed at which the behavior of the airplane gives the pilot a clear and distinctive indication of an acceptable nature that the airplane is stalled. Under proposed § 25.21(g), the stall warning requirements of § 25.207(c) and (d) would apply only to non-icing conditions. For icing conditions, proposed § 25.207(e) requires that stall warning be sufficient to allow the pilot to prevent stalling when the pilot starts the recovery maneuver not less than 3 seconds after the onset of stall warning in a one knot per second deceleration.

The U.K. CAA noted that proposed § 25.207(e) would allow stall warning in icing conditions to occur at a speed slower than the speed for the maximum lift capability of the wing (also known as the 1g stall speed). This would not be true for non-icing conditions because of § 25.207(c). According to U.K. CAA, if the stall warning speed is slower than the 1g stall speed, the airplane will have little or no maneuvering capability at the point that the airplane gives the pilot a warning of an impending stall. The U.K. CAA stated that in an operational scenario, if the airplane slows to a speed slightly above the stall warning speed, any attempt to maneuver the airplane or further reduce speed could lead to an immediate stall. This situation is of most concern to the U.K. CAA in the landing phase because, unlike the cruise or takeoff phases, there are limited options for the crew to recover from a stall. The airplane is already at low altitude and descending towards the ground, the power setting is low, and the potential to trade height for speed is extremely limited.

Due to this concern, the U.K. CAA recommended making the non-icing stall warning speed margin requirements of § 25.207(c) and (d) also apply to icing conditions, but only when the airplane is in the landing configuration. Since the proposed § 25.207(e) was intended to be used in place of § 25.207(c) and (d) for icing conditions, the U.K. CAA suggested that, if § 25.207(c) and (d) are applied to the landing configuration in icing conditions, then § 25.207(e) need not be applied to the landing configuration.

In developing the proposed rule, the FAA accepted a determination by the Flight Test Harmonization Working Group (FTHWG) that the same handling qualities standards should generally apply to flight in icing conditions as apply to flight in non-icing conditions. In certain areas, however, the FTHWG decided that the handling qualities standards for non-icing conditions were inappropriate for flight in icing conditions. In these areas, the FTHWG recommended alternative criteria for flight in icing conditions.

The stall warning margin was one of the areas where the FTHWG recommended alternative criteria for flight in icing conditions. The FTHWG determined that applying the existing stall warning margin requirements of § 25.207(c) and (d) to icing conditions would be far more stringent than the best current practices and would unduly penalize designs that have not exhibited safety problems in icing conditions. The FTHWG further determined the stall warning requirements of the existing § 25.207(c) and (d) could be made less stringent for icing conditions without compromising safety. As a result, we proposed the less stringent § 25.207(e) to address stall warning margin requirements for icing conditions in place of § 25.207(c) and (d).

No changes have been made to this final rule as a result of the U.K. CAA's comment. We acknowledge that the U.K. CAA has pointed out a deficiency with safety implications in the proposed stall warning requirements. However, U.S. manufacturers' initial cost analysis of the U.K. CAA's recommended changes indicates these changes may significantly increase the costs of this rulemaking beyond the benefits provided due to uncertainties in how the increased stall warning margin requirement would affect airplane type certification testing, certification program schedules, and the design of stall warning systems.

In addition, the U.K. CAA's recommended changes would introduce significant regulatory differences from EASA's airworthiness certification requirements, and might not completely resolve the potential safety issue. For these reasons we believe that additional time and aviation industry participation are needed to determine an appropriate way to address this safety concern. However, we do not believe it is appropriate to delay issuance of this final rule pending resolution of this issue.

This final rule significantly improves the affected airworthiness standards and the benefits of these improvements should be achieved as soon as possible. It also satisfies a number of important NTSB recommendations. As these improvements are being implemented, we will continue to work closely with EASA and industry to address the issue raised by the U.K. CAA. This subject has been included on EASA's 2008 rulemaking agenda, and we will work with them in that context to agree on a harmonized approach. Once these efforts are completed, we will initiate new rulemaking, if appropriate, to adopt any necessary revisions to part 25.

11. Stall and Stall Warning Requirements Prior to Activation of the IPS

Proposed § 25.207(h)(2)(ii) would require compliance with the stall characteristics requirements of § 25.203, using the stall demonstration prescribed by § 25.201, for flight in icing conditions before the IPS is activated. This requirement would apply if the stall warning required by § 25.207 is provided by a different means for flight in icing conditions than for non-icing conditions. The stall demonstration prescribed by § 25.201 requires that the stalling maneuver be continued to the point where the airplane gives the pilot a clear and distinctive indication of an acceptable nature that the airplane is stalled.

Raytheon disagreed with this proposal because the ice accretion resulting from a delay in activating the IPS is a short term transient condition. According to Raytheon, the intent should be to demonstrate only the ability to prevent a stall, rather than to also ensure that the airplane has good stall characteristics. Raytheon stated that it is unnecessary to consider that the pilot might ignore the stall buffeting and continue to increase angle-of-attack until the airplane is stalled. To comply with the proposed rule, Raytheon argued that an airplane with a stick pusher stall identification system would be required to have its stick pusher activation based on a contaminated wing leading edge for non-icing conditions. This would require increased takeoff and landing speeds and negatively impact all takeoff and landing performance.

Raytheon also stated that the cost impacts would be excessive for what is only a transient condition. Raytheon's position is that there is no need to consider the airplane's handling qualities after it has stalled. It should be sufficient to show that the pilot can prevent stalling if the recovery maneuver is not begun until at least three seconds after the onset of stall warning, which is also required by the proposed § 25.207(h)(2)(ii).

We do not agree with Raytheon's comments. Because of human factors considerations, proposed § 25.207(b) generally requires that the same means of providing a stall warning be used in both icing and non-icing conditions. Therefore, if a stick shaker is used for stall warning in non-icing conditions (as is the case for most transport category airplanes) it must also be used for stall warning in icing conditions. The reason for this proposed requirement is that in icing accidents and incidents where the airplane stalled before the stick shaker activated, flightcrews have not recognized the buffeting associated with ice contamination in time to prevent stalling. Proposed § 25.207(h)(2)(ii) allows a different means of providing stall warning in icing conditions only for the relatively short time period between when the airplane first enters icing conditions and when the IPS is activated. (This exception to the proposed § 25.207(b) is further limited such that it only applies when the procedures for activating the IPS do not involve waiting until a certain amount of ice has been accumulated.)

Because there is still a safety concern with flightcrews recognizing a stall warning that is provided by a different means than the flightcrew would normally experience, we consider it essential that the airplane also be shown to have safe stall characteristics. Poor stalling characteristics with an iced wing have directly contributed to the severity of icing accidents involving a stall in icing conditions.

As for Raytheon's comment about the cost impacts, we evaluated these as part of the regulatory evaluation conducted for the NPRM, and we do not agree that the cost impacts associated with this requirement are excessive. In addition, the adopted § 25.207 will not require airplanes with stick pusher stall identification systems to have their stick pusher activation based on a contaminated wing leading edge for non-icing conditions. Section 25.207(h)(2)(ii) does not apply if the same stall warning means is used for non-icing and icing conditions. If a stick shaker is used for stall warning and if the stick shaker activation point must be advanced due to the effect of the ice accreted before activation of the IPS, this would result in the same negative effect on takeoff and landing speeds. However, if the procedures for activating the IPS ensure that it is activated before any ice accretes on the wings, neither the stick shaker activation point nor the takeoff and landing speeds will be affected. This could be accomplished, for example, by using an ice detector that would activate the IPS before ice accretes on the wings, or by procedures for activating the IPS based on environmental conditions conducive to icing, but before ice would actually accrete on the wings.

12. Dissipation of Ice Shapes at High Altitudes and High Mach Numbers

Proposed § 25.253(c) specifies the maximum speed for demonstrating stability characteristics in icing conditions. Proposed § 25.253(c)(3) allows this speed to be limited to the speed at which it is demonstrated that the airframe will be free of ice accretion due to the effects of increased dynamic pressure. Raytheon stated that experience has shown that ice shapes dissipate quickly at high altitude and high Mach numbers. Raytheon suggested revising § 25.253(c)(3) to specify the altitude and/or Mach number range that ice shapes would dissipate.

Although we agree that past experience shows that ice shapes dissipate or detach at high altitude and high Mach numbers, the applicable range may vary with airplane type. The particular conditions under which the ice accretions dissipate or detach should be justified as part of the certification program. Since this is consistent with proposed § 25.253(c), we made no changes to the final rule.

13. Critical Ice Shapes

Proposed appendix C, part II(a) defines how to determine the critical ice accretions for each phase of flight. The NTSB commented that for each phase of flight, the applicant should be required to demonstrate that the shape, chordwise and spanwise, and the roughness of the shapes accurately reflect the full range of appendix C conditions in terms of mean effective drop diameter, liquid water content, and temperature during each phase of flight. Additionally, the NTSB suggested that we review the justification and selection of the most critical ice shape for each phase of flight.

Although we believe the proposed requirements already address the NTSB's concerns, we have revised appendix C, part II(a) for additional clarity. We added text to state that applicants must demonstrate that the full range of atmospheric icing conditions specified in part I of appendix C have been considered, including the mean effective drop diameter, liquid water content, and temperature appropriate to the flight conditions.

14. Takeoff Ice Accretions

ALPA noted that the takeoff ice accretions defined in proposed appendix C, part II(a)(2) do not include the entire takeoff flight path. As defined in § 25.111, the takeoff flight path ends at either 1,500 feet above the takeoff surface, or the height at which the transition from the takeoff to the en route configuration is completed and the final takeoff speed (V_{FTO}) is reached, whichever is higher. The takeoff flight path in proposed appendix C, part II(a)(2) ends at 1,500 feet above the takeoff surface. ALPA stated that there are many mountainous airport locations where the takeoff configuration must be maintained above 1,500 feet above the takeoff surface for terrain clearance at maximum takeoff gross weights. Since winter operations in these locations often involve icing conditions, ALPA requested that the takeoff flight path of Appendix C, part II(a)(2) be revised to match that of § 25.111.

ALPA's comment points out an oversight in the text of the proposal. Appendix C, part II(a)(2) has been revised to include the entire takeoff flight path as defined in § 25.111. We consider this to be a technical clarification that does not impose a significant additional burden on applicants.

15. Size of Ice Accretion Before Activation of the IPS

For the pre-activation ice identified in Appendix C, part II(e), ALPA did not support the 30-second time period for the flightcrew to see and respond to ice accreting on the airplane as stated in paragraphs 2c(4)(a) and (b) of Appendix 1, Airframe Ice Accretion, of proposed AC 25.21–1X. ALPA believes that the ice accreted during a more operationally realistic timeframe and the potential degradations in aircraft performance and handling qualities must be accounted for during certification in order to make the proposed requirements and acceptable means of compliance an effective combination. While a well designed human factors study could determine an appropriate time, ALPA proposed that at least the 2-minute time period contained in 14 CFR 33.77, Foreign object ingestion—ice, be used as the time to visually recognize ice is accreting until definitive studies can be completed.

The FAA believes that ALPA has misunderstood the use of the 30-second time period in the proposed AC 25.21–1X acceptable means of compliance. The FAA does not expect the flightcrew to see and respond to ice accumulating on the airplane within 30 seconds. In accordance with § 25.21(g), compliance must be shown using ice accretions consistent with the AFM operating procedures. First, applicants must determine the ice accretion that would be on the airplane when the AFM procedures call for activating the IPS. Then, the 30-second time period is used in combination with the continuous maximum icing environment, as defined in appendix C of part 25, as a standard for determining the additional ice that could accrete on the airplane before the pilot actually activates the IPS. Since the appendix C maximum continuous icing envelope represents at least the 99th percentile of encounters with continuous maximum icing (that is, 99% of the time, less icing would occur), it would take significantly longer than 30 seconds in nearly all actual icing events for the airplane to accrete this much ice.

As a result of this comment, the FAA reviewed the proposed AC 25.21–1X text. Although the use of a-30 second time period in a continuous maximum icing environment is clearly stated, the FAA believes that the text is incomplete regarding what we expect applicants to consider in determining the ice accretion specified by the AFM procedures for activating the IPS. The FAA is revising the proposed AC to state that this ice accretion should be easily recognizable by the pilot under all foreseeable conditions (for example, at night in clouds). No changes have been made to the regulatory requirements.

16. Maximum Size of the Critical Ice Accretion

Dassault noted that, in Europe, the critical ice accretion is limited to a maximum thickness of 3 inches. Dassault did not find such a limitation in the NPRM, nor in the proposed advisory circular (AC) 25.21–1X related to the NPRM. Dassault noted that this omission could result in carrying out performance and handling tests with unrealistic ice accretions (particularly those assumed to build up on the unprotected parts of the airplane during the 45-minute holding flight phase referenced in ACs 25.21–X and 25.1419–1A).

We did not make any changes to the final rule because several existing ACs provide guidance for the size of the most critical ice accretions that should be considered. This longstanding guidance considers a 45-minute holding condition within an icing cloud. Since this guidance is not regulatory, we have accepted applicants' use of service history and other experience with other compliance criteria to determine the maximum ice accretion that needs to be considered. We will continue to address this issue in the same manner. The AC being issued along with this final rule refers to these alternative methods of compliance and provides guidance for their use.

17. Detection of Icing Conditions

A private citizen commented that icing conditions should be monitored by more than the pilot's eyesight. We are unable to address the commenter's issue in this rulemaking because this rulemaking only addresses performance and handling qualities requirements for the current methods of ice detection (which include detection by visual means). However, we are pursuing separate rulemaking for future airplane designs relative to allowable methods for detecting icing and determining when to activate the IPS. In NPRM 07–07, ''Activation of Ice Protection,'' published in the **Federal Register** on April 26, 2007, we proposed to amend the airworthiness standards applicable to transport category airplanes to require a means to ensure timely activation of the airframe IPS.

18. Delayed Activation of the IPS

ALPA recommended modifying all rule language to eliminate references and rule provisions for waiting until a finite amount of ice has accumulated before activating the IPS. ALPA stated that delayed activation of the IPS has been a factor in several accidents and incidents. ALPA also pointed out that the FAA has adopted 17 airworthiness directives requiring immediate activation of IPS at the first sign of ice accretion for a number of airplane types where the previous practice was to wait until a specified amount of ice had accumulated on the airplane. ALPA noted that after an exhaustive review of accident and incident data, ARAC recommended an operating rule that would remove the option of delaying activation of the IPS.

Except for the airworthiness directives referenced by ALPA, current regulations do not prohibit AFM procedures that call for delaying activation of the IPS until a specified amount of ice has accreted. Although we strongly encourage activating the IPS at the first sign of ice accretion, there may be some designs for which delayed activation is currently acceptable, safe, and appropriate. For example, some thermal wing IPS can currently be used in either an anti-ice or deice mode. In the deice mode, the wing IPS is not activated until a certain amount of ice has accreted. This has not resulted in any safety issues, and can be a more economical way of operating the wing IPS.

The purpose of this rulemaking is to provide appropriate performance and handling qualities requirements, considering the currently accepted procedures for activating the IPS. Establishing new requirements for acceptable methods for activating the IPS is beyond the scope of this rulemaking. As ALPA noted, however, ARAC has recommended the FAA adopt new requirements that would ensure flightcrews are provided with a clear means to know when to activate the IPS in a timely manner. We are pursuing separate rulemaking in response to this ARAC recommendation. In NPRM 07–07, ''Activation of Ice Protection,'' published in the **Federal Register** on April 26, 2007, we proposed to amend the airworthiness standards applicable to transport category airplanes to require a means to ensure timely activation of the airframe IPS. We will update the requirements adopted by this final rule related to the means of activating the IPS, if necessary, to be consistent with any final action resulting from NPRM 07–07, ''Activation of Ice Protection.''

19. Harmonization With EASA's NPA

Several commenters noted that the FAA did not fully harmonize the NPRM with the EASA's NPA covering the same icing-related safety issues. They recommended harmonizing the two rule proposals.

We worked closely with EASA to ensure that there are no significant regulatory differences between this amendment and EASA's anticipated final rule. However, since EASA's final rule has not yet been issued, we cannot guarantee that the two final rules will be completely harmonized. We believe that any differences will be primarily editorial and not significant regulatory differences.

20. Accuracy of the Regulatory Flexibility Evaluation

GAMA requested that the FAA review the regulatory flexibility evaluation in the interest of accuracy.

We reviewed the regulatory flexibility evaluation and reaffirmed the determination that this proposed rule would not have a significant economic impact on a substantial number of small entities. All U.S. part 25 aircraft manufacturers exceed the Small Business Administration small-entity criteria of 1,500 employees for aircraft manufacturers.

21. Aircraft Population Used When Determining Cost Versus Benefit

GAMA stated that it appeared the cost proposal considered U.S. manufactured aircraft while the benefit section included international products. GAMA believes that the same aircraft population should be used when determining cost versus benefit. Additionally, GAMA stated that it appeared it was assumed that cost was only attributed to entirely new TC products. GAMA believes it would be appropriate to consider the economic impact to some amount of amended TC and STC projects as well.

Section 1 of Executive Order 12866 states ''Federal agencies should promulgate only such regulations as are required by law, are necessary to interpret the law, or are made necessary by compelling public need, such as material failures of private markets to protect or improve the health and safety of the public, the environment, or the well-being of the American people.'' Section 5 states ''In order to reduce the regulatory burden on the American people, their families, their communities, their State, local, and tribal governments and their industries * * *.'' Therefore, regulatory evaluations and flexibility analyses focus on American people and American industries.

American industries, such as manufacturers and operators of aircraft, must comply with regulations promulgated by Federal agencies. Foreign firms are not required to comply with U.S. regulations unless they choose to sell or operate their aircraft in America.

We determined the costs for this proposal by analyzing only American manufacturing industries, since foreign firms are not required to comply with U.S. regulations unless they choose to sell or operate their aircraft in America. While we do consider foreign manufactured aircraft in the benefit section, we determined the benefits by analyzing only American operators of those aircraft. Hence, the intent of Executive Order 12866 was satisfied.

We did include amended TCs in the analysis. Each TC includes all derivatives for a particular aircraft model. For example, TC No. A16WE initially covered only the Boeing 737–100, but was later amended to include the –200 through –900 Boeing 737 models.

Future applicants for approval of changed products are subject to § 21.101 (Changed Product Rule). There are several provisions of § 21.101 allowing future applicants of changed products to comply with earlier regulation amendments. We have already determined that benefits of the Changed Product Rule exceed the costs. Therefore, we do not estimate the benefits and costs of changed products for new certification rules.

22. Value of Fatalities Avoided

A private citizen claimed that the value of the fatalities avoided by this proposal would be in the neighborhood of $20 billion.

The number of averted fatalities and injuries is based on the historical accident rate extrapolated into the future. The FAA used $3.0 million for an avoided fatality and $132,700 for the additional associated medical and legal costs' for a fatality. The derivation for these values is discussed in the ''Economic Values for FAA Investment and Regulatory Decisions, A Guide.'' [6] Without the rule, we expect that over the 45-year analysis period, approximately three accidents will occur. These three accidents are expected to result in approximately 12 fatalities, six serious injuries, and two minor injuries. From these values, and expected future accidents based on past accident history, we estimated a benefit of about $90 million over the 45-year analysis period.

III. Rulemaking Analyses and Notices

Paperwork Reduction Act

There are no current or new requirements for information collection associated with this amendment.

International Compatibility

In keeping with U.S. obligations under the Convention on International Civil Aviation, it is FAA policy to comply with International Civil Aviation Organization (ICAO) Standards and Recommended Practices to the maximum extent practicable. The FAA has determined that there are no ICAO Standards and Recommended Practices that correspond to these regulations.

Economic Assessment, Regulatory Flexibility Determination, Trade Impact Assessment, and Unfunded Mandates Assessment

Changes to Federal regulations must undergo several economic analyses. First, Executive Order 12866 directs each Federal agency to propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs.

[6] *http://www.faa.gov/regulations_policies/policy_guidance/benefit_cost/media/050404%20Critical%20Values%20Dec%2031%20Report%2007Jan05.pdf.*

Second, the Regulatory Flexibility Act of 1980 requires agencies to analyze the economic impact of regulatory changes on small entities. Third, the Trade Agreements Act (19 U.S.C. 2531–2533) prohibits agencies from setting standards that create unnecessary obstacles to the foreign commerce of the United States. In developing U.S. standards, this Trade Act also requires agencies to consider international standards and, where appropriate, use them as the basis of U.S. standards. Fourth, the Unfunded Mandates Reform Act of 1995 (Pub. L. 104–4) requires agencies to prepare a written assessment of the costs, benefits, and other effects of proposed or final rules that include a Federal mandate likely to result in the expenditure by State, local, or tribal governments, in the aggregate, or by the private sector, of $100 million or more annually (adjusted for inflation with the base year of 1995.)

In conducting these analyses, FAA has determined this rule (1) has benefits that justify its costs, is not a ''significant regulatory action'' as defined in section 3(f) of Executive Order 12866 and is not ''significant'' as defined in DOT's Regulatory Policies and Procedures; (2) will not have a significant economic impact on a substantial number of small entities; (3) will not reduce barriers to international trade; and (4) does not impose an unfunded mandate on state, local, or tribal governments, or on the private sector. These analyses, available in the docket, are summarized below.

Introduction

This portion of the preamble summarizes the FAA's analysis of the economic impacts of a final rule amending part 25 of Title 14, Code of Federal Regulations (14 CFR) to change the regulations applicable to transport category airplanes certificated for flight in icing conditions. It also includes summaries of the regulatory flexibility determination, the international trade impact assessment, and the unfunded mandates assessment. We suggest readers seeking greater detail read the full regulatory evaluation, a copy of which we have placed in the docket for this rulemaking.

Total Benefits and Costs of This Rulemaking

The estimated potential benefits of avoiding 3 accidents over the 45-year analysis interval are $89.2 million ($23.6 million in present value at seven percent). To obtain these benefits, over the 45-year analysis interval, manufacturers will incur additional certification costs of $9.8 million and the operators of these airplanes will pay $52.5 million in additional fuel-burn. We estimate the total cost of this final rule to be about $62.3 million and the seven percent present value cost of the rule will be about $23.0 million.

Who Is Potentially Affected by This Rulemaking

- Operators of part 25 U.S.-registered aircraft conducting operations under FAR Parts 121, 129, and 135, and
- Manufacturers of those part 25 aircraft.

Our Cost Assumptions and Sources of Information

This evaluation makes the following assumptions:

1. This final rule is assumed to become effective immediately.
2. The production runs for newly certificated part 25 airplane models is 20 years.
3. The average life of a part 25 airplane is 25 years.
4. We analyzed the costs and benefits of this final rule over the 45-year period (20 + 25 = 45) 2006 through 2050.
5. We used a 10-year certification compliance period. For the 10-year life-cycle period, the FAA calculated an average of four new certifications will occur.
6. We used $3.0 million as the value of an avoided fatality.
7. New airplane certifications will occur in year one of the analysis time period.

Benefits of This Rulemaking

The benefits of this final rule consist of the value of lives saved due to avoiding three accidents involving part 25 airplanes operating in icing conditions. Based on the historic accident rate, we estimate that a total of 12 fatalities could potentially be avoided by adopting the final rule. Over the 45-year period of analysis, the potential benefit of the propose rule will be $89.2 million ($23.6 million in present value at seven percent).

Costs of This Rulemaking

We estimate the costs of this final rule to be about $62.3 million ($23.0 million in present value at seven percent) over the 45-year analysis period. The total cost of $62.3 million equals the fixed certification costs of $9.8 million incurred in the first year plus the variable annual fuel burn cost of $52.5 million over the 45-year analysis period.

Regulatory Flexibility Determination

The Regulatory Flexibility Act of 1980 (Pub. L. 96–354) (RFA) establishes ''as a principle of regulatory issuance that agencies shall endeavor, consistent with the objectives of the rule and of applicable statutes, to fit regulatory and informational requirements to the scale of the businesses, organizations, and governmental jurisdictions subject to regulation. To achieve this principle, agencies are required to solicit and consider flexible regulatory proposals and to explain the rationale for their actions to assure that such proposals are given serious consideration.'' The RFA covers a wide-range of small entities, including small businesses, not-for-profit organizations, and small governmental jurisdictions.

Agencies must perform a review to determine whether a rule will have a significant economic impact on a substantial number of small entities. If the agency determines that it will, the agency must prepare a regulatory flexibility analysis as described in the RFA.

However, if an agency determines that a rule is not expected to have a significant economic impact on a substantial number of small entities, section 605(b) of the RFA provides that the head of the agency may so certify and a regulatory flexibility analysis is not required. The certification must include a statement providing the factual basis for this determination, and the reasoning should be clear.

In the interest of accuracy, one commenter requested we review the determination we made in the proposed rules regulatory flexibility evaluation. We reviewed the determination from the proposed rule and came to the same conclusions for this final rule for the reasons discussed below.

Currently U.S. manufactured part 25 aircraft type certificate holders include: The Boeing Company, Cessna Aircraft Company (a subsidiary of Textron Inc.), Raytheon Company, and Gulfstream Aerospace Corporation (a wholly owned subsidiary of General Dynamics). All United States part 25 aircraft manufacturers exceed the Small Business Administration small-entity criteria of 1,500 employees for aircraft manufacturers.

This rule will add an additional weighted average monthly fuel burn cost of about $42 per airplane, which is less than an hour of fuel burn and thus a minimal additional cost to all operators.

Given that manufacturers are not small entities and operators incur a minimal additional cost, as the FAA Administrator, I certify that this final rule will not have a significant economic impact on a substantial number of small entities.

International Trade Impact Assessment

The Trade Agreements Act of 1979 (Pub. L. 96–39) prohibits Federal agencies from establishing any standards or engaging in related activities that create unnecessary obstacles to the foreign commerce of the United States. Legitimate domestic objectives, such as safety, are not considered unnecessary obstacles. The statute also requires consideration of international standards and, where appropriate, that they be the basis for U.S. standards. The FAA has assessed the potential effect of this final rule and determined that it will impose the same costs on domestic and international entities and thus has a neutral trade impact.

Unfunded Mandates Assessment

Title II of the Unfunded Mandates Reform Act of 1995 (Pub. L. 104–4) requires each Federal agency to prepare a written statement assessing the effects of any Federal mandate in a proposed or final agency rule that may result in an expenditure of $100 million or more (adjusted annually for inflation with the base year 1995) in any one year by State, local, and tribal governments, in the aggregate, or by the private sector; such a mandate is deemed to be a ''significant regulatory action.'' The FAA currently uses an inflation-adjusted value of $128.1 million in lieu of $100 million.

This final rule does not contain such a mandate. The requirements of Title II do not apply.

Executive Order 13132, Federalism

The FAA has analyzed this final rule under the principles and criteria of Executive Order 13132, Federalism. We determined that this action will not have a substantial direct effect on the States, or the relationship between the national Government and the States, or on the distribution of power and responsibilities among the various levels of government, and therefore does not have federalism implications.

Regulations Affecting Intrastate Aviation in Alaska

Section 1205 of the FAA Reauthorization Act of 1996 (110 Stat. 3213) requires the FAA, when modifying its regulations in a manner affecting intrastate aviation in Alaska, to consider the extent to which Alaska is not served by transportation modes other than aviation, and to establish appropriate regulatory distinctions. In the NPRM, we requested comments on whether the proposed rule should apply differently to intrastate operations in Alaska. We didn't receive any comments, and we have determined, based on the administrative record of this rulemaking, that there is no need to make any regulatory distinctions applicable to intrastate aviation in Alaska.

Environmental Analysis

FAA Order 1050.1E identifies FAA actions that are categorically excluded from preparation of an environmental assessment or environmental impact statement under the National Environmental Policy Act in the absence of extraordinary circumstances. The FAA has determined this rulemaking action qualifies for the categorical exclusion identified in paragraph 312f and involves no extraordinary circumstances.

Regulations That Significantly Affect Energy Supply, Distribution, or Use

The FAA has analyzed this final rule under Executive Order 13211, Actions Concerning Regulations that Significantly Affect Energy Supply, Distribution, or Use (May 18, 2001). We have determined that it is not a ''significant energy action,'' and it is not likely to have a significant adverse effect on the supply, distribution, or use of energy.

List of Subjects in 14 CFR Part 25

Aircraft, Aviation safety, Reporting and recordkeeping requirements.

The Amendment

■ In consideration of the foregoing, the Federal Aviation Administration amends part 25 of Title 14, Code of Federal Regulations, as follows:

PART 25—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY AIRPLANES

■ 1. The authority citation for part 25 continues to read as follows:

Authority: 49 U.S.C. 106(g), 40113, 44701, 44702, and 44704.

■ 2. Amend § 25.21 by adding a new paragraph (g) to read as follows:

§ 25.21 Proof of compliance.

* * * * *

(g) The requirements of this subpart associated with icing conditions apply only if the applicant is seeking certification for flight in icing conditions.

(1) Each requirement of this subpart, except §§ 25.121(a), 25.123(c), 25.143(b)(1) and (b)(2), 25.149, 25.201(c)(2), 25.207(c) and (d), 25.239, and 25.251(b) through (e), must be met in icing conditions. Compliance must be shown using the ice accretions defined in appendix C, assuming normal operation of the airplane and its ice protection system in accordance with the operating limitations and operating procedures established by the applicant and provided in the Airplane Flight Manual.

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

■ 3. Amend § 25.103 by revising paragraph (b)(3) to read as follows:

§ 25.103 Stall speed.

* * * * *

(b) * * *

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

* * * * *

■ 4. Amend § 25.105 by revising paragraph (a) to read as follows:

§ 25.105 Takeoff.

(a) The takeoff speeds prescribed by § 25.107, the accelerate-stop distance prescribed by § 25.109, the takeoff path prescribed by § 25.111, the takeoff distance and takeoff run prescribed by § 25.113, and the net takeoff flight path prescribed by § 25.115, must be determined in the selected configuration for takeoff 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 § 25.121(b) with the takeoff ice accretion defined in appendix C:

(i) The stall speed at maximum takeoff weight exceeds that in non-icing conditions by more than the greater of 3 knots CAS or 3 percent of V_{SR}; or

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

* * * * *

■ 5. Amend § 25.107 by revising paragraph (c)(3) and (g)(2) and adding new paragraph (h) to read as follows:

§ 25.107 Takeoff speeds.

* * * * *

(c) * * *

(3) A speed that provides the maneuvering capability specified in § 25.143(h).

* * * * *

(g) * * *

(2) A speed that provides the maneuvering capability specified in § 25.143(h).

(h) In determining the takeoff 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.

■ 6. Amend § 25.111 by revising paragraph (c)(3)(iii), (c)(4), and adding a new paragraph (c)(5) to read as follows:

§ 25.111 Takeoff path.

* * * * *

(c) * * *

(3) * * *

(iii) 1.7 percent for four-engine airplanes.

(4) The airplane 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 airplane is 400 feet above the takeoff surface; and

(5) If § 25.105(a)(2) requires the takeoff path to be determined for flight in icing conditions, the airborne part of the takeoff must be based on the airplane drag:

(i) With the takeoff ice accretion defined in appendix C, from a height of 35 feet above the takeoff surface up to the point where the airplane is 400 feet above the takeoff surface; and

(ii) With the final takeoff ice accretion defined in appendix C, from the point where the airplane is 400 feet above the takeoff surface to the end of the takeoff path.

* * * * *

■ 7. Revise § 25.119 to read as follows:

§ 25.119 Landing climb: All-engines-operating.

In the landing configuration, the steady gradient of climb may not be less than 3.2 percent, with 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—

(a) In non-icing conditions, with a climb speed of V_{REF} determined in accordance with § 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 § 25.125(b)(2)(ii).

■ 8. Amend § 25.121 by revising paragraphs (b), (c), and (d) to read as follows:

§ 25.121 Climb: One-engine inoperative.

* * * * *

(b) *Takeoff; landing gear retracted.* In the takeoff configuration existing at the point of the flight path at which the landing gear is fully retracted, and in the configuration used in § 25.111 but without ground effect:

(1) The steady gradient of climb may not be less than 2.4 percent for two-engine airplanes, 2.7 percent for three-engine airplanes, and 3.0 percent for four-engine airplanes, at V_2 with:

(i) The critical engine inoperative, the remaining engines at the takeoff power or thrust available at the time the landing gear is fully retracted, determined under § 25.111, unless there is a more critical power operating condition existing later along the flight path but before the point where the airplane reaches a height of 400 feet above the takeoff surface; and

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

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

(i) In non-icing conditions; and

(ii) In icing conditions with the takeoff ice accretion defined in appendix C, if in the configuration of § 25.121(b) with the takeoff ice accretion:

(A) The stall speed at maximum takeoff weight exceeds that in non-icing conditions by more than the greater of 3 knots CAS or 3 percent of V_{SR}; or

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

(c) *Final takeoff.* In the en route configuration at the end of the takeoff path determined in accordance with § 25.111:

(1) The steady gradient of climb may not be less than 1.2 percent for two-engine airplanes, 1.5 percent for three-engine airplanes, and 1.7 percent for four-engine airplanes, 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 takeoff path, determined under § 25.111.

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

(i) In non-icing conditions; and

(ii) In icing conditions with the final takeoff ice accretion defined in appendix C, if in the configuration of § 25.121(b) with the takeoff ice accretion:

(A) The stall speed at maximum takeoff weight exceeds that in non-icing conditions by more than the greater of 3 knots CAS or 3 percent of V_{SR}; or

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

(d) *Approach.* In a configuration corresponding to the normal all-engines-operating procedure in which V_{SR} for this configuration does not exceed 110 percent 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 percent for two-engine airplanes, 2.4 percent for three-engine airplanes, and 2.7 percent for four-engine airplanes, 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 paragraph (d)(1) of this section must be met:

(i) In non-icing conditions; and

(ii) In icing conditions with the approach 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 paragraph (d)(1)(iii) of this section, does not exceed that for non-icing conditions by more than the greater of 3 knots CAS or 3 percent.

■ 9. Amend § 25.123 by revising paragraph (a) introductory text and paragraph (b) to read as follows:

§ 25.123 En route flight paths.

(a) For the en route configuration, the flight paths prescribed in paragraph (b) and (c) of this section must be determined at each weight, altitude, and ambient temperature, within the operating limits established for the airplane. 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 speed not less than V_{FTO}, with—

* * *

(b) The one-engine-inoperative net flight path data must represent the actual climb performance diminished by a gradient of climb of 1.1 percent for two-engine airplanes, 1.4 percent for three-engine airplanes, and 1.6 percent for four-engine airplanes—

(1) In non-icing conditions; and

(2) In icing conditions with the en route ice accretion defined in appendix C, if:

(i) A speed of 1.18 V_{SR} with the en route ice accretion exceeds the en route speed selected for non-icing conditions by more than the greater of 3 knots CAS or 3 percent of 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 paragraph (b) of this section.

* * * * *

■ 10. Revise § 25.125 to read as follows:

§ 25.125 Landing.

(a) The horizontal distance necessary to land and to come to a complete stop (or to a speed of approximately 3 knots for water landings) from a point 50 feet 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 airplane):

(1) In non-icing conditions; and

(2) In icing conditions with the landing ice accretion defined in appendix C if V_{REF} for icing conditions exceeds V_{REF} for non-icing conditions by more than 5 knots CAS at the maximum landing weight.

(b) In determining the distance in paragraph (a) of this section:

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

(2) A stabilized approach, with a calibrated airspeed of not less than V_{REF}, must be maintained down to the 50-foot height.

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

(A) 1.23 V_{SR}0;

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

(C) A speed that provides the maneuvering capability specified in § 25.143(h).

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

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

(B) 1.23 V_{SR}0 with the landing ice accretion defined in appendix C if that speed exceeds V_{REF} for non-icing conditions by more than 5 knots CAS; and

(C) A speed that provides the maneuvering capability specified in § 25.143(h) with the landing ice accretion defined in appendix C.

(3) Changes in configuration, power or thrust, and speed, must be made in accordance with the established procedures for service operation.

(4) The landing must be made without excessive vertical acceleration, tendency to bounce, nose over, ground loop, porpoise, or water loop.

(5) The landings may not require exceptional piloting skill or alertness.

(c) For landplanes and amphibians, the landing distance on land must be determined on a level, smooth, dry, hard-surfaced runway. In addition—

(1) The pressures on the wheel braking systems may not exceed those specified by the brake manufacturer;

(2) The brakes may not be used so as to cause excessive wear of brakes or tires; and

(3) Means other than wheel brakes may be used if that means—

(i) Is safe and reliable;

(ii) Is used so that consistent results can be expected in service; and

(iii) Is such that exceptional skill is not required to control the airplane.

(d) For seaplanes and amphibians, the landing distance on water must be determined on smooth water.

(e) For skiplanes, the landing distance on snow must be determined on smooth, dry, snow.

(f) The landing distance data must include correction factors for not more than 50 percent of the nominal wind components along the landing path opposite to the direction of landing, and not less than 150 percent of the nominal wind components along the landing path in the direction of landing.

(g) If any device is used that depends on the operation of any engine, and if the landing distance would be noticeably increased when a landing is made with that engine inoperative, the landing distance must be determined with that engine inoperative unless the use of compensating means will result in a landing distance not more than that with each engine operating.

■ 11. Amend § 25.143 by redesignating paragraphs (c) through (g) as paragraphs (d) through (h) respectively; adding a new paragraph (c); revising redesignated paragraphs (d), (e), and (f); amending redesignated paragraph (h) by removing the words ''Thrust power setting'' in the fourth column of the table and replacing them with the words ''Thrust/power setting''; and adding paragraphs (i), and (j) to read as follows:

§ 25.143 General.

* * * * *

(c) The airplane must be shown to be safely controllable and maneuverable 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 takeoff;

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

(3) During an approach and landing.

(d) The following table prescribes, for conventional wheel type controls, the maximum control forces permitted during the testing required by paragraph (a) through (c) of this section:

Force, in pounds, applied to the control wheel or rudder pedals	Pitch	Roll	Yaw
For short term application for pitch and roll control—two hands available for control	75	50	
For short term application for pitch and roll control—one hand available for control	50	25	
For short term application for yaw control			150
For long term application	10	5	20

(e) Approved operating procedures or conventional operating practices must be followed when demonstrating compliance with the control force limitations for short term application that are prescribed in paragraph (d) of this section. The airplane must be in trim, or as near to being in trim as practical, in the preceding steady flight condition. For the takeoff condition, the airplane must be trimmed according to the approved operating procedures.

(f) When demonstrating compliance with the control force limitations for long term application that are prescribed in paragraph (d) of this section, the airplane must be in trim, or as near to being in trim as practical.

* * * * *

(i) When demonstrating compliance with § 25.143 in icing conditions—

(1) Controllability must be demonstrated with the ice accretion defined in appendix C that is most critical for the particular flight phase;

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

(3) Any changes in force that the pilot must apply to the pitch control to

maintain speed with increasing sideslip angle must be steadily increasing with no force reversals, unless the change in control force is gradual and easily controllable by the pilot without using exceptional piloting skill, alertness, or strength.

(j) For flight in icing conditions before the ice protection system has been activated and is performing its intended function, the following requirements apply:

(1) If activating the ice protection system depends on the pilot seeing a specified ice accretion on a reference surface (not just the first indication of icing), the requirements of § 25.143 apply with the ice accretion defined in appendix C, part II(e).

(2) For other means of activating the ice protection system, it must be demonstrated in flight with the ice accretion defined in appendix C, part II(e) that:

(i) The airplane is controllable in a pull-up maneuver up to 1.5 g load factor; and

(ii) There is no pitch control force reversal during a pushover maneuver down to 0.5 g load factor.

■ 12. Amend § 25.207 by revising paragraph (b); redesignating paragraphs (e) and (f) as paragraphs (f) and (g) respectively; adding a new paragraph (e); revising redesignated paragraph (f) and adding paragraph (h) to read as follows:

§ 25.207 Stall warning.

* * * * *

(b) The warning must be furnished either through the inherent aerodynamic qualities of the airplane 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 airplane configurations prescribed in paragraph (a) of this section at the speed prescribed in paragraphs (c) and (d) of this section. Except for the stall warning prescribed in paragraph (h)(2)(ii) of this section, the stall warning for flight in icing conditions prescribed in paragraph (e) of this section must be provided by the same means as the stall warning for flight in non-icing conditions.

* * * * *

(e) In icing conditions, the stall warning margin in straight and turning flight must be sufficient to allow the pilot to prevent stalling (as defined in § 25.201(d)) when the pilot starts a recovery maneuver not less than three seconds after the onset of stall warning. When demonstrating compliance with this paragraph, the pilot must perform the recovery maneuver in the same way as for the airplane in non-icing conditions. Compliance with this requirement must be demonstrated in flight with the speed reduced at rates not exceeding one knot per second, with—

(1) The more critical of the takeoff ice and final takeoff ice accretions defined in appendix C for each configuration used in the takeoff phase of flight;

(2) The en route ice accretion defined in appendix C for the en route configuration;

(3) The holding ice accretion defined in appendix C for the holding configuration(s);

(4) The approach ice accretion defined in appendix C for the approach configuration(s); and

(5) The landing ice accretion defined in appendix C for the landing and go-around configuration(s).

(f) The stall warning margin must be sufficient in both non-icing and icing conditions to allow the pilot to prevent stalling when the pilot starts a recovery maneuver not less than one second after the onset of stall warning in slow-down turns with at least 1.5 g load factor normal to the flight path and airspeed deceleration rates of at least 2 knots per second. When demonstrating compliance with this paragraph for icing conditions, the pilot must perform the recovery maneuver in the same way as for the airplane in non-icing conditions. Compliance with this requirement must be demonstrated in flight with—

(1) The flaps and landing gear in any normal position;

(2) The airplane trimmed for straight flight at a speed of 1.3 V_{SR}; and

(3) The power or thrust necessary to maintain level flight at 1.3 V_{SR}.

* * * * *

(h) For flight in icing conditions before the ice protection system has been activated and is performing its intended function, the following requirements apply, with the ice accretion defined in appendix C, part II(e):

(1) If activating the ice protection system depends on the pilot seeing a specified ice accretion on a reference surface (not just the first indication of icing), the requirements of this section apply, except for paragraphs (c) and (d) of this section.

(2) For other means of activating the ice protection system, the stall warning margin in straight and turning flight must be sufficient to allow the pilot to prevent stalling without encountering any adverse flight characteristics when the speed is reduced at rates not exceeding one knot per second and the pilot performs the recovery maneuver in the same way as for flight in non-icing conditions.

(i) If stall warning is provided by the same means as for flight in non-icing conditions, the pilot may not start the recovery maneuver earlier than one second after the onset of stall warning.

(ii) If stall warning is provided by a different means than for flight in non-icing conditions, the pilot may not start the recovery maneuver earlier than 3 seconds after the onset of stall warning. Also, compliance must be shown with § 25.203 using the demonstration prescribed by § 25.201, except that the deceleration rates of § 25.201(c)(2) need not be demonstrated.

■ 13. Amend § 25.237 by revising paragraph (a) to read as follows:

§ 25.237 Wind velocities.

(a) For land planes and amphibians, the following applies:

(1) A 90-degree cross component of wind velocity, demonstrated to be safe for takeoff and landing, must be established for dry runways and must be at least 20 knots or 0.2 V_{SR0}, whichever is greater, except that it need not exceed 25 knots.

(2) The crosswind component for takeoff 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.

* * * * *

■ 14. Amend § 25.253 by revising paragraph (b), and adding a new paragraph (c) to read as follows:

§ 25.253 High-speed characteristics.

* * * * *

(b) *Maximum speed for stability characteristics.* V_{FC}/M_{FC}. V_{FC}/M_{FC} is the maximum speed at which the requirements of §§ 25.143(g), 25.147(E), 25.175(b)(1), 25.177, and 25.181 must be met with flaps and landing gear retracted. Except as noted in § 25.253(c), V_{FC}/M_{FC} 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) *Maximum speed for stability characteristics in icing conditions.* The maximum speed for stability characteristics with the ice accretions defined in appendix C, at which the requirements of §§ 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.

■ 15. Amend § 25.773 by revising paragraph (b)(1)(ii) to read as follows:

§ 25.773 Pilot compartment view.

* * * * *

(b) * * *

(1) * * *

(i) * * *

(ii) The icing conditions specified in § 25.1419 if certification for flight in icing conditions is requested.

* * * * *

■ 16. Amend § 25.941 by revising paragraph (c) to read as follows:

§ 25.941 Inlet, engine, and exhaust compatibility.

* * * * *

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

■ 17. Amend § 25.1419 by revising the introductory text to read as follows:

§ 25.1419 Ice protection.

If the applicant seeks certification for flight in icing conditions, the airplane must be able to safely operate in the continuous maximum and intermittent maximum icing conditions of appendix C. To establish this—

* * * * *

■ 18. Amend appendix C to part 25 by adding a part I heading and a new paragraph (c) to part I; and adding a new part II to read as follows:

Appendix C of Part 25

Part I—Atmospheric Icing Conditions

(a) * * *

(c) *Takeoff maximum icing.* The maximum intensity of atmospheric icing conditions for takeoff (takeoff maximum icing) is defined by the cloud liquid water content of 0.35 g/m3, the mean effective diameter of the cloud droplets of 20 microns, and the ambient air temperature at ground level of minus 9 degrees Celsius (-9(C). The takeoff maximum icing conditions extend from ground level to a height of 1,500 feet above the level of the takeoff surface.

Part II—Airframe Ice Accretions for Showing Compliance With Subpart B.

(a) *Ice accretions—General.* The most critical ice accretion in terms of airplane performance and handling qualities for each flight phase must be used to show compliance with the applicable airplane performance and handling requirements in icing conditions of subpart B of this part. Applicants must demonstrate that the full range of atmospheric icing conditions specified in part I of this appendix have been considered, including the mean effective drop diameter, liquid water content, and temperature appropriate to the flight conditions (for example, configuration, speed, angle-of-attack, and altitude). The ice accretions for each flight phase are defined as follows:

(1) *Takeoffice* 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 liftoff and 400 feet above the takeoff surface, assuming accretion starts at liftoff in the takeoff maximum icing conditions of part I, paragraph (c) of this appendix.

(2) *Final takeoff ice* is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, between 400 feet and either 1,500 feet above the takeoff surface, or the height at which the transition from the takeoff to the en route configuration is completed and V_{FTO} is reached, whichever is higher. Ice accretion is assumed to start at liftoff in the takeoff maximum icing conditions of part I, paragraph (c) of this appendix.

(3) *En route 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 en route phase.

(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) *Approach 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 following exit from the holding flight phase and transition to the most critical approach configuration.

(6) *Landing 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 following exit from the approach flight phase and transition to the final landing configuration.

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

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

(d) For both unprotected and protected parts, the ice accretion for the takeoff phase may be determined by calculation, assuming the takeoff maximum icing conditions defined in appendix C, and assuming that:

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

(2) The ice accretion starts at liftoff;

(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 a normal operating procedure provided in the Airplane Flight Manual, except that after beginning the takeoff roll, it must be assumed that the crew takes no action to activate the ice protection system until the airplane is at least 400 feet above the takeoff surface.

(e) The ice accretion before the ice protection system has been activated and is performing its intended function is the critical ice accretion formed on the unprotected and normally protected surfaces before activation and effective operation of the ice protection system in continuous maximum atmospheric icing conditions. This ice accretion only applies in showing compliance to §§ 25.143(j) and 25.207(h).

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Marion C. Blakey,

Administrator.

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