FAA Aviation Rulemaking Advisory Committee

FTHWG Phase 2

Topic 1 Envelope Protection
Topic 2 Adaptation for Flight in Icing
Topic 6 Stability
Topic 7 Side Stick Controls
Topic 9 Wet Runway Stopping
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Topic 11 Stall In Ground Effect
Topic 12 Steep Approach
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Recommendation Report – Rev A

April, 2017

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List of Abbreviations

AC	Advisory Circular
AFM	Airplane Flight Manual
ALPA	Airline Pilots Association
ANAC	Agência Nacional de Aviação Civil (Brazil)
AOA	Angle of Attack
APC	Airplane-Pilot Coupling
ARAC	Aviation Rulemaking Advisory Committee
CFR	Code of Federal Regulations
CRI	Certification Review Item
CS	Certification Specification
EASA	European Aviation Safety Agency
EFCS	Electronic Flight Control System
ELOS	Equivalent Level of Safety
EPF	Envelope Protection Function
EU OPS	European Union Operations
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation (now referred to as 14CFR, for Title 14, Code of Federal Regulations)
FBW	Fly-by-Wire
FCHWG	Flight Controls Harmonization Working Group
FCTLS	Flight Controls
FTHWG	Flight Test Harmonization Working Group
FTG	Flight Test Guide
FWP	Flight Working Paper
HALF	High Angle of Attack Limiting Function
HQ	Handling Qualities
HQRM	Handling Qualities Rating Method
HUD	Heads-Up Display
ICAO	International Civil Aviation Organization
IP	Issue Paper
JAA	Joint Airworthiness Authorities
NPA	Notice of Proposed Amendment
NPRM	Notice of Proposed Rulemaking
NTSB	National Transportation Safety Board
Nz	Normal Load Factor
OEM	Original Equipment Manufacturer
PIL	Pilot in the Loop
PIO	Pilot Induced Oscillation
PFC	Porous Friction Course
SAIB	Safety Alert Information Bulletin
SAL	Steep Approach Landing
SC	Special Condition
SME	Subject Matter Expert
STPCM	Strategies for Protection against Thrust Control Malfunctions
TALPA ARC	Takeoff and Landing Performance Assessment Aviation Rulemaking Committee
TCCA	Transport Canada Civil Aviation
Vmin1g	Minimum steady flight speed for a given aeroplane configuration corrected to 1g with the high Angle of Attack Protection system operating
VSR	Reference Stall Speed
VSW	Stall Warning Speed

Executive Summary

Pursuant to ARAC tasking given at the 20 March, 2014 FAA assigned to ARAC a tasking to use the Flight Test Harmonization Working Group (FTHWG) to develop recommended standards in the areas of Fly-by-Wire flight controls, takeoff and landing performance, and guidance material for assessing certain aspects of handling qualities.

While transport airplanes incorporating fly-by-wire systems and flight envelope protection features have been certified and in service since the late 1980's, the basis on which the airworthiness was determined has always been Special Conditions (SC's) and Certification Review Items (CRI's) in Europe. The technical content of these individual SC's and CRI's was written specifically in response to a proposed configuration architecture and list of features from each applicant. As a result, while the intended level of safety has been rather consistent, the particular content of the SC's and CRI's was not harmonized across authorities nor across airplane models, nor could it have been expected to be, given the circumstances. This tasking provides an opportunity to look across the industry and across the authorities to achieve a single safety standard (a harmonized set of regulations) and a consistent means of compliance which is intended to be applicable to the architectures represented in the current fleet of transport airplanes as well as those reasonably envisioned by the FTHWG team. These fly-by-wire tasks included use of envelope protection features, adaptation for flight in icing for angle-of-attack protected airplanes, dealing with configurations which do not exhibit static (speed) stability, dealing with airplanes having auto-trim functions in compliance to the out-of-trim maneuvering characteristics, and side stick controls.

For the other topics, the relevant safety issues were identified and addressed. These included harmonization of standards and procedures for certifying steep approach landing, for the assignment of safety hazard classifications for systems failures involving runway excursions, for evaluation and presentation of gusts in crosswind and tailwind testing, for wet runway stopping performance and for the reduction of flight test risk from stalling in ground effect.

The FTHWG undertook this tasking beginning in June of 2014 and worked diligently throughout the period.

Throughout the deliberations, the FTHWG ensured that every member had an equal voice, that all dissenting opinions were documented and dispositioned, and that recommendations for new or modified requirements and guidance material were properly vetted within the group. Though not without its challenges, the FTHWG reached a majority consensus on the intent, and the structure of both proposed regulations and proposed guidance which is harmonized for every topic considered. Some topics required new regulations, some only modified regulations, some only modifications to the guidance material. Some disagreements were encountered concerning some specific words, some specific test conditions, and these are documented.

The consensus decisions and the recommendations are included in the individual reports as Appendices to this report and summarized here. Proposed changes to 14CFR25 and related guidance material is included and color-coded to illustrate the source (topic) of each change.

Organization of this Report

This report is a summary of the work of the Flight Test Harmonization Working Group (FTHWG), pursuant to tasking in the Federal Register dated 11 April, 2014. Because the tasking was very broad, the FTHWG decided that the best course of action was to conduct the technical deliberations on each topic individually, being cognizant of the very close interactions between the topics. As a result, the output of the Working Group is provided in the form of individual reports for each topic. The FTHWG believes they have coordinated the various recommendations to the point that they are compatible with each other.

This report serves as a "wrapper" for those individual reports, and includes a summary. For that reason, in each section of this report, the items of interest will be grouped by topic. Each of the individual topic reports is included as an Appendix to this report. The recommended harmonized regulatory and guidance material is collected in Attachments B and C, respectively, of this report and represents the sum total of the recommended material from each of the individual topic reports, color-coded by topic, so that the reader can easily see from which topic a particular change proposal came.

As the work progressed, the Working Group adopted the topic numbers from the original list of topics as identifiers for each topic. As a result, the individual reports, included as Appendices to this report are not numbered sequentially (i.e., they are listed as Topics 1, 2, 6, 7, 9, 10, 11, 12, 13, and 14), although the Appendix numbers are sequential (i.e. 1-10). It should not come as a surprise, for example, that Appendix 3 contains the report for Topic 6, etc.

Preface to Rev. A of this Report

The original tasking called for an end date of the Phase 2 activities of April, 2017, and the original scheduling of the tasks was done respecting this date. That schedule was subsequently modified to January, 2017, to allow for both TAE and ARAC review of the recommendations by April. The RevNew version of this report met the January date and included the work which had been concluded at that time, along with reference to some work not yet concluded, and recommended next steps.

Notwithstanding the report submittal in January, the Working Group had already scheduled a meeting for March, and was working well via teleconferences, so the work on the unfinished items continued. At the same time, the April TAE and ARAC meetings were cancelled. Therefore, Rev A incorporates the results of the continued work on the part of the Working Group into the report so that the more complete work of Phase 2 can be considered by TAE and ARAC at their next opportunity to meet.

The new material in Revision A is limited to:

- Topic 1 (Envelope Limiting): additional guidance material which had been drafted but not vetted (and therefore not included in RevNew) when the original report was released.
- Topic 10 (Runway Excursion Hazard Classification): an additional dissenting opinion from EASA which came to the attention of the FTHWG only after the RevNew report had been written and approved.
- Topic 12 (Steep Approach Landing): additional detail has been added after reaching majority/dissenting opinions around the issues of the degree of flight path angle variation and associated screen heights for demonstration flight tests, as well as the use of other

mitigating factors (like AFM limitations) to set acceptable limits on demonstrated angle and screen height.

There are no changes to any other sections of the report as a result of Revision A. Revision markings for Revision A changes are provided for all substantive changes with the exception of Attachments B and C. Attachments B and C are the compilation of all Regulatory and Guidance Material from the topic reports and the revision markings in those Attachments show all the changes relative to existing Regulations and Guidance Material. Revision markings for Revision A changes show added text but not the deleted text.

Background

As a result of the 20 March, 2014 ARAC meeting, FAA has assigned and ARAC has accepted a tasking which would use the existing Flight Test Harmonization Working Group (FTHWG).

> The working group should develop recommended standards in the following topic areas. If there are disagreements within the working group, these should be documented, including the reasons for the disagreement and rationale from each party. The following subject areas should be worked upon within this task:
>
> 1. Fly-by-wire Flight Controls.
> Regulatory requirements and associated guidance material for airworthiness certification of airplane designs using fly-by-wire technology to remove the need for longstanding, repetitively-used fly-by-wire special conditions. Specific areas include:
>
> a. Applicability/adaptation of Amendment 25–121 airplane performance and handling characteristics in icing conditions requirements,
> b. Lateral/directional/longitudinal stability,
> c. Out of trim requirements,
> d. Side stick controls, and
> e. Flight envelope protection.
>
> 2. Takeoff and Landing Performance.
> Regulatory requirements and associated guidance material for airworthiness certification in the following areas listed below. (Note: This topic area excludes items addressed by the Takeoff and Landing Performance Assessment Aviation Rulemaking Committee.)
>
> a. Flight test methods used to determine maximum tailwind and crosswind capability. For crosswind testing, better define intended operational use of demonstrated maximum steady and gusting crosswind performance.
>
> b. Wet runway stopping performance.
> Recent landing overruns on wet runways have raised questions regarding current wet runway stopping performance requirements and methods. Analyses indicate that the braking coefficient of friction in each case was significantly lower than expected for a wet runway (i.e., lower than the level specified in FAA regulations). Consideration should also be given to the scheduling of landing performance on wet porous friction course and grooved runway surfaces. Recommendations may include the need for additional data gathering, analysis, and possible rulemaking.
>
> c. Steep approach landing performance.
> Current airplane certification standards are not harmonized among the U.S., Canadian, Brazilian, and European airworthiness authorities.
>
> d. Guidance material addressing the adverse effects on stall speed in ground effect.
>
> e. Runway excursion hazard classification. Current safety assessments are not harmonized among the U.S., Canadian, Brazilian, and European airworthiness authorities.
>
> 3. Handling Characteristics. Guidance material for airworthiness certification in the following areas:
>
> a. Guidance material for assessing handling qualities.
> Current Advisory Circular 25–7, ‘‘Flight Test Guide for Certification of Transport Category Airplanes,’’ provides an FAA Handling Quality Rating Method that is intended to provide a systematic way of determining appropriate minimum handling qualities requirements and evaluating those handling qualities for conditions affecting an airplane’s flying qualities. The FAA handling quality rating system is not universally accepted within industry, nor is it accepted by EASA.

b. Guidance for assessing susceptibility to pilot-induced oscillations/airplane-pilot coupling (PIO/APC). Guidance provided in Advisory Circular 25–7C for evaluating PIO/APC is also not well accepted by airplane manufacturers, is not harmonized with EASA, and has been superseded to some extent in recent certification programs. Modified guidance is needed to both simplify and standardize the methods for evaluating an airplane's susceptibility to PIO/APC.

The FTHWG, in planning this work statement divided the tasking as given into 12 topics, as follows:

1. Topic 1 Flight Envelope Protection
2. Topic 2 Adaptation for Flight in Icing for high angle of attack limiting function airplanes
3. Topic 6 Stability
4. Topic 7 Side Stick Controls
5. Topic 9 Wet Runway Stopping Performance
6. Topic 10 Runway Excursion Hazard Classification
7. Topic 11 Stall in Ground Effect
8. Topic 12 Steep Approach Landing
9. Topic 13 Out of Trim
10. Topic 14 Tailwind/Crosswind
11. Topic 15 Pilot Induced Oscillation (PIO)
12. Topic 16 Handling Qualities Rating Method (HQRM)

The initial presumption during planning was that because many of these topics involve different populations of Subject Matter Experts, many could be worked simultaneously. This presumption was valid for the technical SME's involved, but turned out to be not valid for others on the Working Group. In reality, most of the members of the working group were interested in all of the topics. This fact, together with the realization that the planning was more than a bit optimistic led to a re-planning effort.

In the summer of 2016, it became clear that the work involved in the tasking was significantly more involved than originally planned. FTHWG asked for, and was granted the following modifications to the plan:

1. Defer Topic 15 (PIO) to Phase 3, planned to begin in March, 2017.
2. Defer Topic 16 (Handling Qualities Rating Method) to Phase 3, planned to begin in March, 2017.
3. Split Topic 9: Provide an interim report addressing the safety aspects outlined in Topic 9 by 11 January, 2017 (included in this report), planning to complete tasks 2 and 3 in July, 2017.

It is noted that the initial due date for this work was given in the tasking as 11 April, 2017. About a year into the work, it was realized that the planning to the 11 April, 2017 date did not include necessary time for review by TAE and similarly by ARAC. As a result, the working due-date was backed up to 11 January, 2017. As that date approached and the early 2017 TAE meeting date became more firm, the due date for release to TAE was re-negotiated to be 25 January, 2017. As noted above, the RevNew version of this report was submitted on time. Since that time, the FTHWG has continued to work and has produced Revision A, for consideration by TAE and ARAC.

A. What is the underlying safety issue addressed by the CS/FAR?

The stated motivation for the Fly-by-Wire tasks (Topics 1, 2, 6, 7, and 13) is to remove the need for repetitively used Special Conditions. The FTHWG believes that the recommended proposals will allow that to happen, and that the result will be a single, harmonized set of standards which will have the effect of ensuring a consistent safety standard across authorities. The standard of safety used by the working group is a composite of that taken to be the current airworthiness requirements applied to conventional (not-flight-envelope-protected) configurations and the various SC's and CRI's applied to current fly-by-wire, protected types.

The underlying safety issues addressed by the other topics are detailed in each of the topic reports and are summarized below.

Topic	**Underlying Safety Issue**	**Reference for more detail**
1 Envelope Protection	Lack of harmonized standard	Appendix 1
2 Adaptation for Flight in Icing	Lack of harmonized standard	Appendix 2
6 Stability	Lack of harmonized standard	Appendix 3
7 Side Sticks	Lack of harmonized standard	Appendix 4
9 Wet Runway Stopping	Several accidents and incidents have raised questions regarding landing performance on wet runways. There has been evidence that airplanes could not obtain the expected wheel braking performance during these accidents and incidents as defined by CFR 25.109	Appendix 5
10 Runway Excursion Hazard	Failures in certain systems could cause a runway excursion.	Appendix 6
11 Stall IGE	The need for improved awareness and understanding of ground effects on stall angle-of-attack and maximum lift coefficient.	Appendix 7
12 Steep Approach	Lack of harmonized standard	Appendix 8
13 Out of Trim	Lack of harmonized standard	Appendix 9
14 Tailwind-Crosswind	Neither 14CFR25 and CS25 mandate an evaluation on the effects of gusts on handling qualities during takeoff and landing. For tailwinds above 10 kts, the two standards consider gusts in different ways.	Appendix10

B. What is the task?

From the general tasking statement above, individual work plans for each topic were developed and further refined in the FTHWG Phase 1 report, dated 30 January, 2014. These specific work plans appear in each individual topic report, in the Appendices to this report.

C. Why is this task needed?

For the fly-by-wire tasks (Topics 1, 2, 6, 7, and 13), an appropriate harmonized safety standard simply did not exist. As a result, as new airplane configurations and architectures appeared, each was certified to SC's and CRI's which were written specifically to address each configuration and architecture. The industry appeared to be diverging, with each manufacturer using a custom certification standard. The result was increased administrative burden on both the manufacturers and the authorities.

Topic	Why is this task needed?	Reference for more detail
1 Envelope Protection	Lack of harmonized standard	Appendix 1
2 Adaptation for Flight in Icing	Lack of harmonized standard	Appendix 2
6 Stability	Lack of harmonized standard	Appendix 3
7 Side Sticks	Lack of harmonized standard	Appendix 4
9 Wet Runway Stopping	There has not been a discussion as to the factors affecting the ability of the airplane to create wet runway wheel braking due to the tire ground interaction nor whether the combination of the CFR 25 methods and operating requirements could be improved.	Appendix 5
10 Runway Excursion Hazard	Authorities do not have a common/harmonized policy/guidance for classifying systems failures that could cause runway excursions.	Appendix 6
11 Stall IGE	Inaccurate accounting of ground effect stall for takeoff speed schedule development may impact maximum performance flight tests such as V_{MU} and abused takeoff demonstrations.	Appendix 7
12 Steep Approach	Lack of harmonized standard	Appendix 8
13 Out of Trim	Lack of harmonized standard	Appendix 9
14 Tailwind-Crosswind	Harmonize the presentation of crosswinds in the AFM and remove risks of different interpretation. For tailwinds, to harmonize the compliance methodology.	Appendix10

D. Who has worked the task?

This task has been worked by the Flight Test Harmonization Working Group (FTHWG) specialists in Aerodynamics, Stability and Control, Flight Test, and Airplane Performance from the following organisations:

- Authorities : FAA, EASA, TCCA, JCAB*, CAAI*
- Manufacturers : Airbus, Boeing, Bombardier, Dassault, Embraer, Gulfstream, Textron
- Airlines : American Airlines, Delta Airlines*
- Labour Union: ALPA
- Airport Authoritites* (for Topic 12, Steep Approach)

(*) non-voting members

Early in the tasking period, one manufacturer informed the Working Group that they would be forced to discontinue their participation in the group for a period of several months. They later rejoined the group and contributed productively for the remainder of the tasking period. Similarly, one authority encountered temporary budgetary issues which caused them to back away from the groups meeting schedule for a more brief period, later rejoining the group.

About a year into the task, ANAC informed the Working Group that they would not be able to support the remaining work of this task. Nevertheless, the FTHWG will still recommend that FAA to encourage ANAC to adopt these harmonized proposals.

E. Any relation with other topics?

The topics are intertwined and ultimately touch nearly all of Subpart B. The relationships are described in more detail in the individual reports. A summary and reference to the source information is included below:

Topic	**Relationship to other Topics**	**Reference for explanation**
1 Envelope Protection	2, 6, 7, 13, 15 (Phase 3), 16 (Phase 3), 17 (Phase 3)	Appendix 1
2 Adaptation for Flight in Icing	1	Appendix 2
6 Stability	1,2,7	Appendix 3
7 Side Sticks	1,2, 6, 13, 15 (Phase 3), 16 (Phase 3), and 17(Phase 3)	Appendix 4
9 Wet Runway Stopping	10, 20 (Phase 3)	Appendix 5
10 Runway Excursion Hazard	9, 16 (Phase 3), 17 (Phase 3)	Appendix 6
11 Stall IGE	1,2	Appendix 7
12 Steep Approach	None	Appendix 8
13 Out of Trim	1,6,7	Appendix 9
14 Tailwind-Crosswind	None	Appendix10

Historical Information

The FTHWG worked these topics diligently, with 10 face-to-face meetings (5 days each), 63 formal teleconferences of between 2 and 4 hours duration, and many, many more less-formal teleconferences, phone calls, and e-mail exchanges.

At each face-to face meeting and during each formal telecom, protocols were established and kept, minutes were kept and action items were recorded. Previous actions were reviewed at each meeting and each telecom, per topic.

The face-to-face meetings, dates, and topics discussed are shown below.

Meeting	Location/Host	Topics	Dates
FTHWG-31	Cologne / EASA	T1 (Envelope Limiting) T6 (Lateral / Directional / Longitudinal	2-6 June, 2014

		Stability)	
FTHWG-32	Seattle / Boeing	T2 (Adaptation for flight in icing) T1 (Envelope Limiting) T12 (Steep Approach Landing)	20-21 October, 2014 22 October, 2014 23-24October, 2014
FTHWG-33	Toulouse / Airbus	T1 (Envelope Limiting) T2 (Adaptation for flight in icing) T6 (Lateral / directional / longitudinal Stability)	9-10 March, 2015 11 March, 2015 12-13 March, 2015
FTHWG-34	Savannah / Gulfstream	T6 (Lateral / directional / longitudinal stability) T13 (Out of trim characteristics) T7 (Side stick controls)	15-16 June, 2015 17 June, 2015 18-19 June, 2015
FTHWG-35	Cologne / EASA	T9 (Wet runway stopping performance) T10 (Runway excursion hazard classification)	21-23 Sept. 2015 24-25 Sept. 2015
FTHWG-36	Melbourne / Embraer	T1 (Envelope limiting) T2 (Flight in icing) T11 (Stall speed in ground effect)	7-8 Dec. 2015 9 Dec. 2015 10-11 Dec. 2015
FTHWG-37	Cologne / EASA	T14 (Tailwind / Crosswind) T9 (Wet runway stopping performance)	7-9 March 2016 10-11 March 2016
FTHWG-38	Montreal / Bombardier	T10 (Runway excursion hazard classification) T1/T2 (Envelope protection / icing) T14 (Crosswind / Tailwind)	13-14 June 2016 15 June 2016 16-17 June 2016
FTHWG-39	Bordeaux / Dassault	T14 (Tailwind / Crosswind) T9 (wet runway stopping performance)	19-20 Sept. 2016 21-13 Sept. 2016
FTHWG-40	Washington DC / FAA	T (Runway Excursion Hazard Factor) T14 (Crosswind / Tailwind)	5-6 Dec. 2016 7-9 Dec. 2016

The practice of supplementing the face-to-face meetings with Webex teleconferences was established immediately during the first face-to-face meeting in Cologne in June of 2014. The single largest challenge for these was the selection of a time, with participants spread from Japan to Israel. The time slot which seemed to work the best had the Japanese observers joining at around 11PM their time, and the meeting ending for our Israeli participants at around 7PM. The teleconference calls began at a frequency of 1 / month, quickly escalating to once / week, finally becoming a daily occurrence in the last couple of weeks leading to this report.

The processes used by the FTHWG to accomplish the assigned tasks were similar for each topic. The topic leader was responsible for ensuring that the FTHWG addressed all of the relevant issues presented by the topic definition and tasking. At the same time, the Co-Chairs were responsible for ensuring that each participant had an equal voice in the deliberations.

In general, as topics were introduced, each participant was asked to come to the table with their organizations' positions on a number of questions posed by the topic leader to set the stage for the discussions to follow (a process born of forethought to produce informed direction). As the deliberations proceeded, usually the main issues, the most controversial issues which would determine the direction of the deliberations and ultimately the recommendations were identified first and usually adjudicated rather early (although there were some exceptions to this norm).

Each Topic addressed the current state of certification standard, whether the current 14CFR25 and CS25 and their guidance material or the recently used SC's and CRI's[1]. Armed with an understanding of these and of the current state of the industry in terms of control system architectures, safety events, etc., the Working Group then set about proposing regulatory structures which would be able to accommodate the tasking.

At various times, the participants were asked to provide analysis summarizing their own products for comparison to those of their counterparts and to give the FTHWG a clear view of the technical status of the industry. Examples of those will be found in the individual reports in Appendices 1-10. In general, the participants were willing to share their experiences. While there were some details or identifying features not available to share, for the most part everyone stepped up to help the cause. Similarly, the participants were able to pick up the offerings of data from the various corners of the industry to generate productive analyses to indicate possible ways forward. For the most part, these techniques have been very positive; the results in these recommendations have benefited from the joint use of participants' data.

Real-time, group writing of recommendations is nearly impossible. The FTHWG made extensive use of small sub-teams to progress details of regulatory proposals and guidance material. For the most part, this technique worked well. For some more controversial topics the progression went from small sub-team to larger sub-team, to the whole group who then wanted to dissect the entire output. This is not entirely unexpected in a group of experienced technical specialists with unavoidable parochial interests and well-established procedures for doing what they do.

These things take time, and the result is shown: some issues resulted in differences of opinion which could not be entirely resolved in the time available to produce this report. In almost every case, the differences of opinion, documented in the Consensus section were not about the large issues, those which were discussed early and hard; the differences showed up in specific selection of words or specific implementation details. The only case which involved a "difference of opinion in direction" appeared in Topic 7, Side Stick in which one participant's dissenting opinion disagreed with use of specific numerical values of force levels. Details of that discussion are included in the Topic 7 report.

One key element in the fly-by-wire tasks was to determine the structure of the proposed regulations to accommodate modern control system architectures. This was addressed in the very first face-to-face meeting in Cologne in June of 2014, and this was one of the most controversial subjects to be discussed. The resulting branching structure which provides parallel certification paths for conventional or modern architectures came out of a series of workshop exercises in which competing schemes for accommodating different architectures were compared. It is felt that this proposed structure, while more complicated in terms of the regulations, provided the most flexibility in dealing with different control system architectures both now and in the future.

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[1] With the use of the term Certification Review Items (CRI's) in this report, FTHWG means to refer to those CRI's which convey regulatory-like material (as opposed to e.g. means of compliance material).

A. What are the current regulatory and guidance material CS 25 and FAR 25?

Detailed analysis of the differences in regulatory and guidance material is given in the individual Topic reports. Obviously, some material had previously been harmonized, some had not.

B. What, if any, are the differences in the existing regulatory and guidance material CS 25 and FAR 25?

Detailed analysis of the differences in regulatory and guidance material is given in the individual Topic reports. Obviously, some material had previously been harmonized; some had not. In addition, some had become disharmonized.

C. What are the existing CRIs/IPs (SC and MoC)?

Detailed information for the existing CRI's and SC's is given in the individual Topic reports. Obviously, some material had previously been harmonized, some had not.

D. What, if any, are the differences in the Special Conditions (CRIs/IPs) (SC and MoC) and what do these differences result in?

Detailed information for the existing CRI's and SC's is given in the individual reports. Obviously, some material had previously been harmonized, some had not.

Consensus

Because of the breadth of the discussion topics and the individual foci of the participants, full consensus was not always available on each topic, and for some issues on some topics, not always available in the time available. Deliberations were always open and honest, focusing on the technical issues at hand. In most cases, the dissenting opinion affects only one paragraph or a small portion of the recommended regulatory or guidance material. In all cases except one there were no dissenting opinions regarding the intent or general direction being taken. That one case, mentioned earlier is documented in the Topic 7 report. In every case, where there were dissenting opinions, they were documented, and the majority documented the reasons for selecting the recommendation to go forward. These will be discussed here on a topic-by-topic basis in summary; details are in the individual final reports in the Appendices. If not noted here, at least general consensus was achieved on all other details (which is a very large number).

Topic	Dissenting Opinions	Reference for explanation
1 Envelope Protection	Against Proposed Regulation: • Two members disagree with having a specific failure rate requirement in the regulation for load factor limiting. • One member wants not only a specific failure rate requirement, but a specific numerical requirement for load factor limiting. • One member disagrees with having a specific failure rate	Appendix 1

	requirement for high angle of attack limiting. • One member wants not only a specific failure rate requirement, but a specific numerical requirement for high angle of attack limiting. Against Proposed Guidance: • Two members disagree with having a specific failure rate requirement quoted in AC 25-7C paragraph 20.e(2)(a) • One member disagrees with having a specific failure rate for HALF credit in AC 25-7C paragraph 29.(d)(5). • One member wants not only a specific failure rate requirement, but a specific numerical requirement as well. • One member disagrees with the MOC in 25-7C paragraph 29h(2)(g) to demonstrate limiting angle of attack at the maximum altitude expected in service. • One member disagrees with the demonstration in proposed AC 25-7C paragraph 29.(h)(3)(e)(i)-(iii) requiring an abrupt step for side sticks while only requiring 3 kt/sec for conventional columns. • One member disagrees with the proposed MOC regarding side sticks with conventional stability force gradients to be allowed less than abrupt input to full aft control. • Two members disagree with the guidance that loss of both HALF and stall warning be extremely improbable. • Four members disagree with the proposal to allow in excess of 1.5g during recovery from 14CFR25.253 “Speed increase and recovery characteristics” maneuvers of AC25-7C, paragraphs 32c(1)-(5) if applied by a high speed protection functcion (HSPF) with the pitch controller at neutral. • One member disagrees with the proposed guidance that HSPF have a probability of failure no greater than “improbable”. • Two members disagree the the proposal to allow an HSPF to be disabled as ameans to demonstrate characteristics at a speed greater than can be achieved with full forward pitch control. No disagreement with intent or specific construct of the proposed regulations or guidance.	
2 Adaptation for Flight in Icing	• One member does not agree with the “more critical power setting” for pre-activation ice specified by proposed 14CFR25.202(d)(5) compared to the comparable procedure in AC 25-25A for compliance to 25.207(h) which specifies “idle” thrust for conventional airplanes. The member considers that the required power setting should be the same for both conventional and protected airplanes. • One member does not agree with the proposed application of icing accountability thresholds as proposed in 14CFR25.105(a)(2)(i), and has proposed different wording.	Appendix 2

	• One member is concerned that the proposed revision of AC25-25A, paragraph 2.6.1 is not now aligned with the proposed 14CFR25.105(a)(2) or 14CFR25.121(b)(2)(ii) regarding V2 accountability thresholds in icing conditions, in light of the unresolved issue noted below, and has proposed alternate words. • Several members disagreed with a proposed new paragraph 2.6 in AC25-25A regarding inclusion of ice effects during the determination of the takeoff path and takeoff performance parameters, and suggests alternate wording. No disagreement with the conditions or characteristics required to ensure safe characteristics in icing with angle-of-attack limiting systems, or with the branching structure to implement parallel certification paths, only the accountability thresholds for performance determination.	
6 Stability	• One disagreement with specific wording used to correct an inconsistency in 14CFR25.177. No disagreement with the intent, only the choice of words.	Appendix 3
7 Sidesticks	• One member does not see the need for specific force criteria rather than the qualitative criteria currently in many of the regulations. Further, even in the presence of quantitative criteria, a qualitative criterion is still necessary. • Three members consider that there is insufficient data to support maximum and minimum control force values in the proposal • One member considers that the focus only on maximum and minimum forces is incomplete and that the additional handling qualities requirements in the proposed 14CFR25.143(k) insufficient; other considerations should be included	Appendix 4
9 Wet Runway Stopping	No dissenting opinions.	Appendix 5
10 Runway Excursion Hazard	• One member believes that the 90% criteria is not numerically substantiated and is not apparently consistent with 1309 which considers the entire operating envelope in which the airplane is approved to operate. • One member suggests that dry runway ONLY is not explained or substantiated. • One member believes that rationale for not considering crosswinds above 25 kt should be explained or substantiated. • One member believes that crosswind: method1 is not in line with 25. 1309 because this method makes assumptions about hazards that are more appropriately a fallout of system safety assessment process. • One member believes that the FTHWG should update 25.1309 AC (arsenal or not) instead of updating AC 25-7X because this topic more closely aligns with the topics in that AC. • One member believes that the following disclaimer is an appropriate additional clarification:	Appendix 6

	The speed-based methodology is only applicable when engine thrust is reduced to a point where the airplane is not accelerating as it departs the runway. Failures where that is not the case should be examined on a case-by-case basis to determine if the speed-based methodology is appropriate. • One member does not agree /support the Lateral runway excursion speed criteria. • One member disagrees with the crosswind accountability methods presented, and suggests that there should be an overarching method to allow determination of the crosswind value at which point the system failure would become catastrophic, hazardous, or major.	
11 Stall IGE	No dissenting opinions	Appendix 7
12 Steep Approach	Consensus has been reached on a number of important issues for this Topic. For some issues, the consensus position was to allow some limited administrative variation: • Screen height definition: consensus to keep the definition of AC25-7C para.231(c)(3) (50 ft) and accept a wider range (35 to 60 ft) within the EASA definition. Screen heights from 35 to 60 feet can still be proposed via other administrative means (i.e. equivalent safety findings) for all regulatory authorities. For issues which did not achieve consensus, the following dissenting opinions have been raised: • One member did not agree that it is appropriate to use flight test data to define the maximum expected operational variation in flight path angle. • One member considers that the existing requirements of CS SAL 25.5 "Safe operational and flight characteristics", which already include two different abuse cases (-2° steep with a flare initiated at 150% screen height and Vrefsal-5 kt with flare initiated at screen height) are adequate to demonstrate proper airplane robustness to various extreme variations in a SAL operation and doesn't see the credit of an extra test point. • One member disagrees with the majority view of demonstrating both 2 degrees abuse from 150% of the screen height and 1 degree abuse at the screen height, and submitted extensive alternate advisory material. See Appendix 8 for details. • One member disagrees with using the most conservative of AEO or OEI for landing distances for those cases in which the steep approach approval is sought ONLY for the AEO case.	Appendix 8
13 Out of Trim	• One member believes that the proposed modified 14CFR25.255(f) represents an additional testing burden compared to their current practice with their CRI. • One member disagrees with the specification of failure rate of "not more probable than remote" in the proposed modified 14CFR25.255(e) as being more restrictive than their current practice with their CRI. • One member believes that the requirement to demonstrate 1.5 g's at Vdf/Mdf in the proposed 14CFR25.155(f) represents an	Appendix 9

	increased testing burden, and only possible with high speed protection disabled.	
14 Tailwind-Crosswind	No dissenting opinions regarding the proposal to maintain the existing regulations. No dissenting opinions regarding the conclusion that crosswind limitations need not be established (unless actually found to be limiting).	Appendix10

There was one issue in Topic 2 on which consensus could not be achieved before this report was written. This issue revolves around the new icing accountability thresholds proposed in 14CFR25.105(a)(2)(iii) and 14CFR25.121(b)(2)(ii)(C), the intent of the regulation change introduced at Amendment 25-121, and the standard reflected in the various CS's and CRI's. Details of the two opposing positions are given in Appendix 2.

Recommendation

In general, the FTHWG recommends that the FAA, EASA, TCCA, ANAC, and other national authorities adopt or encourage the adoption of the proposed harmonized regulatory and guidance material. In cases in which there were dissenting opinions, the minority positions are explained and the majority positions documented. In some cases, the deliberations of the FTHWG uncovered other areas in which additional work should be undertaken, and these are recommended as well. Specific recommendations are given in each Appendix for each topic, and are summarized here.

Topic	Recommendations	Reference for explanation
1 Envelope Protection	1. FAA should adopt the harmonized regulatory and guidance material proposed in Attachment 1B and 1C of Appendix 1 (and incorporated in Attachment B of this report). 2. FAA should liaise with EASA, TCCA, ANAC, and other national authorities to ensure consistent implementation of a harmonized standard. 3. FTHWG should address the use of angle of attack limiting systems in aircraft being certified under existing stall regulations. 4. FTHWG should complete development of guidance and means of compliance material for effects of atmospheric disturbances on airplanes with flight envelope limiting. 5. FTHWG should develop guidance material related to the question of Vmu credit for envelope limiting similar to that afforded to geometry limited airplanes. 6. FTHWG, with appropriate support from structures and systems should be tasked to achieving a “harmonized” position on consideration of high-speed protection functions and associated speed/Mach margins affecting 14CFR25.253, 335, and 1505, and the use of load factor limiting systems affecting 14CFR143(g) and 337. This is expected to be undertaken in Phase 3. Note that recommendations 3 through 6 are the result of deliberations undertaken for this topic, but shelved in favor of finishing the other aspects of this topic. While the FTHWG believes the work done through recommendations 1 and 2 will produce a complete stand-alone package, it would be better if these other issues were resolved as well; these other aspects should not be allowed to fall through a crack.	Appendix 1
2 Adaptation for Flight in Icing	1. FAA should adopt the harmonized standard and guidance identified in Attachments 2B and 2C of Appendix 2. 2. FAA should liaise with EASA, TCCA, ANAC, and other national authorities to encourage them to similarly adopt the harmonized regulatory and guidance material in Attachments 2B and 2C of Appendix 2.	Appendix 2
6 Stability	1. FAA should adopt the harmonized regulatory and guidance	Appendix 3

	material identified in Attachment 6B and 6C of Appendix 3 (and incorporated in attachment B and C of this report) 2. FAA should liaise with EASA, TCCA, ANAC, and other national authorities to encourage them to similarly adopt the harmonized regulatory and guidance material identified in Attachments 6B and 6C of Appendix 3 (and incorporated in Attachments B and C of this report). 3. FTHWG should be tasked to complete the development of guidance material on the subject of flight in the presence of atmospheric disturbances, recommending detailed harmonized Means of Compliance.	
7 Side Sticks	1. FAA and EASA adopt regulations and guidance as proposed in Attachment 7A and 7B of Appendix 4 (and incorporated in Attachments B and C of this report). In addition, FAA should liaise with other national authorities to ensure consistent implementation in their associated regulations and guidance. 2. EASA should delete CS25.777(i). 3. Harmonization and implementation of special conditions for side stick control system design, including design loads, controller coupling and failure awareness, active controller standards, and deterrence of dual pilot input and dual input awareness be considered for future tasking for the Flight Controls Harmonization Working Group, with participation from members of the FTHWG.	Appendix 4
9 Wet Runway Stopping	1. Landing Safety Training Aid: if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the appropriate FAA/EASA/TCCA. 2. Codify TALPA ARC Recommendations: if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the appropriate FAA/EASA/TCCA. 3. Identification of Poor Performing Wet Runways: if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the appropriate FAA personnel when considering proposed FAA future research programs and to the Tech Center Airport research team for discussion in their upcoming "Expert" panel meeting on future wet runway research. The first meeting of this "Expert" panel is planned for mid-February of 2017. 4. CFR 25 standard that reflects the physics: if the ARAC concurs with the recommendation it is requested that no other action be taken and the FTHWG will continue forward with Task 2 and 3 as assigned in the original tasking. 5. Ground Spoiler not armed warning regulation/guidance: if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to	Appendix 5

	communicate with the Transport Standards organizations of the FAA/EASA/TCCA. 6. Require of a ROPs/RSAT/Smart Landing type systems for CFR 25: No recommendations at this time, however when/if EASA does propose a CS25 standard it is recommended the ARAC request the FTHWG review the EASA proposal for consideration by the FAA and TCCA working towards a harmonized standard.	
10 Runway Excursion Hazard	1. FAA should amend AC 25-7X Chapter 6, Section 1, Paragraph 174 'Equipment, Systems, and Installations- §25.1309' to include the proposed criteria for establishing Runway Excursion Hazard Classification following system failures as presented in Attachment 10B of Appendix 6. 2. Further, the FAA should liaise with other airworthiness authorities to ensure consistent implementation in their associated guidance material. 3. FAA policy PS-ANM-25-11 (2013) should be cancelled.	Appendix 6
11 Stall IGE	1. FAA should adopt proposed changes to guidance material. 2. FAA should liaise with other airworthiness authorities to ensure consistent implementation.	Appendix 7
12 Steep Approach	1. The FTHWG recommends that FAA amend AC25-7C, para 231 as proposed in Attachment B to Appendix 8. 2. FTHWG recommends that ANAC, and TCCA revise their requirements and guidance material and EASA revise their certification standards (Appendix Q) accordingly.	Appendix 8
13 Out of Trim	1. FAA should adopt 14CFR25.255 and associated guidance as proposed 2. FTHWG and Structures HWG should liaise to coordinate 14CFR25.253, 335, and 1505.	Appendix 9
14 Tailwind-Crosswind	1. FAA should adopt the proposed harmonized guidance that consists of an update of relevant AC25-7 parts. 2. FAA should make sure that the proposed standard, established for an airplane control perspective is acceptable for evaluation of engine operations in tailwind conditions. 3. Further, the FAA should liaise with other regulatory authorities to ensure consistent implementation in their jurisdictions.	Appendix10

A. Rulemaking

1. What is the proposed action?

The FTHWG recommends changes to 14CFR25 for Topics 1, 2, 6, 7, and 13. Further, the FTHWG recommends identical changes to similar paragraphs of the EASA Certification Standard CS-25; TCCA part 525, ANAC, part 25 and encourages the authorities to further encourage world-wide adoption of these standards.

Topic 9 does not recommend any rulemaking action at this time.

Topic 10 does not recommend any rulemaking action, only modifications to guidance material.

Topic 11 does not recommend any rulemaking action, only modifications to guidance material.

Topic 12 recommends changes to AC 25-7C and to CS25, Appendix Q with further recommendations for similar amendments to TCCA and ANAC requirements and guidance material.

Topic 14 does not recommend any rulemaking action, only modifications to guidance material.

2. What should the harmonized standard be?

The recommended regulatory material for Topics 1, 2, 6, 7, and 13 is provided in Attachment B. This has been consolidated from each of the individual Topic reports. The text in Attachment B is color-coded to indicate the source document for each change from the baseline 14CFR25 paragraph. Rationale for each recommended change or addition is given in the individual reports.

Topic 9 does not recommend any rulemaking action at this time.

Topic 10 does not recommend any rulemaking action, only modifications to guidance material.

Topic 11 does not recommend any rulemaking action, only modifications to guidance material.

Topic 12 will recommend only guidance material changes for FAA, TCCA, ANAC, and changes to EASA Appendix Q are detailed in Appendix 8.

Topic 14 does not recommend any rulemaking action, only modifications to guidance material.

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

For the fly-by-wire topics, where there was no harmonized safety standard before, the established standard will have the effect of ensuring a consistent safety standard across all authorities for airplanes with modern control architectures.

Topic 9 does not recommend any rulemaking action at this time, but the recommendations are intended to improve the level of safety.

Topic 10 does not recommend any rulemaking action, only modifications to guidance material.

Topic 11 does not recommend any rulemaking action, only modifications to guidance material.

Topic 12 does not recommend any FAA rulemaking action, only modifications to guidance material. Recommended changes to EASA Appendix Q are given in Appendix 8.

For Topic 13, this proposal standardizes the way the intent of the original §25.255 is to be applied for auto-trim aircraft as well as conventional aircraft.

Topic 14 does not recommend any rulemaking action, only modifications to guidance material.

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

For each topic, the deliberations of the FTHWG included whether the proposed standard changes the level of safety relative to that provided by the current 14CFR25. The conclusions are summarized below. Complete descriptions are given in the individual Topic reports in the Appendices.

Topic 9 does not recommend any rulemaking action at this time, but the recommendations are intended to improve the level of safety.

Topic 10 does not recommend any rulemaking action, only modifications to guidance material.

Topic 11 does not recommend any rulemaking action, only modifications to guidance material. This material, however, is expected to have the effect of increasing flight test safety.

Topic 12 does not recommend any FAA rulemaking action, only modifications to guidance material. Recommendations for changes to EASA Appendix Q are given in Appendix 8.

Topic 14 does not recommend any rulemaking action, only modifications to guidance material.

Topic	**Level of Safety**	**Reference for explanation**
1 Envelope Protection	Same	Appendix 1
2 Adaptation for Flight in Icing	Same	Appendix 2
6 Stability	Same	Appendix 3
7 Side Sticks	Same	Appendix 4
9 Wet Runway Stopping	Increase	Appendix 5
10 Runway Excursion Hazard	N/A	Appendix 6
11 Stall IGE	Increase	Appendix 7
12 Steep Approach	Same	Appendix 8
13 Out of Trim	Same	Appendix 9
14 Tailwind-Crosswind	Same, but with increased harmony and clarity	Appendix10

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

For each topic, the deliberations of the FTHWG included whether the proposed standard changes the level of safety relative to current industry practice. The conclusions are summarized below. Complete descriptions are given in the individual Topic reports in the Appendices.

Topic 9 does not recommend any rulemaking action at this time, but the recommendations are intended to improve the level of safety.

Topic 11 does not recommend any rulemaking action, only modifications to guidance material. This material, however, is expected to have the effect of increasing flight test safety for some.

Topic 12 does not recommend any FAA rulemaking action, only modifications to guidance material. Recommendations for changes to EASA Appendix Q are given in Appendix 8.

Topic 14 does not recommend any rulemaking action, only modifications to guidance material.

Topic	**Level of Safety**	**Reference for explanation**
1 Envelope Protection	Same	Appendix 1
2 Adaptation for Flight in Icing	Same	Appendix 2
6 Stability	Same	Appendix 3
7 Side Sticks	Same	Appendix 4
9 Wet Runway Stopping	Increase	Appendix 5
10 Runway Excursion Hazard	N/A	Appendix 6
11 Stall IGE	Increase for some; Same for others	Appendix 7
12 Steep Approach	Same	Appendix 8
13 Out of Trim	Same	Appendix 9
14 Tailwind-Crosswind	Same, but with increased harmony and clarity	Appendix10

6. Who would be affected by the proposed change?

The FTHWG considers the affected groups for each topic as follows. Detailed considerations are given in each of the Appendices.

Topic	**Who would be Affected**	**Reference for explanation**
1 Envelope Protection	OEM's, Authorities	Appendix 1
2 Adaptation for Flight in Icing	OEM's	Appendix 2
6 Stability	OEM's, Authorities	Appendix 3
7 Side Sticks	OEM's	Appendix 4
9 Wet Runway Stopping	OEM's, Operators	Appendix 5
10 Runway Excursion Hazard	OEM's	Appendix 6
11 Stall IGE	OEM's	Appendix 7
12 Steep Approach	OEM's, Authorities	Appendix 8
13 Out of Trim	OEM's	Appendix 9
14 Tailwind-Crosswind	OEM's, Operators	Appendix10

7. Does the proposed standard affect other HWG's and what is the result of any consultation with other HWGs?

Throughout the deliberations, the FTHWG was aware of the multi-disciplinary nature of this work, and the subject of regulations and guidance in Subparts C, D, F, G, and H were discussed many times. Ultimately, it was felt not necessary to consult directly with other HWG's to complete this work, however it is important to note that most (if not all) of the FTHWG participants stayed in close contact with their counterparts in other disciplines and on other HWG's throughout the working period.

Some of the work resulted in recommendations for future work in areas of other HWG's. These are indicated below, and described in more detail in the individual reports in the Appendices.

Topic	**Other HWG's Affected or Consulted**	**Reference for explanation**
1 Envelope Protection	None, but proposed future work	Appendix 1
2 Adaptation for Flight in Icing	None	Appendix 2
6 Stability	None	Appendix 3
7 Side Sticks	None, but proposed future work	Appendix 4
9 Wet Runway Stopping	None at this time	Appendix 5
10 Runway Excursion Hazard	N/A	Appendix 6
11 Stall IGE	None	Appendix 7
12 Steep Approach	None	Appendix 8
13 Out of Trim	None, but proposed future work	Appendix 9
14 Tailwind-Crosswind	N/A	Appendix10

B. Advisory Material

1. Is existing FAA advisory material adequate? If not, what advisory material should be adopted?

The FTHWG believes that the current FAA advisory material is not adequate. Proposed changed material is provided for each of the Topics. For some Topics, the only recommendation is for amended advisory material. For others, both regulations and guidance material are recommended.

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

In each case, proposed harmonized guidance material is included in the individual reports. To ensure harmonization, EASA, TCCA and ANAC standards (e.g EASA CS-25 book 1) and Material guidance (e.g CS-25 book 2) should be updated the same way and Special Conditions and Interpretative Material Guidance should be replaced with the new standards and guidance.

Economics

A. What is the cost impact of complying with the proposed standard?

Because the approach taken by the FTHWG on this topic was to bring the experiences of current SC's and CRI's into the current regulatory structure, the FTHWG does not believe the cost impact will be significant for the same level of safety. The proposed standards for the fly-by-wire topics (1, 2, 6, 7, and 13) will allow elimination of the existing Special Conditions that will reduce the certification burden and associated cost for authorities and OEMs.

Detailed analysis is given in each of the Topic reports in the appendices. In particular, Topic 2 (Icing) notes the potential for additional flight testing to comply with the proposed standard compared to their current status, although these might be conducted, in certain cases, in combination with other already existing flight tests.

In Topic 2, it is to be noted that the additional HALF reliability/availability requirement being set to be Improbable, might affect the HALF Change Product Rule Airplanes as this requirement was not specifically considered in the existing Special Conditions.

Topic 10 is not expected to change costs to either manufacturers or authorities.

Topic 11 is not expected to increase costs to either OEM's or operators. For those applicants using the current EASA accepted means of compliance for takeoff performance testing and not AC25-7C, a small number of additional takeoff conditions may be necessary when these recommendations are adopted by EASA and implemented in CS-25 Book 2. The recommended guidance changes are intended to enhance the awareness of the aerodynamic influence of ground effects on the stall angle-of-attack and maximum lift coefficient within the flight test community and reduce the risks associated with takeoff field performance flight testing.

Relative to current FAA guidance, Topic 12 is not expected to result in a cost impact. Relative to EASA guidance, additional flight testing will be required. The benefit is in having one consistent standard reducing administrative burden for multi-agency certification.

For Topic 13, it is expected that the resulting cost impact for the OEM's will vary according to their respective status quo in regards to §25.255 compliance.

If FAA economists are employed to generate specific analyses, the FTHWG would like to be engaged in that activity as it happens.

B. Does the HWG want to review the draft NPRM prior to publication in the Federal Register?

Yes.

ICAO Standards
How does the proposed standard compare to the current ICAO standard?

ICAO Annex 8, at Amendment 105b, Part IIIB specifies international standards for airworthiness for large airplanes. The standard of Annex 8 is written quite broadly. In some cases this broadly worded language of Annex 8 can be taken to cover the topic at hand. In other cases, the Annex 8 standard is simply silent on a particular topic. In all cases except Topic 1, the FTHWG believes that, the recommended harmonized regulatory and guidance material proposed is not incompatible with the ICAO standard.

For Topic 1, the ICAO standard explicitly calls for stall warning, which is not required in the proposed regulatory and guidance material for angle-of-attack limited airplanes.

Topic 10 observes that there are no ICAO standards applicable to runway excursion hazard classification and that Annex 14 is compatible with the recommendations being made.

For Topic 11, there are no known ICAO standards relating to takeoff speeds or takeoff field performance flight testing.

For Topic 12, there are no known ICAO standards relating to steep approach procedures for transport aircraft.

For Topic 13, there are no current ICAO Annex 8 standards regarding Airworthiness of Aircraft for Large Aeroplanes that specifically address designs with auto-trim functions, nor any standards specifically addressing out-of-trim conditions.

For Topic 14, the proposed guidance changes associated with this task are not considered to be in conflict with the ICAO standard.

Details are presented in each of the Appendices.

Attachment A ARAC Tasking from Federal Register

20296 Federal Register / Vol. 79, No. 70 / Friday, April 11, 2014 / Notices

DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
Aviation Rulemaking Advisory Committee—Transport Airplane Performance and Handling Characteristics—Continuing a Task

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of phase 2 task assignment for the Aviation Rulemaking Advisory Committee (ARAC).

SUMMARY: The FAA assigned the Aviation Rulemaking Advisory Committee (ARAC) a new phase 2 task to provide recommendations regarding new or updated standards in the highest priority topic areas for airplane performance and handling characteristics. This task addresses the Flight Test Harmonization Working Group's recent recommendations. This notice informs the public of phase 2 ARAC activity and does not solicit membership for the existing Flight Test Harmonization Working Group (FTHWG).

FOR FURTHER INFORMATION CONTACT: Joe Jacobsen, Airplane & Flight Crew Interface Branch, ANM–111, Transport Airplane Directorate, Federal Aviation Administration, 1601 Lind Avenue SW., Renton, Washington 98057–3356; telephone 425–227–2011, facsimile 425–227–1149; email *joe.jacobsen@ faa.gov.*

SUPPLEMENTARY INFORMATION:

ARAC Acceptance of Task

As a result of the March 20, 2014, ARAC meeting, the FAA has assigned and ARAC has accepted this task and will use the existing FTHWG. The FTHWG will serve as staff to ARAC and provide advice and recommendations on the assigned task. ARAC will review and approve the recommendation report that will be sent to the FAA.

Background

The FAA established ARAC to provide advice and recommendations to the FAA Administrator, through the Associate Administrator of Aviation Safety, on the FAA's rulemaking activities. ARAC's objectives are to improve the development of the FAA's regulations by providing information, advice, and recommendations related to aviation issues. The FTHWG will provide advice and recommendations to ARAC on new and updated standards for the highest priority topic areas for airplane performance and handling characteristics.

In March 2013, the FAA tasked ARAC to provide advice and recommendations in prioritizing potential topic areas for the development of new or revised standards for airplane performance and handling characteristics in new transport category airplanes. The output of that task is now complete and is the basis for this new task. The highest priority topic areas were determined to be new or updated standards for fly-by wire (FBW) flight controls, wet runway stopping performance, runway excursion hazard classification, stall speed in ground effect, steep approach, flight test methods used to determine maximum tailwind and crosswind capability, susceptibility to pilot induced oscillations/airplane-pilot coupling (PIO/APC), and guidance material for assessing handling qualities. This task will be to develop these high priority topic areas.

The Task

The working group should develop recommended standards in the following topic areas. If there are disagreements within the working group, these should be documented, including the reasons for the disagreement and rationale from each party. The following subject areas should be worked upon within this task:

1. Fly-by-wire Flight Controls.

Regulatory requirements and associated guidance material for airworthiness certification of airplane designs using fly-by-wire technology to remove the need for longstanding, repetitively-used fly-by-wire special conditions. Specific areas include:

a. Applicability/adaptation of Amendment 25–121 airplane performance and handling characteristics in icing conditions requirements,

b. Lateral/directional/longitudinal stability,

c. Out of trim requirements,

d. Side stick controls, and

e. Flight envelope protection.

2. Takeoff and Landing Performance.

Regulatory requirements and associated guidance material for airworthiness certification in the following areas listed

below. (Note: This topic area excludes items addressed by the Takeoff and Landing Performance Assessment Aviation Rulemaking Committee.)

a. Flight test methods used to determine maximum tailwind and crosswind capability. For crosswind testing, better define intended operational use of demonstrated maximum steady and gusting crosswind performance.

b. Wet runway stopping performance.

Recent landing overruns on wet runways have raised questions regarding current wet runway stopping performance requirements and methods. Analyses indicate that the braking coefficient of friction in each case was significantly lower than expected for a wet runway (i.e., lower than the level specified in FAA regulations). Consideration should also be given to the scheduling of landing performance on wet porous friction course and grooved runway surfaces. Recommendations may include the need for additional data gathering, analysis, and possible rulemaking.

c. Steep approach landing performance.

Current airplane certification standards are not harmonized among the U.S., Canadian, Brazilian, and European airworthiness

authorities.

d. Guidance material addressing the adverse effects on stall speed in ground effect.

e. Runway excursion hazard classification. Current safety assessments are not harmonized among the U.S., Canadian, Brazilian, and European airworthiness authorities.

3. Handling Characteristics. Guidance material for airworthiness certification in the following areas:

a. Guidance material for assessing handling qualities.

Current Advisory Circular 25–7, ‘‘Flight Test Guide for Certification of Transport Category Airplanes,’’ provides an FAA Handling Quality Rating Method that is intended to provide a systematic way of determining appropriate minimum handling qualities requirements and evaluating those handling qualities for conditions affecting an airplane’s flying qualities. The FAA handling quality rating system is not universally accepted within industry, nor is it accepted by EASA.

b. Guidance for assessing susceptibility to pilot-induced oscillations/airplane-pilot coupling (PIO/APC). Guidance provided in Advisory Circular 25–7C for evaluating PIO/APC is also not well accepted by airplane manufacturers, is not harmonized with EASA, and has been superseded to some extent in recent certification programs. Modified guidance is needed to both simplify and standardize the methods for evaluating an airplane’s susceptibility to PIO/APC.

Schedule

The recommendation report must be submitted to the FAA for review and acceptance no later than 3 years from the publication date of this tasking. The FAA expects to publish additional ARAC taskings for follow-on phases to develop other topic areas which were lower in priority.

Working Group Activity

The FTHWG must comply with the procedures adopted by ARAC. As part of the procedures, the working group must:

1. Conduct a review and analysis of the assigned task and any other related materials or documents.
2. Draft and submit a work plan for completion of the task, including the rationale supporting such a plan, for consideration by the Transport Airplane and Engine (TAE) Subcommittee.
3. Provide a status report at each TAE Subcommittee meeting.
4. Draft and submit the recommendation report based on the review and analysis of the assigned tasks.
5. Present the recommendation report at the TAE Subcommittee meeting.

Participation in the Working Group

The existing FTHGW is comprised of technical experts having an interest in the assigned task. A working group member need not be a representative or a member of the full committee.

In accordance with the June 18, 2010, memorandum entitled ‘‘Lobbyists on Agency Boards and Commissions,’’ members are not federally registered lobbyists, who are subject to the registration and reporting requirements of the Lobbying Disclosure Act of 1995 (LDA) as amended, 2 U.S.C. 1603, 1604, and 1605, at the time of appointment or reappointment to an advisory committee, and has not served in such a role for three consecutive quarters prior to appointment. (For further information see the Office of Management and Budget final guidance on appointment of lobbyists to federal boards and commissions (76 FR 61756, October 5, 2011).

All existing FTHWG members who wish to participate in this task must actively participate by attending all meetings, and providing written comments when requested to do so. Each member must devote the resources necessary to support the working group in meeting any assigned deadlines. Each member must keep their management chain, and those they may represent, advised of working group activities and decisions to ensure the proposed technical solutions do not conflict with their sponsoring organization’s position when the subject is presented to ARAC for approval. Once the FTHWG has begun deliberations, members will not be added or substituted without the approval of the FAA and the Working Group Chair.

The Secretary of Transportation determined the formation and use of ARAC is necessary and in the public interest in connection with the performance of duties imposed on the FAA by law. ARAC meetings are open to the public. However, meetings of the FTHWG are not open to the public, except to the extent individuals with an interest and expertise are selected to participate. The FAA will make no public announcement of FTHWG meetings.

Issued in Washington, DC, on April 8, 2014.

Lirio Liu,

Designated Federal Officer, Aviation
Rulemaking Advisory Committee.

[FR Doc. 2014–08139 Filed 4–10–14; 8:45 am]

BILLING CODE 4910–13–P

Attachment B Proposed Regulatory Material

Colors for Regulation changes
Topic 1 Envelope Protection
Topic 2 Adaptation for Flight in Icing
Topic 6 Stability
Topic 7 Side Sticks
Topic 13 Out of Trim

Subpart B—Flight

PERFORMANCE

§25.103 Reference Stall 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:

$$V_{SR} \geq \frac{V_{CL_{MAX}}}{\sqrt{n_{zw}}}$$

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where:

V_{CLMAX} = Calibrated airspeed obtained when the load factor-corrected lift coefficient

$$\left(\frac{n_{zw}W}{qS}\right)$$

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is first a maximum during the maneuver prescribed in paragraph (c) of this section. 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 takeoff 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 $1.13V_{SR}$ and not greater than $1.3V_{SR}$.

(7) If installed, the High Angle-of-Attack Limiting Function disabled or adjusted, at the option of the applicant, to allow reaching the angle of attack corresponding to V_{SR}.

(c) Starting from the stabilized trim condition, apply the longitudinal control to decelerate the airplane in straight flight so that the speed reduction does not exceed one knot per second, until stall as defined in Section 25.201(d) or the angle of attack corresponding to V_{SR} is reached; or until activation of a stall identification device (e.g., stick pusher), if installed.

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

(e) In addition to the requirements of paragraph (a) of this section, when a High Angle-of-Attack Limiting Function is installed and compliance is shown with §§25.202 and 25.204, the one-g minimum steady flight speed, V_{MIN1g}, must be established if it is used to determine compliance with a required performance standard or other requirements demonstrations in non-icing or icing conditions.

(1) The one-g minimum steady flight speed, V_{MIN1g}, is the minimum calibrated airspeed at which the airplane can develop a lift force (normal to the flight path) equal to its weight, while stabilized at the limit angle of attack achieved with the High Angle-of-Attack Limiting Function operating normally.

(2) V_{MIN1g} is determined with:

(i) Engines idling;

(ii) Flaps and landing gear in any likely combination of positions approved for operation;

(iii) The weight used when the reference stall speed, V_{SR}, is being used as a factor to determine compliance with a required performance standard;

(iv) The center of gravity position that results in the highest value of V_{MIN1g};

(v) The airplane trimmed for straight flight at a speed selected by the applicant, but not less than 1.13 V_{MIN1g} (or the minimum trim speed if higher than 1.13 V_{MIN1g}), and not greater than $1.3V_{MIN1g}$, and

(vi) The ice accretions appropriate for the condition existing in the performance standard for which V_{MIN1g} is being used.

[Doc. No. 28404, 67 FR 70825, Nov. 26, 2002, as amended by Amdt. 25-121, 72 FR 44665, Aug. 8, 2007]

§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 used to show compliance with §25.121(b), and with the most critical of the takeoff ice accretion(s) defined in appendices C and O of this part, as applicable, in accordance with §25.21(g):

(i) The reference 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} (This requirement does not apply if compliance is shown to §§ 25.202 and 25.204);; 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); or).

(iii) V_2 exceeds the non-icing V_2.

(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.

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-92, 63 FR 8318, Feb. 18, 1998; Amdt. 25-121, 72 FR 44665, Aug. 8, 2007; Amdt. 25-140, 79 FR 65525, Nov. 4, 2014]

§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 §25.149(e).

(2) V_1, in terms of calibrated airspeed, is selected by the applicant; however, V_1 may not be less than V_{EF} plus the speed gained with 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) 1.13 V_{SR} (applicable in non-icing conditions; also applicable in icing conditions if compliance is not shown to §§25.202 and 25.204), for—

~~(1) 1.13 V_{SR} 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 stall speed;

(2) 1.08 V_{SR} (applicable in non-icing conditions; also applicable in icing conditions if compliance is not shown to §§25.202 and 25.204), for—

~~(2) 1.08 V_{SR} 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 stall speed; and

(3) 1.10 times V_{MC} established under §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 §25.121(b) but may not be less than—

(1) V_{2MIN};

(2) V_R plus the speed increment attained (in accordance with §25.111(c)(2)) before reaching a height of 35 feet above the takeoff surface; and

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

(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 paragraphs (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 §25.111(c)(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 —

(A) 110 percent of V_{MU} in the all-engines-operating condition, and 105 percent of V_{MU} determined at the thrust-to-weight ratio corresponding to the one-engine-inoperative condition; or

(B) If the V_{MU} attitude is limited by the geometry of the airplane (*i.e.,* tail contact with the runway), 108 percent of V_{MU} in the all-engines-operating condition, and 104 percent of V_{MU} determined at the thrust-to-weight ratio corresponding to the one-engine-inoperative condition.

(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 paragraphs (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 §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 §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} (applicable in non-icing conditions; also applicable in icing conditions if compliance is not shown to §25.202 and §25.204); and~~(1) 1.18 V_{SR}; and~~

(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.

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-38, 41 FR 55466, Dec. 20, 1976; Amdt. 25-42, 43 FR 2320, Jan. 16, 1978; Amdt. 25-92, 63 FR 8318, Feb. 18, 1998; Amdt. 25-94, 63 FR 8848, Feb. 23, 1998; Amdt. 25-108, 67 FR 70826, Nov. 26, 2002; Amdt. 25-121, 72 FR 44665, Aug. 8, 2007; Amdt. 25-135, 76 FR 74654, Dec. 1, 2011]

§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 §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 §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; and

(2) The weight equal to the weight existing when retraction of the landing gear is begun, determined under §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 §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 most critical of the takeoff ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g), if in the configuration used to show compliance with §25.121(b) with this takeoff ice accretion:

(A) The reference 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}, (This requirement does not apply if compliance is shown to §§25.202 and 25.204);; 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); or).

(C) V_2 exceeds the non-icing V_2.

(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 most critical of the final takeoff ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g), if:

(A) The reference stall speed at maximum takeoff weight, in the configuration used to show compliance with §25.121(b) with the takeoff ice accretion used to show compliance with §25.111(c)(5)(i), exceeds that in non-icing conditions by more than the greater of 3 knots CAS or 3 percent of V_{SR}, (This requirement does not apply if compliance is shown to §§25.202 and 25.204); or):

(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), with the takeoff ice accretion used to show compliance with §25.111(c)(5)(i),) is greater than one-half of the applicable actual-to-net takeoff flight path gradient reduction defined in §25.115(b); or.

(C) V_{FTO} with final takeoff ice exceeds the non-icing V_{FTO}.

(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 most critical of the approach ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g).

(A) 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; or.

(B) If compliance is shown to §§25.202 and 25.204, the climb speed established with normal landing procedures, but not more than 1.4 V_{SR} (V_{SR} determined in non-icing conditions), may be used if in a configuration corresponding to the normal all-engines-operating procedure the V_{MIN1G} for this configuration does not exceed 110% of the V_{MIN1G} for the related all-engines-operating landing configuration in icing conditions

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-84, 60 FR 30749, June 9, 1995; Amdt. 25-108, 67 FR 70826, Nov. 26, 2002; Amdt. 25-121, 72 FR 44666; Aug. 8, 2007; Amdt. 25-140, 79 FR 65525, Nov. 4, 2014]

§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 V_{ER}, in terms of calibrated airspeed, selected by the applicantnot 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; and

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

(5) A minimum speed not less than a speed that provides the maneuvering capability specified in § 25.143(h); and

(6) A minimum speed not less than 1.18 V_{SR} (in non-icing and icing conditions if compliance is required under §(b)(2)(i) of this section) applicable for altitudes up to the lower of 20,000 feet or the pressure altitude at which the gradient of the one-engine-inoperative actual flight path is zero for the en route configuration. (This requirement does not apply in icing conditions if compliance is shown to §§25.202 and 25.204).

(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 most critical of the en route ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g), if:

(i) A speed of 1.18 V_{SR}, applicable for altitudes in accordance with paragraph (a)(6) of this section,"V_{SR0} 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}, (This requirement does not apply if compliance is shown to §§25.202 and 25.204);; 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; or.

(iii) V_{ER} exceeds the non-icing V_{ER}.

(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.

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-121, 72 FR 44666; Aug. 8, 2007; Amdt. 25-140, 79 FR 65525, Nov. 4, 2014]

§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 most critical of the landing ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g), 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) A speed determined by one of the following;

(1~~(B~~) 1.23 V_{SR0} with the most critical of the landing ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g), if that speed exceeds V_{REF} selected for non-icing conditions by more than 5 knots CAS; or~~and~~

(2) 1.17 V_{MIN1G} or, at the option of the applicant, 1.23 V_{SR0} – 5 knots CAS, with the most critical of the landing ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with § 25.21(g), if compliance is shown to §§25.202 and 25.204.

(C) A speed that provides the maneuvering capability specified in §25.143(h) with the most critical of the landing ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g).

(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.

[Amdt. 25-121, 72 FR 44666; Aug. 8, 2007; 72 FR 50467, Aug. 31, 2007; Amdt. 25-140, 79 FR 65525, Nov. 4, 2014]

Controllability and Maneuverability

§25.143 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) The airplane must be shown to be safely controllable and maneuverable with the most critical of the ice accretion(s) appropriate to the phase of flight as defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g), and with the critical engine inoperative and its propeller (if applicable) in the minimum drag position:

(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 relevant **control** ~~**wheel or rudder pedals**~~	**Pitch**	**Roll**	**Yaw**
(1) For short term application:	75	50	
Control wheel (~~for pitch and roll control—~~two hands available for control)	50	25	
Control wheel (one hand available for control)	35	15/11[1]	
Side stick			
Rudder pedal			150
~~For short term application for pitch and roll control—one hand available for control~~	~~50~~	~~25~~	~~—~~
~~For short term application for yaw control~~	~~—~~	~~—~~	~~150~~
(2) For long term application:			
Control wheel	10	5	
Side stick	7	3	
Rudder pedal			20

[1] 15 lb inward, 11 lb outward

(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.

(g) When maneuvering at a constant airspeed or Mach number (up to V_{FC}/M_{FC}), the stick forces and the gradient of the stick force 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 if a load factor limiting function is not included that prevents overstressing the airframe, the stick forces must not be so low that the airplane can easily be overstressed inadvertently. If a load factor limiting function is used to prevent inadvertent overstressing of the airframe, its failure must be improbable. Changes of gradient that occur with changes of load factor must not cause undue difficulty in 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	[2]V_2 + XX	40°	All-engines-operating climb.[3]
Final Takeoff~~En route~~	V_{FTO}	40°	Asymmetric WAT-Limited.[1]
En route	[4]V_{ER}	40°	Asymmetric Thrust for Level Flight.[4]
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 takeoff condition at V_2, or any lesser thrust or power setting that is used for all-engines-operating initial climb procedures.

[4]The en route maneuvering capability requirement is applicable at all altitudes up to the pressure altitude at which the gradient of the one-engine-inoperative actual flight path is zero for the en route configuration.

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

(1) Controllability must be demonstrated with the most critical of the ice accretion(s) for the particular flight phase as defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g);

(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 for a control wheel or 35 pounds for a side stick; 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, it must be demonstrated in flight with the most critical of the ice accretion(s) defined in Appendix C, part II, paragraph (e) of this part and Appendix O, part II, paragraph (d) of this part, as applicable, in accordance with §25.21(g), that:

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

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

(k) It must be shown that unsuitable pilot-in-the-loop control characteristics are not encountered when considering precision path control tasks and turbulence. In addition, pitch and roll control force sensitivity and displacement sensitivity must be compatible, so that normal inputs on one control axis will not cause significant unintentional inputs on the other.

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-42, 43 FR 2321, Jan. 16, 1978; Amdt. 25-84, 60 FR 30749, June 9, 1995; Amdt. 25-108, 67 FR 70826, Nov. 26, 2002; Amdt. 25-121, 72 FR 44667, Aug. 8, 2007; Amdt. 25-129, 74 FR 38339, Aug. 3, 2009; Amdt. 25-140, 79 FR 65525, Nov. 4, 2014]

§25.144 Envelope Protection Functions—General.

For airplanes that employ envelope protection functions:

(a) Envelope protection functions must not unduly limit the maneuvering capability of the airplane nor interfere with its ability to perform maneuvers required for normal and emergency operations.

(b) Onset characteristics of each envelope protection function must be appropriate to the phase of flight and type of maneuver, and must not conflict with the ability of the pilot to satisfactorily control the airplane flight path, speed, or attitude.

(c) Excursions of a limited flight parameter beyond its nominal design limit value due to dynamic maneuvering, airframe and system tolerances, and non-steady atmospheric conditions must not result in unsafe flight characteristics or conditions.

(d) Operation of envelope protection functions must not adversely affect aircraft control during expected levels of atmospheric disturbances, nor impede the application of recovery procedures in case of wind-shear.

(e) Simultaneous action of envelope protection functions must not result in adverse coupling or adverse priority.

(f) In case of abnormal attitude or excursion of any flight parameters outside the protected boundaries, operation of envelope protection functions must not hinder airplane recovery.

§25.145 Longitudinal control.

(a) It must be possible, at any point between the trim speed prescribed in §25.103(b)(6) and stall identification (as defined in §25.201(d)) or the angle of attack achieved at full aft control input if compliance is shown with §§ 25.202 and 25.204,)), to pitch the nose downward so that the acceleration to this selected trim speed is prompt with

(1) The airplane trimmed at the trim speed prescribed in §25.103(b)(6);

(2) The landing gear extended;

(3) The wing flaps (i) retracted and (ii) extended; and

(4) Power (i) off and (ii) at maximum continuous power on the engines.

(b) With the landing gear extended, no change in trim control, or exertion of more than 50 pounds control force for a control wheel (representative of the maximum short term force that can be applied readily by one hand) or 35 pounds for a side stick may be required for the following maneuvers:

(1) With power off, flaps retracted, and the airplane trimmed at 1.3 V_{SR1}, extend the flaps as rapidly as possible while maintaining the airspeed at approximately 30 percent above the reference stall speed existing at each instant throughout the maneuver.

(2) Repeat paragraph (b)(1) except initially extend the flaps and then retract them as rapidly as possible.

(3) Repeat paragraph (b)(2), except at the go-around power or thrust setting.

(4) With power off, flaps retracted, and the airplane trimmed at 1.3 V_{SR1}, rapidly set go-around power or thrust while maintaining the same airspeed.

(5) Repeat paragraph (b)(4) except with flaps extended.

(6) With power off, flaps extended, and the airplane trimmed at 1.3 V_{SR1}, obtain and maintain airspeeds between V_{SW}, or the greater of V_{REF} - 5 knots CAS and the activation of a low airspeed caution or warning alert in accordance with § 25.1322 if compliance is shown with §§ 25.202 and 25.204, and either 1.6 V_{SR1} or V_{FE}, whichever is lower.

(c) It must be possible, without exceptional piloting skill, to prevent loss of altitude when complete retraction of the high lift devices from any position is begun during steady, straight, level flight at 1.08 V_{SR1} for propeller powered airplanes, or 1.13 V_{SR1} for turbojet powered airplanes, with—

(1) Simultaneous movement of the power or thrust controls to the go-around power or thrust setting;

(2) The landing gear extended; and

(3) The critical combinations of landing weights and altitudes.

(d) If gated high-lift device control positions are provided, paragraph (c) of this section applies to retractions of the high-lift devices from any position from the maximum landing position to the first gated position, between gated positions, and from the last gated position to the fully retracted position. The requirements of paragraph (c) of this section also apply to retractions from each approved landing position to the control position(s) associated with the high-lift device configuration(s) used to establish the go-around procedure(s) from that landing position. In addition, the first gated control position from the maximum landing position must correspond with a configuration of the high-lift devices used to establish a go-around procedure from a landing configuration. Each gated control position must require a separate and distinct motion of the control to pass through the gated position and must have features to prevent inadvertent movement of the control through the gated position. It must only be possible to make this separate and distinct motion once the control has reached the gated position.

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-23, 35 FR 5671, Apr. 8, 1970; Amdt. 25-72, 55 FR 29774, July 20, 1990; Amdt. 25-84, 60 FR 30749, June 9, 1995; Amdt. 25-98, 64 FR 6164, Feb. 8, 1999; 64 FR 10740, Mar. 5, 1999; Amdt. 25-108, 67 FR 70827, Nov. 26, 2002]

STABILITY

§25.171 General.

The airplane must have longitudinal, lateral~~be longitudinally, directionally~~, and directional stability characteristics~~laterally stable~~ in accordance with the provisions of §§25.173 through 25.181~~177~~. In addition, both suitable stability and suitable control feel are~~(static stability) is~~ required in any condition normally encountered in service.~~, if flight tests show it is necessary for safe operation.~~

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-7, 30 FR 13117, Oct. 15, 1965]

§25.173 Static longitudinal stability.

In each flight phase, the airplane must comply with §25.176 or §25.173(a) through (d):

Under the conditions specified in §25.175, the characteristics of the elevator control forces (including friction) must be as follows:

(a) A pull must be required to obtain and maintain speeds below the specified trim speed, and a push must be required to obtain and maintain speeds above the specified trim speed. This must be shown at any speed that can be obtained except speeds higher than the landing gear or wing flap operating limit speeds or V_{FC}/M_{FC}, whichever is appropriate, or lower than the minimum speed for steady unstalled flight.

(b) The airspeed must return to within 10 percent of the original trim speed for the climb, approach, and landing conditions specified in §25.175 (a), (c), and (d), and must return to within 7.5 percent of the original trim speed for the cruising condition specified in §25.175(b), when the control force is slowly released from any speed within the range specified in paragraph (a) of this section.

(c) The average gradient of the stable slope of the stick force versus speed curve may not be less than 1 pound for each 6 knots for a control wheel, or 1 pound for each 9 knots for a side stick..

(d) Within the free return speed range specified in paragraph (b) of this section, it is permissible for the airplane, without control forces, to stabilize on speeds above or below the desired trim speeds if exceptional attention on the part of the pilot is not required to return to and maintain the desired trim speed and altitude.

[Amdt. 25-7, 30 FR 13117, Oct. 15, 1965]

§25.175 Demonstration of static longitudinal stability.

In each flight phase, the airplane must comply with §25.176 or the applicable paragraph of §25.175(a) through (d):

Static longitudinal stability must be shown as follows:

(a) *Climb.* The stick force curve must have a stable slope at speeds between 85 and 115 percent of the speed at which the airplane—

(1) Is trimmed, with—

(i) Wing flaps retracted;

(ii) Landing gear retracted;

(iii) Maximum takeoff weight; and

(iv) 75 percent of maximum continuous power for reciprocating engines or the maximum power or thrust selected by the applicant as an operating limitation for use during climb for turbine engines; and

(2) Is trimmed at the speed for best rate-of-climb except that the speed need not be less than 1.3 V_{SR1}.

(b) *Cruise.* Static longitudinal stability must be shown in the cruise condition as follows:

(1) With the landing gear retracted at high speed, the stick force curve must have a stable slope at all speeds within a range which is the greater of 15 percent of the trim speed plus the resulting free return speed range, or 50 knots plus the resulting free return speed range, above and below the trim speed (except that the speed range need not include speeds less than 1.3 V_{SR1}, nor speeds greater than V_{FC}/M_{FC}, nor speeds that require a stick force of more than 50 pounds for a control wheel or 35 pounds for a side stick), with—

(i) The wing flaps retracted;

(ii) The center of gravity in the most adverse position (see §25.27);

(iii) The most critical weight between the maximum takeoff and maximum landing weights;

(iv) 75 percent of maximum continuous power for reciprocating engines or for turbine engines, the maximum cruising power selected by the applicant as an operating limitation (see §25.1521), except that the power need not exceed that required at V_{MO}/M_{MO}; and

(v) The airplane trimmed for level flight with the power required in paragraph (b)(1)(iv) of this section.

(2) With the landing gear retracted at low speed, the stick force curve must have a stable slope at all speeds within a range which is the greater of 15 percent of the trim speed plus the resulting free return speed range, or 50 knots plus the resulting free return speed range, above and below the trim speed (except that the speed range need not include speeds less than 1.3 V_{SR1}, nor speeds greater than the minimum speed of the applicable speed range prescribed in paragraph (b)(1), nor speeds that require a stick force of more than 50 pounds for a control wheel or 35 pounds for a side stick), with—

(i) Wing flaps, center of gravity position, and weight as specified in paragraph (b)(1) of this section;

(ii) Power required for level flight at a speed equal to (V_{MO} + 1.3 V_{SR1})/2; and

(iii) The airplane trimmed for level flight with the power required in paragraph (b)(2)(ii) of this section.

(3) With the landing gear extended, the stick force curve must have a stable slope at all speeds within a range which is the greater of 15 percent of the trim speed plus the resulting free return speed range, or 50 knots plus the resulting free return speed range, above and below the trim speed (except that the speed range need not include speeds less than 1.3 V_{SR1}, nor speeds greater than V_{LE}, nor speeds that require a stick force of more than 50 pounds for a control wheel or 35 pounds for a side stick), with—

(i) Wing flap, center of gravity position, and weight as specified in paragraph (b)(1) of this section;

(ii) 75 percent of maximum continuous power for reciprocating engines or, for turbine engines, the maximum cruising power selected by the applicant as an operating limitation, except that the power need not exceed that required for level flight at V_{LE}; and

(iii) The aircraft trimmed for level flight with the power required in paragraph (b)(3)(ii) of this section.

(c) *Approach.* The stick force curve must have a stable slope at speeds between V_{SW} or the airspeed achieved at full aft control input if compliance is shown with §§ 25.202 and 25.204 and 1.7 V_{SR1}, with—

(1) Wing flaps in the approach position;

(2) Landing gear retracted;

(3) Maximum landing weight; and

(4) The airplane trimmed at 1.3 V_{SR1} with enough power to maintain level flight at this speed.

(d) *Landing.* The stick force curve must have a stable slope, and the stick force may not exceed 80 pounds for a control wheel or 40 pounds for a side stick, at speeds between V_{SW} or the airspeed achieved at full aft control input if compliance is shown with §§ 25.202 and 25.204 and 1.7 V_{SR0} with—

(1) Wing flaps in the landing position;

(2) Landing gear extended;

(3) Maximum landing weight;

(4) The airplane trimmed at 1.3 V_{SR0} with—

(i) Power or thrust off, and

(ii) Power or thrust for level flight.

~~(5) The airplane trimmed at 1.3 V_{SR0} with power or thrust off.~~

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-7, 30 FR 13117, Oct. 15, 1965; Amdt. 25-108, 67 FR 70827, Nov. 26, 2002; Amdt. 25-115, 69 FR 40527, July 2, 2004]

§25.176 Static Longitudinal Stability- Alternate.

In each flight phase, the airplane must comply with 25.173 and 25.175 or 25.176(a) through (c):

a) Strong positive static longitudinal stability must be present which provides adequate cueing to the crew that the speed is above Vmo/Mmo or below the minimum speed for hands-free stabilized flight. Static longitudinal characteristics must be shown to be suitable based on the airplane handling qualities, including an evaluation of pilot workload and pilot compensation including the effects of atmospheric turbulence. These characteristics must be shown for appropriate combinations of configuration and thrust for climb, cruise, approach, landing and go-around.
   1) Release of the controller at speeds above Vmo/Mmo or below the minimum speed for hands-free stabilized flight, must produce a prompt recovery towards normal operating speeds without resulting in a hazardous condition.
   2) There must be no means by which a pilot can retrim the controller forces resulting from this stability.

b) Acceptable characteristics must include (b)(1) through (b)(4):
   1) Adequate control of speed and flight path without creating excessive pilot workload.
   2) Ability to acquire and maintain small changes in speed and altitude without exceptional attention on the part of the pilot.
   3) Acceptable envelope protection with regard to airspeed or Mach.
   4) Adequate cues to the pilot of significant speed excursions beyond the normal flight envelope.

c) The airplane must provide adequate alerting to the pilot, in accordance with 25.1322, of a low energy (low speed/low thrust/low height) state to alert the crew of unsafe operating conditions and to enable them to take appropriate corrective action.
   1) Low energy alerting must be active at appropriate altitudes and in appropriate configurations (e.g., at low altitude, in the approach and landing configurations).
   2) Low energy alerting must not be activated during normal operation, including conditions specified in 25.143(h), and operation in moderate turbulence.
   3) The pilot must not be able to cancel the low energy alert until the airplane has achieved a higher energy state.
   4) Evaluation of low energy alerting must ensure that low energy cues are not a nuisance in all take-off and landing altitude ranges for which certification is requested. These evaluations must include all relevant combinations of weight, center of gravity position, configuration, airbrakes position, and available thrust, including reduced and derated take-off thrust operations and engine failure cases. The evaluation must assess the level of energy alerting and the effects of energy management errors.

§25.177 Static lateral-directional stability.

(a) The static directional stability (as shown by the tendency to recover from a skid with the directional controls~~rudder~~ free) must be positive for any landing gear and flap position and symmetric power condition, at speeds from 1.13 V_{SR1}, up to V_{FE}, V_{LE}, or V_{FC}/M_{FC} (as appropriate for the airplane configuration).

(b) The static lateral stability (as shown by the tendency to raise the low wing in a sideslip with the lateral~~aileron~~ controls free) for any landing gear and flap position and symmetric power condition, may not be negative at any airspeed (except that speeds higher than V_{FE} need not be considered for flaps extended configurations nor speeds higher than V_{LE} for landing gear extended configurations) in the following airspeed ranges:

(1) From 1.13 V_{SR1} to V_{MO}/M_{MO}.

(2) From V_{MO}/M_{MO} to V_{FC}/M_{FC}, unless the divergence is—

(i) Gradual;

(ii) Easily recognizable by the pilot; and

(iii) Easily controllable by the pilot.

(c) The following requirement must be met for the configurations and speed specified in paragraph (a) of this section. In straight, steady sideslips over the range of sideslip angles appropriate to the operation of the airplane, the directional~~aileron and rudder~~ control movements and forces must be substantially proportional to the angle of sideslip in a stable sense. The~~This~~ factor of proportionality must lie between limits found necessary for safe operation. During these straight, steady sideslips, necessary lateral control movements and forces must not be in the unstable sense with the exception of speeds above Vmo/Mmo per 25.177(b)(2). The range of sideslip angles evaluated must include those sideslip angles resulting from the lesser of:

(1) One-half of the available directional (pedal)~~rudder~~ control input; and

(2) A directional (pedal)~~rudder~~ control force of 180 pounds.

(d) For sideslip angles greater than those prescribed by paragraph (c) of this section, up to the angle at which full directional (pedal)~~rudder~~ control is used or a directional (pedal)~~rudder~~ control force of 180 pounds is obtained, the directional~~rudder~~ control forces may not reverse, and increased directional control~~rudder~~ deflection must be needed for increased angles of sideslip. Compliance with this requirement must be shown using straight, steady sideslips. However, if~~, unless~~ full lateral control input is achieved before reaching either full directional~~rudder~~ control input or a directional~~rudder~~ control force of 180 pounds,~~;~~ a straight, steady sideslip need not be maintained~~ after achieving full lateral control input~~. This requirement must be met at all approved landing gear and flap positions for the range of operating speeds and power conditions appropriate to each landing gear and flap position with all engines operating.

[Amdt. 25-135, 76 FR 74654, Dec. 1, 2011]

§25.181 Dynamic stability.

(a) Any short period oscillation, not including combined lateral-directional oscillations, occurring between 1.13 V_{SR} and maximum allowable speed appropriate to the configuration of the airplane must be heavily damped with the primary controls—

(1) Free; and

(2) In a fixed position.

(b) Any combined lateral-directional oscillations ("Dutch roll") occurring between 1.13 V_{SR} and maximum allowable speed appropriate to the configuration of the airplane must be positively damped with controls free, and must be controllable with normal use of the primary controls without requiring exceptional pilot skill.

[Amdt. 25-42, 43 FR 2322, Jan. 16, 1978, as amended by Amdt. 25-72, 55 FR 29775, July 20, 1990; 55 FR 37607, Sept. 12, 1990; Amdt. 25-108, 67 FR 70827, Nov. 26, 2002]

STALLS

§25.201 Stall demonstration.

(a) Stalls must be shown in straight flight and in 30 degree banked turns with—

(1) Power off; and

(2) The power necessary to maintain level flight at 1.5 V_{SR1} (where V_{SR1} corresponds to the reference stall speed at maximum landing weight with flaps in the approach position and the landing gear retracted).

(b) In each condition required by paragraph (a) of this section, it must be possible to meet the applicable requirements of §25.203 with—

(1) Flaps, landing gear, and deceleration devices in any likely combination of positions approved for operation;

(2) Representative weights within the range for which certification is requested;

(3) The most adverse center of gravity for recovery; and

(4) The airplane trimmed for straight flight at the speed prescribed in §25.103(b)(6).

(c) The following procedures must be used to show compliance with §25.203;

(1) Starting at a speed sufficiently above the stalling speed to ensure that a steady rate of speed reduction can be established, apply the longitudinal control so that the speed reduction does not exceed one knot per second until the airplane is stalled.

(2) In addition, for turning flight stalls, apply the longitudinal control to achieve airspeed deceleration rates up to 3 knots per second.

(3) As soon as the airplane is stalled, recover by normal recovery techniques.

(d) The airplane is considered stalled when the behavior of the airplane gives the pilot a clear and distinctive indication of an acceptable nature that the airplane is stalled. Acceptable indications of a stall, occurring either individually or in combination, are—

(1) A nose-down pitch that cannot be readily arrested;

(2) Buffeting, of a magnitude and severity that is a strong and effective deterrent to further speed reduction; or

(3) The pitch control reaches the aft stop and no further increase in pitch attitude occurs when the control is held full aft for a short time before recovery is initiated.

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-84, 60 FR 30750, June 9, 1995; Amdt. 25-108, 67 FR 70827, Nov. 26, 2002]

§25.202 Handling demonstrations for high angle-of-attack limiting functions.

(a) Applicability: If a High Angle-of-Attack Limiting Function is installed that meets the capability and reliability requirements of paragraphs (a)(1) through (a)(5) of this section, compliance with the high angle-of-attack handling demonstrations defined by paragraphs (b) through (e) of this section and the high angle of attack characteristics requirements of Section 25.204 can be shown in lieu of compliance with Sections 25.201 and 25.203.

(1) The HALF must be provided for all configurations used for normal operation, in icing and non-icing conditions;

(2) It must not be possible to encounter a stall during the pilot induced maneuvers required by paragraphs (b)-(d) of this section in icing and non-icing conditions;

(3) The airplane must be protected against stalling and the operation of the High Angle-of-Attack Limiting Function must not adversely affect airplane control during expected levels of atmospheric disturbances, nor may it impede the application of recovery procedures in case of wind-shear;

(4) The High Angle-of-Attack Limiting Function must be provided in each abnormal configuration of the high lift devices following high lift system failures not shown to be improbable; and

(5) Failure of the High Angle-of-Attack Limiting Function must be improbable.

(b) Maneuvers to the limit of the longitudinal control, in the nose up sense, must be shown in straight flight and in 30° banked turns with:

(1) The High Angle-of-Attack Limiting Function operating normally and the automatic power or thrust increase system inhibited, if applicable;

(2) Initial power or thrust conditions of:

(i) Engines idling; and

(ii) Power or thrust necessary to maintain level flight at 1.5 V_{SR1} (where V_{SR1} corresponds to the reference stall speed at maximum landing weight with flaps in the approach position and the landing gear retracted in non-icing conditions).

(c) In each condition required by paragraph (b) of this section, it must be possible to meet the applicable requirements of §25.204(b)-(e) with –

(1) Flaps, landing gear and deceleration devices in any likely combination of positions approved for operation;

(2) Representative weights within the range for which certification is requested;

(3) The most adverse center of gravity; and

(4) The airplane trimmed for straight flight at the all-engine minimum normal operating speed appropriate for the configuration.

(d) The following procedures must be used to show compliance with §25.204(b)-(e) in icing and non-icing conditions:

(1) Starting at a speed such that the angle of attack is sufficiently below the AOA-limit to ensure that a steady rate of speed reduction can be established, apply the longitudinal control so that the speed reduction does not exceed one knot per second until the control reaches the aft stop.

(2) The longitudinal control must be maintained at the stop until the airplane has reached a stabilized flight condition. With the control at the aft stop it must be shown that the airplane presents a satisfactory level of lateral control.

(3) The airplane must be recovered by normal recovery techniques.

(4) The demonstrations of paragraphs (b) and (c) of this section must also be conducted with increased entry rates, up to the maximum practical entry rate in non-icing conditions, and up to 3 knots per second in icing conditions. For approach and landing configurations, rapid application of go-around power or thrust at any time following initiation of the maneuver to the time at which the longitudinal control reaches the aft stop must also be considered, if more critical.

(5) For flight in icing conditions before the ice protection system has been activated and is performing its intended function, the handling demonstration requirements identified in paragraphs (b) and (c) of this section, except with all automatic protection functions operating normally, at the more critical power (or thrust) setting of paragraph (b)(2) of this section, must be met with the ice accretion defined in Appendix C, part II(e) of this part in a steady deceleration up to 1 knot per second. The deceleration must be continued until the first of (i)-(iii) is reached:

(i) A suitable warning alert, in accordance with §25.1322, followed by normal recovery input delayed by 1 second;

(ii) A suitable caution alert, in accordance with §25.1322, combined with engagement of an automatic protection function that operates to deter further reduction in airspeed, followed by normal recovery input delayed by 3 seconds; or

(iii) The aft control stop, followed by normal recovery input delayed by 3 seconds.

If the time from entry into icing conditions until the ice protection system is activated and performing its intended function is not sufficiently brief, the requirements of paragraph (d)(1)-(4) are applicable in lieu of this paragraph.

(e) In addition to the requirements outlined by paragraphs (b) through (d) of this section, maneuvers with a deceleration of not more than 1 knot per second up to the greater of the angle of attack corresponding to V_{SR} obtained per § 25.103(a) (if determined) and that reached during maneuvers from § 25.202(d)(1)-(4) must be shown be shown to meet the characteristics requirements of § 25.204(f) in straight flight (non-icing and icing conditions) and in 30° banked turns (non-icing conditions only) with:

(1) The High Angle-of-Attack Limiting Function deactivated or adjusted, at the option of the applicant, to allow the airplane to achieve the angle of attack specified above;

(2) Automatic power or thrust increase system inhibited (if applicable);

(3) Engines idling;

(4) Flaps, landing gear and deceleration devices in any likely combination of positions approved for operation;

(5) The most adverse center of gravity; and

(6) The airplane trimmed for straight flight at the speed prescribed in § 25.202(c)(4).

§25.203 Stall characteristics.

(a) It must be possible to produce and to correct roll and yaw by unreversed use of the aileron and rudder controls, up to the time the airplane is stalled. No abnormal nose-up pitching may occur. The longitudinal control force must be positive up to and throughout the stall. In addition, it must be possible to promptly prevent stalling and to recover from a stall by normal use of the controls.

(b) For level wing stalls, the roll occurring between the stall and the completion of the recovery may not exceed approximately 20 degrees.

(c) For turning flight stalls, the action of the airplane after the stall may not be so violent or extreme as to make it difficult, with normal piloting skill, to effect a prompt recovery and to regain control of the airplane. The maximum bank angle that occurs during the recovery may not exceed—

(1) Approximately 60 degrees in the original direction of the turn, or 30 degrees in the opposite direction, for deceleration rates up to 1 knot per second; and

(2) Approximately 90 degrees in the original direction of the turn, or 60 degrees in the opposite direction, for deceleration rates in excess of 1 knot per second.

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-84, 60 FR 30750, June 9, 1995]

§25.204 Flight characteristics for high angle-of-attack limiting functions.

(a) Applicability: If a High Angle-of-Attack Limiting Function is installed and compliance is being shown to §25.202 in lieu of §25.201, the high angle-of-attack flight characteristics during the handling demonstrations required by §25.202 must meet the requirements of paragraphs (b) through (f) in lieu of §25.203.

(b) Throughout maneuvers with a deceleration of not more than 1 knot per second, both in straight flight and in 30° banked turns, and with the High Angle-of-Attack Limiting Function operating normally, the airplane's characteristics must be as follows:

(1) There must be no abnormal nose-up pitching;

(2) There must be no uncommanded nose-down pitching indicative of stall. Reasonable attitude changes associated with stabilizing the angle-of-attack at the AOA-limit as the longitudinal control reaches the stop are acceptable;

(3) There must be no uncommanded lateral or directional motion indicative of stall, and the airplane must exhibit good lateral and directional control by conventional use of the controls throughout the maneuver; and

(4) The airplane must not exhibit buffeting of a magnitude and severity that would act as a deterrent from completing the maneuvers.

(c) In maneuvers with increased rates of entry some degradation of characteristics is acceptable, associated with a transient excursion beyond the stabilized AOA-limit. However, the airplane must not exhibit hazardous characteristics or characteristics that would deter the pilot from holding the longitudinal control on the stop for a period of time appropriate to the maneuver.

(d) It must always be possible to reduce angle-of-attack by conventional use of the controls.

(e) The High Angle-of-Attack Limiting Function must not unduly damp airplane pitch rate capability preventing achievement of decelerations deemed necessary for normal operation and for showing compliance with §25.202.

(f) Throughout the maneuvers with the High Angle-of-Attack Limiting Function deactivated or adjusted for demonstration of §25.103(a)-(c) and §25.202(e) the following characteristics must be shown:

(1) The airplane must not exhibit hazardous characteristics;

(2) It must always be possible to reduce angle of attack by conventional use of the controls; and

(3) The airplane must exhibit good lateral and directional control by conventional use of the controls

§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 paragraphs (c) and (d) of this section. Except for the stall warning prescribed in paragraph (h)(3)(ii) of this section, the stall warning for flight in icing conditions must be provided by the same means as the stall warning for flight in non-icing conditions.

(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, 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 most critical of the takeoff ice and final takeoff ice accretions defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g), for each configuration used in the takeoff phase of flight;

(2) The most critical of the en route ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g), for the en route configuration;

(3) The most critical of the holding ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g), for the holding configuration(s);

(4) The most critical of the approach ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g), for the approach configuration(s); and

(5) The most critical of the landing ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g), 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}.

(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) The following stall warning margin is required for flight in icing conditions before the ice protection system has been activated and is performing its intended function. Compliance must be shown using the most critical of the ice accretion(s) defined in Appendix C, part II, paragraph (e) of this part and Appendix O, part II, paragraph (d) of this part, as applicable, in accordance with §25.21(g). 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:

(1) The speed is reduced at rates not exceeding one knot per second;

(2) The pilot performs the recovery maneuver in the same way as for flight in non-icing conditions; and

(3) The recovery maneuver is started no earlier than:

(i) One second after the onset of stall warning if stall warning is provided by the same means as for flight in non-icing conditions; or

(ii) Three seconds after the onset of stall warning if stall warning is provided by a different means than for flight in non-icing conditions.

(i) In showing compliance with paragraph (h) of this section, if stall warning is provided by a different means in icing conditions than for non-icing conditions, compliance with §25.203 must be shown using the accretion defined in appendix C, part II(e) of this part. Compliance with this requirement must be shown using the demonstration prescribed by §25.201, except that the deceleration rates of §25.201(c)(2) need not be demonstrated.

(j) If a High Angle-of-Attack Limiting Function is installed and compliance is shown with §§25.202 and 25.204, the stall warning requirements of paragraphs (a) through (i) are not required when the High Angle-of-Attack Limiting Function is operating normally. Following failures affecting the High Angle-of-Attack Limiting Function not shown to be extremely improbable, such that the capability of the function no longer satisfies §§25.202 and 25.204, stall warning must be provided that meets the requirements of § 25.207(a) and (g), and the requirements of § 25.207(b) except that the speed margins of the required stall warning must be as prescribed in (1) and (2) below. In addition,

(1) In non-icing conditions, stall warning must provide sufficient margin to prevent encountering unacceptable characteristics or encountering stall in the following conditions:

(i) In engines idling straight deceleration not exceeding one knot per second to a speed 5 knots or 5 percent CAS, whichever is greater, below the warning onset; and

(ii) In engines idling turning flight deceleration at entry rates up to 3 knots per second when recovery is initiated not less than one second after the warning onset.

(2) In the icing conditions identified in paragraphs (e)(3)-(5) of this section, stall warning must provide sufficient margin to prevent encountering unacceptable characteristics and encountering stall, in engines idling straight and turning flight decelerations not exceeding one knot per second, when the pilot starts a recovery maneuver not less than three seconds after the onset of stall warning.

(3) Once initiated, stall warning must continue until the angle of attack is reduced to approximately that at which stall warning began.

(4) For paragraphs (1) and (2) above, indications of a stall encounter include uncommanded nose-down pitching that cannot be readily arrested or buffeting of a magnitude and severity that would act as a deterrent to further speed reduction. An airplane exhibits unacceptable characteristics during straight or turning flight decelerations if it is not always possible to produce and to correct roll and yaw by conventional use of lateral and directional controls, or if abnormal nose-up pitching occurs.

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-7, 30 FR 13118, Oct. 15, 1965; Amdt. 25-42, 43 FR 2322, Jan. 16, 1978; Amdt. 25-108, 67 FR 70827, Nov. 26, 2002; Amdt. 25-121, 72 FR 44668, Aug. 8, 2007; Amdt. 25-129, 74 FR 38339, Aug. 3, 2009; Amdt. 25-140, 79 FR 65526, Nov. 4, 2014]

MISCELLANEOUS FLIGHT REQUIREMENTS

§25.255 Out-of-trim characteristics.

(a) From an initial condition with the airplane trimmed at cruise speeds up to $V_{MO}/M_{MO,}$ the airplane must have satisfactory maneuvering stability and controllability with the degree of out-of-trim in both the airplane nose-up and nose-down directions, consistent with the design and normal operational characteristics of the longitudinal trim function, including ~~which results from the greater of~~—

(1) For airplanes with a longitudinal trim function where the pilot directly adjusts the longitudinal trim surface position or otherwise affects the longitudinal trim state, a three-second application of the trim function~~(1) A three-second movement of the longitudinal trim system~~ at its normal rate for the particular flight condition with no aerodynamic load (or an equivalent degree of trim for airplanes that do not have a power-operated trim system), except as limited by stops in the trim system, including those required by §25.655(b) for adjustable stabilizers,~~;~~ or as limited by other design features in the system;

(2) The maximum mistrim that can be sustained by the autopilot while maintaining level flight in the high speed cruising condition; and~~.~~

(3) For airplanes with a longitudinal trim function where the pilot does not directly adjust the longitudinal trim surface position and the trim surface is controlled by an automatic function, the maximum mistrim must include any position that the longitudinal trim surface could achieve during expected atmospheric disturbances and normal maneuvering while in high speed cruising conditions.

(b) In the out-of-trim condition specified in paragraph (a) of this section, when the normal acceleration is varied from +1 g to the positive and negative values specified in paragraph (c) of this section—

(1) The stick force vs. g curve must have a positive slope at any speed up to and including V_{FC}/M_{FC}; and

(2) At speeds between V_{FC}/M_{FC} and any achievable speed (under normal flight control system operation) up to V_{DF}/M_{DF} the direction of the primary longitudinal control force may not reverse.

(c) Except as provided in paragraphs (d) and (e) of this section, compliance with the provisions of paragraph (a) of this section must be demonstrated in flight over the acceleration range—

(1) −1 g to +2.5 g; or

(2) 0 g to 2.0 g, and extrapolating by an acceptable method to −1 g and +2.5 g~~.~~

(d) If the procedure set forth in paragraph (c)(2) of this section is used to demonstrate compliance and marginal conditions exist during flight test with regard to reversal of primary longitudinal control force, flight tests must be accomplished from the normal acceleration at which a marginal condition is found to exist to the applicable limit specified in paragraph (c~~b~~)(1) of this section.

(e) During flight tests required by paragraph (a) of this section, the limit maneuvering load factors prescribed in §§25.333(b) and 25.337, and the maneuvering load factors associated with probable inadvertent excursions beyond the boundaries of the buffet onset envelopes determined under §25.251(e), need not be exceeded. The demonstrations may also be restricted to limits permitted by flight control system characteristics or other system features, including envelope protections, if failure of those features is not more probable than remote. In addition, the entry speeds for flight test demonstrations at normal acceleration values less than 1 g must be limited to the extent necessary to accomplish a recovery, without exceeding V_{DF}/M_{DF}.

(f) In the out-of-trim condition specified in paragraph (a) of this section, it must be possible from an overspeed condition at V_{DF}/M_{DF} to produce at least 1.5 g for recovery by applying not more than 125 pounds of longitudinal control force for a control wheel or 50 pounds for a side stick, using either the primary longitudinal control system alone or the primary longitudinal control and the longitudinal trim system. If the longitudinal trim system is used to assist in producing the required load factor, it must be shown at V_{DF}/M_{DF}, that the longitudinal trim surface can be actuated in the airplane nose-up direction with the primary surface loaded to correspond to the least of the following airplane nose-up control forces:

(1) The maximum control forces expected in service as specified in §§25.301 and 25.397.

(2) The control input~~force~~ required to produce 1.5 g with elevator deflection alone, or as limited by elevator control system characteristics.~~.~~

(3) The control input~~force~~ corresponding to buffeting or other phenomena of such intensity that it is a strong deterrent to further application of primary longitudinal control force.

[Amdt. 25-42, 43 FR 2322, Jan. 16, 1978]

§25.1323 Airspeed indicating system.

~~(~~d) From 1.23 VSR to the speed at which stall warning begins or the airspeed achieved at full aft control input if compliance is shown with §§ 25.202 & 25.204, the IAS must change perceptibly with CAS and in the same sense, and at speeds below this range~~stall warning speed~~ the IAS must not change in an incorrect sense.

Appendix C to Part 25

Part II—Airframe Ice Accretions for Showing Compliance With Subpart B.

(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), 25.202(d)(5), ~~and~~ 25.207(h), and 25.207(i).

[Doc. No. 4080, 29 FR 17955, Dec. 18, 1964, as amended by Amdt. 25-121, 72 FR 44669, Aug. 8, 2007; 72 FR 50467, Aug. 31, 2007; Amdt. 25-129, 74 FR 38340, Aug. 3, 2009; Amdt.25-140, 79 FR 65528, Nov. 4, 2014]

Attachment C Proposed Guidance Material

Colors for AC 25-7C changes
Topic 1 Envelope Protection
Topic 2 Adaptation for Flight in Icing
Topic 6 Stability
Topic 7 Side Sticks
Topic 10 Runway Excursion Hazard
Topic 11 Stall IGE
Topic 12 Steep Approach
Topic 13 Out of Trim
Topic 14 Tailwind-Crosswind

U.S. Department
of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Flight Test Guide For Certification Of Transport Category Airplanes

Date: 10/16/12
Initiated By: ANM-110

AC No: 25-7C

This advisory circular (AC) provides guidance for the flight test evaluation of transport category airplanes. This AC includes flight test methods and procedures to show compliance with the regulations contained in subpart B of Title 14, Code of Federal Regulations (14 CFR) part 25, which address airplane performance and handling characteristics. This revision, AC 25-7C, is a complete revision to reduce the number of differences from the European Aviation Safety Agency's Flight Test Guide, provide acceptable means of compliance for the regulatory changes associated with amendments 107, 109, 113, 115, 119, and 123 to part 25, respond to National Transportation Safety Board recommendations, and to provide a general update to reflect current FAA and industry practices and policies.

John Piccola
Acting Manager, Transport Airplane Directorate
Aircraft Certification Service

Chapter 2 - Flight

Section 1. General

3. Proof of Compliance - § 25.21.

a. Explanation. In an effort to provide the necessary guidelines for the flight test evaluation of transport category airplanes, without producing a cumbersome document, this AC assumes a conventional transport airplane configuration. In general, a conventional airplane configuration is one with distinct wing and fuselage elements that are joined together, aft-mounted horizontal and vertical stabilizers that are attached to the fuselage, and propulsion provided either by turbojet/turbofan engines that do not provide any significant increase in lift due to their operation or engine-driven propellers. The effects of non-conventional airplane configurations (e.g., blown flaps) on the compliance methods should be evaluated and determined based on the intent of the guidelines presented for conventional airplane configurations.

(1) Section 25.21(a) - Proof of Compliance.

(2) Section 25.21(c) - Proof of Compliance (Altitude Effect on Flight Characteristics).

(3) Section 25.21(d) - Proof of Compliance (Flight Test Tolerances).

(4) Section 25.21(f) - Proof of Compliance (Wind Measurement and Corrections).

(7) Airplane Airspeed Variation Due to Wind Profile Variation Combined With Speed Changes Due to Airplane Dynamic Performance.

(8) Expansion of Takeoff and Landing Data for a Range of Airport Elevations.

(9) Tailwind Takeoff and Landing.

(a) Tailwind~~Wind~~ Velocities of 10 Knots or Less - Approval may be given for performance, controllability, and engine operating characteristics for operations in reported tailwind velocities up to 10 knots without conducting additional flight tests at specific wind speeds.

(b) Tailwind~~Wind~~ Velocities Greater than 10 Knots, up to 15 knots.

1 Performance. It is considered that takeoff, rejected takeoff, and landing distances, measured in tailwind conditions greater than 10 knots, are unreliable for use in determining airplane performance. Wind conditions of such magnitude are generally not sufficiently consistent over the length of the runway or over the time period required to perform the test maneuver. The 150 percent operational tailwind factor, required by §§ 25.105(d)(1) and 25.125(f), provides a satisfactory level of safety for operation in tailwinds up to 15 knots when using AFM data based on flight tests in nominally calm wind conditions.

> **NOTE:** The design requirements of § 25.479 (Level landing conditions) also require the effects of increased contact speeds to be investigated if approval for landings with tailwinds greater than 10 knots is desired.

2 Control Characteristics. The test tailwind velocity for demonstrating handling qualities should be equal to the proposed limit tailwind increasedfactored by 5 knots150 percent. The intent of the 5 knot increase150 percent factor is to provide adequate margin for wind variability in operations, including currency of the wind data, averaging of the data by the measuring and reporting method, and the highly variable nature of higher wind conditions. Therefore, the test wind condition 5 knots higher thanof 150 percent of the proposed tailwind limit should be an averaged or smoothed wind speed, not a peak wind speed. (Refer to Section 7. 30. e. (c) 7 - Guidance to § 25.237 for explanation on averaged crosswind speed, to be adapted to tailwind.) Airplane control characteristics should be evaluated under the following conditions with the c.g. at the aft limit and the test mean tailwind velocity equal to the proposed limit tailwind increasedfactored by 5 knots150 percent:

(aa) Takeoff. Both all-engines-operating and one-engine-inoperative (i.e., with a simulated failure of the critical engine at the engine failure speed, V_{EF}) takeoffs should be evaluated at a light weight with maximum approved takeoff flap deflection.

(bb) Landing. Approach and landing at light weight with maximum approved landing flap deflection.

(cc) Determination of the increased ground speed effect on gear vibration or shimmy, and flight director, or autopilot instrument landing system (ILS) approaches, terrain awareness warning system (TAWS) sink rate modes, etc.

(dd) It should be demonstrated that deviations above the glideslope are recoverable. In particular, it should be demonstrated that the approach speed can be maintained, in tailwind conditions, on a glide path that is 1° steeper than a typical 3° glideslope. This can be shown by analysis. Whatever method is used for the glideslope recovery demonstration, the actual tailwind (i.e. without correction to 10 meters height) need not be higher than the proposed tailwind limit increased by 5 knots.

(dd) If engine idle power or thrust is increased to account for the increased tailwind velocity, ensure that deviations above the glideslope are recoverable.

3 Weight Limits. Consistent with the requirements of §§ 25.105(d)(1) and 25.125(f), the maximum takeoff and maximum quick turnaround weights should be determined using brake energies and tire speeds, as appropriate, calculated with the limit tailwind velocity factored by 150 percent.

4 Engine Operating Characteristics. Satisfactory engine operation should be demonstrated at the limit tailwind velocity increasedfactored by 5 knots150 percent. The demonstrations should include:

(aa) Zero groundspeed operation.

(bb) Takeoff power or thrust setting procedure used for AFM performance (typically completed by approximately 80 knots), both manually and automatically (autothrottle).

(cc) Reverse thrust operations.

5 Airplane Flight Manual. The AFM should contain a statement that the limitation for tailwinds greater than 10 knots reflects the capability of the airplane as evaluated in terms of airworthiness but does not constitute approval for operation in tailwinds exceeding 10 knots.

b. Procedures.

(1) The performance-related flight test procedures are discussed in each of the following paragraphs of this AC:

10. Takeoff and Takeoff Speeds
11. Accelerate-Stop Distance
12. Takeoff Path
13. Takeoff Distance and Takeoff Run
14. Takeoff Flight Path
15. Climb: General
16. Landing Climb
17. Climb: One Engine Inoperative
18. En Route Flight Path
19. Landing

(2) Performance Data for Multiple Flap or Additional Flap Positions. If approval of performance data is requested for flap settings at which no test data are available, the data may be obtained from interpolation of flight data obtained at no less than four flap settings that are within a constant configuration of other lift devices. If the span of flap settings is small and previously obtained data provide sufficient confidence (i.e., the shape of the curves are known and lend themselves to accurate interpolation), data from three flap settings may be acceptable.

(3) Flight Characteristics for Abnormal Configurations (Ref. § 25.671(c)).

(a) For purposes of this AC, an abnormal configuration is an operational configuration that results from any single failure or any combination of failures not shown to be improbable.

(b) Flight characteristics for abnormal configurations may be determined by test or analysis to assure that the airplane is capable of continued safe flight and landing. Flight tests, if required, should be conducted at the critical conditions of altitude, weight, c.g., and engine power or thrust associated with the configuration, and at the most critical airspeed between the speed reached one second after stall warning occurs (see paragraph 29e(2)(h) of this AC) and the maximum operating airspeed for the configuration.

4. Load Distribution Limits - § 25.23. [Reserved]

5. Weight Limits and Center of Gravity Limits - §§ 25.25 and 25.27. [Reserved]

6. Empty Weight and Corresponding Center of Gravity - § 25.29. [Reserved]

7. Removable Ballast - § 25.31.

a. Explanation. None.

b. Procedures. Ballast may be carried during the flight tests whenever it is necessary to achieve a specific weight and c.g. location. Consideration should be given to the vertical as well as horizontal location of the ballast in cases where it may have an appreciable effect on the flying qualities of the airplane. The strength of the supporting structures should be considered in order to make sure they do not fail as a result of the anticipated loads that may be imposed during the particular tests. As required by § 21.35(a), applicants must show that these structures comply with the applicable structural requirements of part 25 before conducting flight tests with these structures in place.

Section 2. Performance

10. Takeoff and Takeoff Speeds - §§ 25.105 and 25.107.

a. Explanation. Section 25.105 specifies the conditions that must be considered in determining the takeoff speeds, accelerate-stop distances, takeoff path, takeoff distance, and takeoff run in accordance with part 25 requirements. The primary objective of the takeoff tests required by § 25.107 is to determine the takeoff speeds for all takeoff configurations at all weight, altitude, and temperature conditions within the operational limits selected by the applicant.

(1) Background Information.

This information is not related to means of compliance for §§ 25.105 and 25.107, but is included to increase awareness of the risks associated with in-ground-effect stall during execution of the required flight testing. The information is based upon previous industry experience and recommended best practices, much of which resulted from investigations following a flight test accident during takeoff performance testing. It is recommended that the following considerations be included in the applicant's flight test hazard assessment in preparation for the takeoff performance flight testing.

(a) Ground Effect Considerations. It is important to understand the aerodynamic characteristics of the airplane in ground effect to avoid an inadvertent stall while operating at high angles of attack in close proximity to the ground. Ground effect is the phenomenon that modifies a body's aerodynamic characteristics when it is generating lift close to the ground. The proximity of the ground suppresses downwash and wing tip vortices and can also cause a blockage of flow between the airplane and the ground, causing a slowing of the airstream under the wing, producing a positive pressure or buoyancy field. The impact of ground effect is largely dependent on the height of the wing above the ground and the magnitude of the resultant pressure field that exists between the underside of the wing and the ground plane. When the distance between the wing and ground is small (typically 5-10% of wing span), the pressure field and extent of upwash/downwash suppression is large. When a significant blockage effect is experienced, the excess flow that cannot pass under the wing traverses the wing upper surface causing increased suction on the wing leading edge and increased lift at low angles of attack; this effect growing with larger and more powerful trailing edge flaps and their proximity to ground at liftoff attitude. The increased leading edge suction tends to steepen the adverse pressure gradient behind the suction peak that can promote early aerodynamic flow separation, especially if the wing is already characterized by a leading edge stall. It is especially important to note that when this effect is large, it will not only reduce the stall angle-of-attack but it can also consequently decrease the maximum lift of the airplane in ground effect below the value observed in free air. Also important to understand is the effect that Mach number has on the stall angle-of-attack in the range expected for takeoff. Experience has shown that reductions in stall angle-of-attack with increasing Mach number observed in free air conditions can also be considered applicable in ground effect.

Due to remaining uncertainties in the in-ground-effect stall angle-of-attack, the test pilots involved in the takeoff testing should be familiar with the free air stall characteristics of the airplane, any predicted changes in the stall characteristics in ground-effect, and have established stall recovery techniques in the event that a stall is encountered, including allowance for stall angle-of-attack hysteresis to re-attach the airflow in the recovery.

(b) Ground Effect Estimation Methods: Industry experience has shown that a reduction in stall angle-of-attack in ground effect relative to free air of 4-5 degrees for takeoff flap deflections is a reasonable estimate in the absence of more configuration-specific data, though due to configuration differences there is no assurance that this estimate will be conservative in all cases. Wind tunnel results obtained at lower Reynolds numbers than full-scale flight should be used with extreme caution when predicting ground effects. While the "linear range" effects of such sub-scale testing can be accurate, the impact of ground effect on stall may not be captured at low Reynolds numbers. Computational Fluid Dynamics (CFD) results have been shown to produce useful indications of in-ground-effect stall, but the undertaking of predicting stall angles with CFD is in general, not trivial. Before using wind-tunnel or CFD predicted in-ground-effect stall angles, comparisons should be made with results from free air stall flight testing in order to understand and/or improve the accuracy of the predictions. Caution should be exercised to ensure that conservative margins are identified for flight test use.

b. Procedures.

(1) Section 25.105(c)(1) requires the takeoff performance data to be determined for smooth, dry and wet, hard-surfaced runways. Paragraph 11 of this AC describes methods for determining the accelerate-stop distances required by § 25.109. Paragraph 13 describes methods for determining the takeoff distance and takeoff run required by § 25.113.

(2) In accordance with § 25.101(f), testing for determining the accelerate-stop distances, takeoff flight paths, and takeoff distances should be accomplished using procedures established by the applicant for operation in service. In accordance with §25.101(h), these procedures must be able to be consistently executed in service by crews of average skill, use methods or devices that are safe and reliable, and include allowances for any time delays in the execution of the procedures that may reasonably be expected in service. These requirements prohibit the use of exceptional piloting techniques, such as higher control force inputs or higher pitch rates than would occur in operational service, from being used to generate unrealistic takeoff distances. The intent of these requirements is to establish takeoff performance representative of that which can reasonably be expected to be achieved in operational service.

(3) Attention should be paid to all potential sources of airspeed error, but special consideration should be given to airplanes with electronic instruments in the cockpit that apply electronic filtering to the airspeed data. This filtering, which causes a time delay in the airspeed

indication, can be a source of significant systematic error in the presentation of airspeed to the flightcrew. With normal takeoff acceleration, the airplane will be at a higher speed than is indicated by the cockpit instrument, which can result in longer distances than are presented in the AFM, particularly in the event of a rejected takeoff near the indicated V_1 speed. The effects of any time delays caused by electronic filtering, pneumatic system lag, or other sources should be adequately addressed in the AFM speed and distance presentations. Further explanation of airspeed lag, particularly pertaining to airplanes with electronic instruments in the cockpit, and procedures for calibrating the airspeed indicating system (§ 25.1323(b)) are presented in paragraph 177 of this AC.

(4) Section 25.107(a)(1) - Engine Failure Speed (V_{EF}). The engine failure speed (V_{EF}) is defined as the calibrated airspeed at which the critical engine is assumed to fail and must be selected by the applicant. V_{EF} cannot be less than the ground minimum control speed (V_{MCG}).

(5) Section 25.107(a)(2) - V_1. V_1 may not be less than V_{EF} plus the speed gained with the critical engine inoperative during the time interval between V_{EF} and the instant at which the pilot takes action after recognizing the engine failure. This is indicated by pilot application of the first deceleration means such as brakes, throttles, spoilers, etc. during accelerate-stop tests. The applicant may choose the sequence of events. Refer to paragraph 11 of this AC, addressing § 25.109, for a more complete description of rejected takeoff (RTO) transition procedures and associated time delays.

(6) Section 25.107(b) - Minimum Takeoff Safety Speed (V_{2MIN}).

(a) V_{2MIN}, in terms of calibrated airspeed, cannot be less than:

1 1.1 times the V_{MC} defined in § 25.149.

2 1.13 times V_{SR} for two-engine and three-engine turbopropeller and reciprocating engine-powered airplanes and for all turbojet airplanes that do not have provisions for obtaining a significant reduction in the one-engine inoperative power-on stalling speed (i.e., boundary layer control, blown flaps, etc.). The value of V_{SR} to be used in determining V_{2MIN} is the free air reference stall speed in the applicable takeoff configuration, landing gear retracted, except for those airplanes with a fixed landing gear or for gear-down dispatch.

(b) V_{2MIN} may be reduced to 1.08 times V_{SR} for turbopropeller and reciprocating engine-powered airplanes with more than three engines, and turbojet powered airplanes with adequate provisions for obtaining significant power-on reference stall speed reduction through the use of such things as boundary layer control, blown flaps, etc.

(c) For propeller-driven airplanes, the difference between the two margins, based upon the number of engines installed on the airplane, is because the application of power ordinarily reduces the stalling speed appreciably. In the case of the two-engine propeller-driven airplane, at least half of this reduction is eliminated by the failure of an engine. The difference in the required factors therefore provides approximately the same margin over the actual stalling speed under the power-on conditions that are obtained after the loss of an engine, no matter what the number of engines (in excess of one) may be. Unlike the propeller-driven airplane, the turbojet/turbofan powered airplane does not show any appreciable difference between the power-on and power-off stalling speed. This is due to the absence of the propeller, which ordinarily induces a slipstream with the application of power causing the wing to retain its lift to a speed lower than the power-off stalling speed. The applicant's selection of the two speeds specified will influence the nature of the testing required in establishing the takeoff flight path.

(7) Section 25.107(c) - Takeoff Safety Speed (V_2). V_2 is the calibrated airspeed that is attained at or before the airplane reaches a height of 35 ft. above the takeoff surface after an engine failure at V_{EF} using an established rotation speed (V_R). From the liftoff point, the takeoff surface extends to the end of the takeoff distance continuing at the same slope as the runway. During the takeoff speeds demonstration, V_2 should be continued to an altitude sufficient to assure stable conditions beyond the 35 ft height. V_2 cannot be less than V_{2MIN}. In addition, V_2 cannot be less than the liftoff speed, V_{LOF}, which is defined in § 25.107(f). In accordance with § 25.107(c), V_2 in terms of calibrated airspeed may not be less than V_R plus the speed increment attained before reaching a height of 35 feet above the takeoff surface using a takeoff maneuver that can be executed consistently by crews of average skill per the requirement of § 25.101(h)(1) and a speed that provides the maneuvering capability specified in § 25.143(h). Due to the constraints on V_R and V_{LOF} specified in § 25.107(e), and also accounting for other constraints required for safe operation such as maintaining adequate margin to the in-ground-effect stall angle-of-attack during a dynamic takeoff maneuver, V_2 may be forced to be greater than V_{2MIN} for some, if not all, of the thrust/weight range of operation.~~and a speed that provides the maneuvering capability specified in § 25.143(h).and a speed that provides the maneuvering capability specified in § 25.143(h).~~ In addition, § 25.111(c)(2) stipulates that the airplane must reach V_2 before it is 35 feet above the takeoff surface and continue at a speed *not less than* V_2 until it is 400 feet above the takeoff surface. These requirements were first expressed in Special Civil Air Regulation No. SR-422, Turbine-Powered Transport Category Airplanes of Current Design (SR-422A), paragraphs 4T.114(b)(4) and (c)(3) and 4T.116(e). The concern that the regulation change was addressing was the overshoot of V_2 after liftoff under the previous requirement that the airplane attain V_2 on, or near, the ground. The intent of the current requirement is to allow an acceleration to V_2 after liftoff but not to allow a decrease in the field length required to attain a height of 35 feet above the takeoff surface by attaining a speed greater than V_2, under low drag ground conditions, and using the excess kinetic energy to attain the 35 foot height.

(a) In the case of turbojet powered airplanes, when most of the one-engine-inoperative data have been collected using throttle chops, V_2, and its relationship to V_R, should be substantiated by at least a limited number of fuel cuts at V_{EF}. For derivative programs not involving a modification that would affect thrust decay characteristics, demonstrations of fuel cuts may be unnecessary.

(b) For propeller-driven airplanes, the use of fuel cuts can be more important in order to ensure that the takeoff speeds and distances are obtained with the critical engine's propeller attaining the position it would during a sudden engine failure. The number of tests that should be conducted using fuel cuts depends on the correlation obtained with the throttle chop data and substantiation that the data analysis methodology adequately models the effects of a sudden engine failure.

(8) Section 25.107(d) - Minimum Unstick Speed (V_{MU}).

(a) Section 25.107(d) states, "V_{MU} speeds must be selected by the applicant." An applicant can either determine the lowest possible V_{MU} speeds or select a higher speed that supports the takeoff performance targets of the airplane. Regardless of how the applicant selects the V_{MU} speeds, compliance must be shown with § 25.107(d), (e)(1)(iv), (e)(3), and (e)(4) to show that the selected V_{MU} speeds allow the airplane to safely lift off the ground and continue the takeoff.

(b) An applicant should comply with § 25.107(d) by conducting minimum unstick speed (V_{MU}) tests with all engines operating and also with one engine inoperative. During these tests, the takeoff should be continued until the airplane is out of ground effect. The airplane pitch attitude should not be decreased after liftoff.

(c) V_{MU} testing to demonstrate the lowest V_{MU} speed is a maximum performance flight test maneuver, and liftoff may occur very near the angle-of-attack for maximum lift coefficient in ground effect with the minimum margin to in-ground-effect stall occurring in the vicinity of liftoff. As discussed in paragraph 10.a.(1) of this AC, to ensure flight test safety, a thorough understanding of the stall angle-of-attack in ground effect and appropriate angle-of-attack margins should be established and maintained during testing (see Figure 10-1).~~.~~ Also, even though pitch attitude may be held fairly constant during the maneuver, environmental conditions and transiting through ground effect may result in changes in angle-of-attack. It is permissible to lift off at a speed that is below the normal stall warning speed, provided no more than light buffet is encountered. The use of a flight test device that restricts the on-ground pitch attitude has been found useful by some manufactures in reducing the risk of over-rotation and in-ground-effect stall.

1 It is important for the flight test team to understand the control laws and any transitions between control laws during takeoff (e.g., based on weight on wheels) for an electronic flight control system that may present unique hazards that should be taken into account.

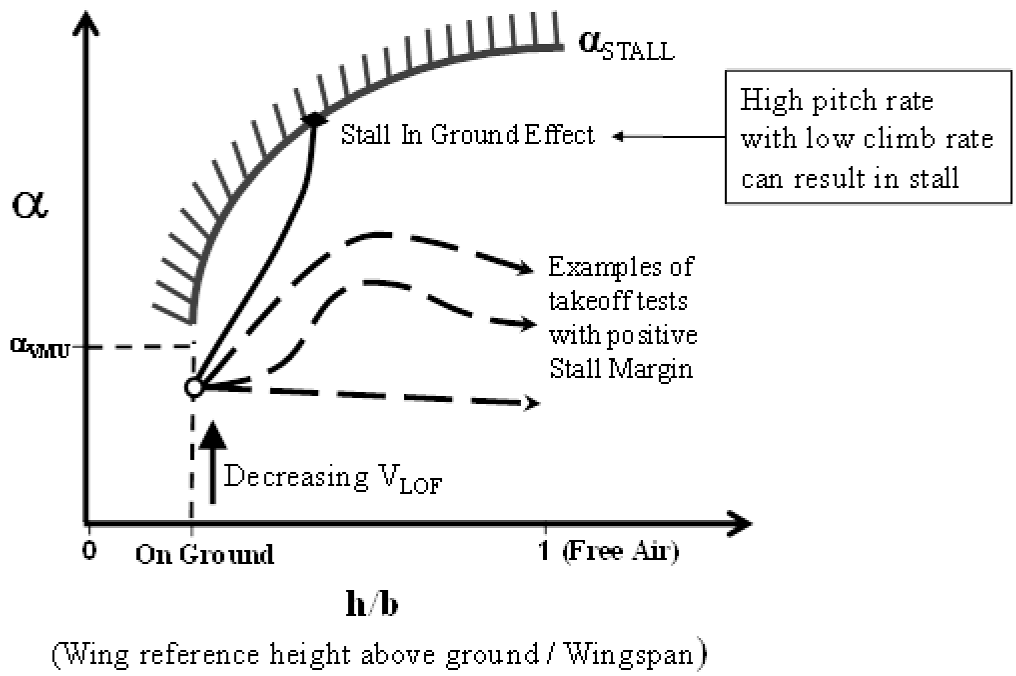
2 An artificial stall warning system (e.g., a stick shaker) may be disabled or adjusted to a more suitable value during V_{MU} testing~~during V_{MU} testing, although doing so will require extreme caution and depend upon a thorough knowledge of the airplane's stall characteristics, both in and out of ground effect~~.

3 If the airplane is equipped with a stick pusher, high angle-of-attack limiting function~~limiter~~, or other system that may affect the conduct of the test, the angle of attack setting for activation of the system may be selected by the applicant and differ from the nominal setting. The system may alternatively be disabled or its activation delayed for test purposes until a safe altitude is reached. However, for airplanes equipped with a stick pusher that is not designed to be inhibited during takeoff, the V_{MU} test demonstrations will need to be

assessed and will only remain valid if the stick pusher would not have activated with the angle-of-attack indication means set at the lowest angle within production tolerances.

4 Note that due to changes to an airplane's aerodynamic stall angle due to ground effect, a stall warning system, stick pusher, or high angle-of-attack limiting function that is not specifically designed to account for ground effect may not activate prior to aerodynamic stall during a V_{MU} test. The airplane's stall angle-of-attack and angle-of-attack sensor corrections, both in and out of ground effect, must be thoroughly understood by the test crew to determine if these systems will provide the benefit of protecting the airplane during V_{MU} testing.

Figure 10-1. In-Ground-Effect Stall Margin



(d) In lieu of conducting one-engine-inoperative V_{MU} tests, the applicant may conduct all-engines-operating V_{MU} tests if all pertinent factors that would be associated with an actual one-engine-inoperative V_{MU} test are simulated or otherwise taken into account. To take into account all pertinent factors, it may be necessary to adjust the resulting V_{MU} test values analytically. The factors to be accounted for should include at least the following:

1 Thrust/weight ratio for the one-engine-inoperative range.

2 Controllability (may be related to one-engine-inoperative free air tests, such as V_{MCA}).

3 Increased drag due to use of lateral/directional control systems.

4 Reduced lift due to use of devices such as wing spoilers for lateral control.

5 Adverse effects of use of any other systems or devices on control, drag, or lift.

(e) The number of V_{MU} tests needed may be minimized by testing only the critical all-engines-operating and one-engine-inoperative thrust/weight ratios, provided the V_{MU} speeds determined at these critical conditions are used for the range of thrust/weights appropriate to the all-engines-operating and one-engine-inoperative configurations. The critical thrust/weight is established by correcting, to the V_{MU} speed, the thrust that results in the airplane achieving its limiting one-engine-inoperative climb gradient at the normally scheduled speed and in the appropriate configuration.

(f) Amendment 25-42, effective March 1, 1978, revised §§ 25.107(d) and 25.107(e)(1)(iv) in order to permit the one-engine-inoperative V_{MU} to be determined by all-engines-operating tests at the thrust/weight ratio corresponding to the one-engine-inoperative condition. As revised, § 25.107(d) specifies that V_{MU} must be selected for the range of thrust/weight ratios to be certificated, rather than for the all-engines-operating and one-engine-inoperative conditions as was previously required. In determining the all-engines-operating thrust/weight ratio that corresponds to the one-engine-inoperative condition, consider trim and control drag differences between the two configurations in addition to the effect of the number of engines operating. The minimum thrust/weight ratio to be certificated is established by correcting, to the V_{MU} speed, the thrust that results in the airplane achieving its limiting engine-out climb gradient in the appropriate configuration and at the normally scheduled speed.

(g) To conduct the V_{MU} tests, rotate the airplane as necessary to achieve the V_{MU} attitude. It is acceptable to use some additional nose-up trim over the normal trim setting during V_{MU} demonstrations. Even on airplanes that have sufficient control authority to achieve the target V_{MU} attitude prior to liftoff, use of additional nose-up trim can be beneficial to the conduct of the test by giving the pilot additional time to stabilize on the V_{MU} attitude prior to lifting off. If additional nose-up trim is ~~required~~ used, the additional considerations of paragraph (~~g~~h), below, apply. V_{MU} is the speed at which the weight of the airplane is completely supported by aerodynamic lift and thrust forces. Some judgment may be necessary on airplanes that have tilting main landing gear bogies. Determining the liftoff point from gear loads and wheel speeds has been found acceptable in past programs. After liftoff, the airplane should be flown out of ground effect. During liftoff and the subsequent climbout, the airplane should be fully controllable.

(h) V_{MU} Testing for Airplanes Having Limited Pitch Control Authority.

1 For some airplanes with limited pitch control authority, it may not be possible, at forward c.g. and normal trim, to rotate the airplane to a liftoff attitude where the airplane could otherwise perform a clean flyaway at a minimum speed had the required attitude been achieved. This may occur only over a portion of the takeoff weight range in some configurations. Though generally associated with the inability of the pitch control surfaces to provide adequate pitching moment to rotate the airplane to the desired pitch attitude at low thrust/weight ratio conditions, the same phenomenon may occur at high thrust/weight ratio conditions for airplanes with high thrust lines (e.g., aft engines mounted high on the fuselage).

When limited pitch control authority is clearly shown to be the case, V_{MU} test conditions may be modified to allow testing aft of the forward c.g. limit and/or with use of more airplane nose-up trim than normal. The V_{MU} data determined with this procedure should be corrected to those values representative of the appropriate forward limit; the variation of V_{MU} with c.g. may be assumed to be like the variation of free air stalling speed with c.g. Although the development of scheduled takeoff speeds may proceed from these corrected V_{MU} data, additional tests are required (see paragraph 2 below) to check that the relaxed V_{MU} criteria have not neglected problems that might arise from operational variations in rotating airplanes with limited pitch control authority.

2 In the following assurance test, the airplane should demonstrate safe flyaway characteristics.

(aa) Minimum speed liftoff should be demonstrated at the critical forward c.g. limit with normal trim. For airplanes with a cutback forward c.g. at heavy weight, two weight/c.g. conditions should be considered. The heavy weight tests should be conducted at maximum structural or maximum sea level climb-limited weight with the associated forward c.g. The full forward c.g. tests should be conducted at the highest associated weight. Alternatively, testing may be conducted at a single weight if an analysis is provided that identifies the critical weight/c.g. combination with regard to limited pitch attitude capability for liftoff.

(bb) These assurance tests should be conducted at the thrust/weight ratio that is most critical for attaining a pitch attitude that will provide a minimum liftoff speed.

(i) For airplanes that are limited by low thrust/weight conditions, tests should be conducted at the minimum thrust/weight ratio for both the simulated one-engine-inoperative test (i.e., symmetrical reduced thrust) case and the all-engines-operating case.

(ii) For airplanes that are limited by high thrust/weight conditions, tests should be conducted at the highest thrust/weight ratio within the airplane's operating envelope for both the simulated one-engine-inoperative case (i.e., symmetrical reduced thrust) and the all-engines-operating case.

(cc) One acceptable test technique is to hold full nose-up control column as the airplane accelerates. As pitch attitude is achieved to establish the minimum liftoff speed, pitch control may be adjusted to prevent over-rotation, but the liftoff attitude should be maintained as the airplane flies off the ground and out of ground effect.

(dd) The resulting liftoff speeds are acceptable if the test proves successful and the liftoff speed is at least 5 knots below the normally scheduled liftoff speed.

(ee) This minimum 5 knot margin from the scheduled liftoff speed provides some leeway for operational variations such as mis-trim, c.g. errors, etc., that could further limit the elevator authority. The reduced V_{MU} margins arising from this test, relative to those specified in § 25.107(e)(1)(iv), are considered acceptable because of the reduced probability of a pitch control authority-limited airplane getting into a high drag condition due to over-rotation.

(i) V_{MU} Testing for Geometry Limited Airplanes.

1 For airplanes that are geometry limited (i.e., the minimum possible V_{MU} speeds are limited by tail contact with the runway), § 25.107(e)(1)(iv)(B) allows the V_{MU} to V_{LOF} speed margins to be reduced to 108 percent and 104 percent for the all-engines-operating and one-engine-inoperative conditions, respectively. The V_{MU} demonstrated should be sound and repeatable. As discussed in paragraph 10.a.(1) of this AC, to ensure flight test safety, a thorough understanding of the stall angle-of-attack in ground effect and appropriate angle-of-attack margins should be established and maintained during testing.

2 An airplane that is deemed to be geometry limited at the conditions tested is expected to be geometry limited over its entire takeoff operating envelope. If this is not the case, the airplane is not considered geometry limited and the reduced V_{MU} to V_{LOF} speed margins do not apply. Also, if a flight-test device is used with the intent to artificially restrict the rotation attitude (typically more than 0.5 degrees below the production configuration) to prevent over-rotation, and the airplane would not otherwise be geometry limited, this airplane would not be considered geometry limited and the reduced V_{MU} to V_{LOF} speed margins do not apply.

3 One acceptable means for demonstrating compliance with §§ 25.107(d) and 25.107(e)(1)(iv) with respect to the capability for a safe liftoff and fly-away from the geometry limited condition is to show that at the lowest thrust-to-weight ratio for the all-engines-operating condition:

(aa) In the speed range from 96 to 100 percent of the actual liftoff speed), the aft under-surface of the airplane should be in contact with the runway. Because of the dynamic nature of the test, it is recognized that contact will probably not be maintained during this entire speed range, so some judgment is necessary. It has been found acceptable for contact to exist approximately 50 percent of the time that the airplane is in this speed range.

(bb) Beyond the point of liftoff to a height of 35 feet, the airplane's pitch attitude should not decrease below that at the point of liftoff, nor should the speed increase more than 10 percent.

(cc) The horizontal distance from the start of the takeoff to a height of 35 feet above the takeoff surface should not be greater than 105 percent of the distance determined in accordance with § 25.113(a)(2) without applying the 115 percent factor.

(j) V_{MU} for a Stretched Version of a Tested Airplane.

1 V_{MU} speeds obtained by flight testing one model of an airplane type may be used to generate V_{MU} speeds for a geometry-limited stretched version of that airplane. If the short body airplane met the criteria for the 104/108 percent V_{MU}/V_{LOF} speed margin for geometry limited airplanes as permitted by § 25.107(e)(1)(iv)(B) and discussed in paragraph 10b(8)(i)1,

the flight tests described in paragraph 10b(8)(i)3 should be performed on the stretched derivative. Otherwise, the flight tests described in paragraph 10b(8)(j)2(bb) should be performed on the stretched derivative.

2 Since the concern for tail strikes is increased with the stretched airplane, the following should be accomplished, in addition to normal takeoff tests, when the V_{MU} schedule of the stretched derivative is derived from that of the shorter body parent airplane:

(aa) The minimum unstick speed (V_{MU}) of the stretched derivative airplane should be determined by correcting the V_{MU} of the shorter body tested airplane for the reduced runway pitch attitude capability and revised c.g. range of the stretched airplane. Alternatively, stretched airplane V_{MU} speeds not determined in this manner should be substantiated by flight testing or a rational analysis. Scheduled rotation speeds (V_R) for the stretched airplane should result in at least the required liftoff speed margins above the corrected V_{MU} required by § 25.107(e)(1)(iv) for the one-engine-inoperative and all-engines-operating takeoff conditions.

(bb) At both the forward and aft c.g. limits, and over the thrust-to-weight range for each takeoff flap, the following takeoff tests should be accomplished. The tests described in paragraphs (i) and (ii), below, should be accomplished with not more than occasional, minor (i.e., non-damaging) tail strikes. As discussed in paragraph 10.a.(1) of this AC, to ensure flight test safety, a thorough understanding of the stall angle-of-attack in ground effect and appropriate angle-of-attack margins should be established and maintained during testing.

(i) All-engines-operating, early rotation tests specified in paragraph 10b(9)(c)2, including both the rapid rotations and over-rotations as separate test conditions.

(ii) One-engine-inoperative, early rotation tests specified in paragraph 10b(9)(b).

(iii) All-engines-operating, moderate rotation rate (i.e., more rapid than normal) takeoff tests, using the scheduled V_R and normal pitch attitude after liftoff. Tail strikes should not occur for this condition.

(9) Section 25.107(e) - Rotation Speed (V_R).

(a) The rotation speed, (V_R) in terms of calibrated airspeed, must be selected by the applicant. V_R has a number of constraints that must be observed in order to comply with § 25.107(e):

1 V_R may not be less than V_1; however, it can be equal to V_1 in some cases.

2 V_R may not be less than 105 percent of the air minimum control speed (V_{MCA}).

3 V_R must be a speed that will allow the airplane to reach V_2 at or before reaching a height of 35 ft. above the takeoff surface, when the takeoff is conducted using normal takeoff procedures.

4 V_R must be a speed that will result in liftoff at a speed not less than 110 percent of V_{MU} (unless geometry limited) for the all-engines-operating condition and not less than 105 percent of the V_{MU} (unless geometry limited) determined at the thrust/weight ratio corresponding to the one-engine-inoperative condition for each set of conditions such as weight, altitude, temperature, and configuration when the airplane is rotated at its maximum practicable rate. For this requirement, maximum practicable rate depends on the airplane configuration, type of pitch controller, flight control system design and the takeoff procedure. The rotation rate need not be increased beyond the point that prevents capturing the normal takeoff rotation attitude without using exceptional piloting skill or strength. Rotation rates between 120% and 150% of the nominal rate used in determination of the takeoff performance in accordance with §§ 25.105, 25.111 and 25.113 have previously been found acceptable. Alternatively, this rotation rate can be determined analytically as a representatively high rotation rate from a significant sampling of takeoffs performed during the flight test program, including the takeoff field performance tests.

5 V_R may not be less than the speed necessary to demonstrate the one-engine inoperative and all-engines-operating in-service variation tests (early rotation, over-rotation, out-of-trim) from the requirements of § 25.107(e)(3) and (4) without encountering unsafe characteristics. As discussed in paragraph 10.a.(1) of this AC, to ensure flight test safety, a thorough understanding of the stall angle-of-attack in ground effect and appropriate angle-of-attack margins should be established and maintained during testing. It should be noted that ensuring successful demonstrations for these in-service variation criteria may in some cases require increasing V_R (and thus V_2) to a higher speed than what would otherwise be required by § 25.107(e)(1).

(b) Early rotation, one-engine-inoperative test.

1 In showing compliance with § 25.107(e)(3), some guidance relative to the airspeed attained at the 35 ft. height during the associated flight test is necessary. As this requirement only specifies an early rotation (V_R-5 knots), it is interpreted that pilot technique is to remain the same as normally used for a one-engine-inoperative condition. With these considerations in mind, it is apparent that the airspeed achieved at the 35 ft. point can be somewhat below the normal scheduled V_2 speed. However, the amount of permissible V_2 speed reduction should be limited to a reasonable amount as described below.

2 These test criteria apply to all unapproved, new, basic model airplanes. They also apply to previously approved airplanes when subsequent testing is warranted. However, for those airplanes where these criteria are more stringent than those previously applied, consideration will be given to permitting some latitude in the test criteria.

3 In conducting the flight tests required by § 25.107(e)(3), the test pilot should use the normal/natural rotation technique associated with the use of scheduled takeoff speeds for the airplane being tested. Intentional tail or tail skid contact is not considered

acceptable. Non-damaging contact due to inadvertent over-rotation is acceptable provided there is a prompt recovery to the normal one-engine-inoperative takeoff pitch attitude. Further, the airspeed attained at the 35 ft. height during this test should not be less than the scheduled V_2 value minus 5 knots. These speed limits should not be considered or used as target V_2 test speeds, but rather are intended to provide an acceptable range of speed departure below the scheduled V_2 value. To ensure flight test safety, the maximum angle-of-attack as a function of height above ground expected for this maneuver should be confirmed to either fall below those previously demonstrated by V_{MU} tests or provide conservative margin to predicted in-ground-effect stall angle-of-attack as a function of height above ground (see Figure 10-1). (Note: Experience has shown that the lowest margin to in-ground-effect stall angle-of-attack occurs in the vicinity liftoff.)

4 In this test, the simulated engine failure should be accomplished sufficiently in advance of the V_R test speed to allow for engine spin-down, unless this would be below the V_{MCG}, in which case V_{MCG} should govern. The normal one-engine-inoperative takeoff distance may be analytically adjusted to compensate for the effect of the early power or thrust reduction. Further, in those tests where the airspeed achieved at the 35-ft. height is slightly less than the V_2-5 knots limiting value, it will be permissible, in lieu of conducting the tests again, to analytically adjust the test distance to account for the excessive speed decrement.

(c) All-engines-operating tests.

1 Section 25.107(e)(4) states that there must not be a “marked increase” in the scheduled takeoff distance when reasonably expected service variations such as early and excessive rotation and out-of-trim conditions are encountered. This has been interpreted as requiring takeoff tests with all engines operating with:

(aa) A lower than scheduled rotation speed, and

(bb) Out-of-trim conditions, but with rotation at the scheduled V_R speed.

NOTE: The expression “marked increase” in the takeoff distance is considered to be any amount in excess of 1 percent of the scheduled takeoff distance. Thus, the tests should not result in field lengths more than 101 percent of the takeoff field lengths calculated in accordance with the applicable requirements of part 25 for presentation in the AFM.

2 For the early rotation condition with all engines operating, and at a weight as near as practicable to the maximum sea level standard day takeoff weight limit, it should be shown by tests that when the airplane is rotated at a speed below the scheduled V_R, no “marked increase” in the scheduled AFM field length will result. For these tests, the airplane should be rotated at a speed equal to the scheduled V_R minus 7 percent or the scheduled V_R minus 10 knots, whichever results in the higher rotation speed. Tests should be conducted at: (1) a rapid rotation rate to the normal takeoff attitude, and, as a separate test, (2) an over-rotation of 2 degrees above normal attitude after liftoff at the normal rotation rate. For this requirement, the rapid rotation rate achievable at V_R-10 kt (or -7%) depends on the airplane configuration, type of

pitch controller, flight control system design and the normal takeoff procedure. The rotation rate need not be increased beyond the point that prevents capturing the normal takeoff rotation attitude without using exceptional piloting skill or strength. For tests using over rotations, the resulting increased pitch attitude should be maintained until the airplane is out of ground effect. Tail strikes during this demonstration are acceptable if they are minor and do not result in unsafe conditions. The maximum angle-of-attack as a function of height above ground expected for both of these maneuvers should be confirmed to either fall below those previously demonstrated by V_{MU} tests or provide conservative margin to the predicted in-ground-effect stall angle-of-attack as a function of height above ground (see Figure 10-1). (Note: Experience has shown that the lowest margin to in-ground-effect stall angle-of-attack occurs in the vicinity of liftoff.)

3 For reasonably expected out-of-trim conditions with all engines operating and as near as practicable to the maximum weight allowed under sea level standard day conditions, it should be shown that there will not be a "marked increase" in the scheduled AFM takeoff distance when rotation is initiated in a normal manner at the scheduled V_R speed. The amount of mistrim should be the maximum mistrim that would not result in a takeoff configuration warning, including taking into account the takeoff configuration warning system rigging tolerance. It is permissible to accept an analysis in lieu of actual testing if the analysis shows that the out-of-trim condition would not present unsafe flight characteristics or a "marked increase" in the scheduled AFM field lengths.

4 Section 25.107(e)(4) also states that the reasonably expected variations in service from the established takeoff procedures for the operation of the airplane may not result in unsafe flight characteristics. For example, for an airplane loaded to obtain a forward c.g. position and mistrimmed for an aft c.g. loading, it may not be possible to rotate at the normal operating speeds due to excessive control force or lack of primary pitch control authority. This may result in an excessive delay in accomplishing the rotation. Such a condition would be considered an unsafe flight characteristic. Similarly, for an airplane loaded to obtain an aft c.g. position and mistrimmed for a forward c.g. loading, it may not be possible to readily arrest a self-rotating tendency. This rotation, if abrupt enough and rapid enough, could lead to stall. Qualitative assessments should be made by the test pilot in the following takeoff tests with all engines operating:

(aa) The test pilot should determine that no unsafe characteristics exist with the airplane loaded to the forward c.g. limit and the stabilizer mistrimmed in the airplane nose-down direction. The amount of mistrim should be the maximum mistrim that would not result in a configuration warning (including taking into account takeoff warning system tolerances). Rotation should be initiated at the scheduled rotation speed for the airplane weight and ambient conditions. Unsafe characteristics include an excessive pitch control force to obtain normal airplane response or an excessive time to achieve perceptible rotation.

(bb) The test pilot should determine that no unsafe characteristics exist with the airplane loaded to the aft c.g. limit and the stabilizer mistrimmed in the airplane nose-up direction. The amount of mistrim should be the maximum mistrim that would not result in a configuration warning (including taking into account takeoff warning system tolerances). The airplane should be rotated at the scheduled rotation speed for the airplane weight and ambient conditions. Unsafe characteristics include: an abrupt self rotating tendency that cannot be checked with normal control input, or an excessive pitch control force required to maintain the airplane in the normal pitch attitude prior to the scheduled rotation speed or during rotation and initial climb.

(cc) For the tests described in paragraphs (aa) and (bb) above, the flight characteristics should be assessed at the most critical combinations of airplane weight, wing flap position and engine power or thrust for the out of trim position being considered.

(d) Stall Warning During Takeoff Speed Tests. The presumption is that if an operational pilot was to make an error in takeoff speeds that resulted in an encounter with stall warning, the likely response would be to recover aggressively to a safe flight condition rather than trying to duplicate the AFM takeoff flight path. Therefore, the activation of any stall warning devices, or the occurrence of airframe buffeting during takeoff speed testing, is unacceptable.

(e) Stick Forces During Takeoff Speed Tests. Per § 25.143(a)(1) and (b), stick forces to initiate rotation and continue the takeoff during takeoff flight testing must comply with the control force limits of § 25.143(d). This includes the mistrim takeoff tests described in paragraphs 10b(9)(c)4(aa) and (bb) to show compliance with § 25.107 (e)(4), which are considered to represent probable operating conditions under § 25.143(b). Stick forces should be those that result from using the takeoff procedures established by the manufacturer for use in operational service in accordance with § 25.101(f) and must comply with § 25.101(h).

Section 3. Controllability and Maneuverability

20. General - § 25.143. and § 25.144.

a. Explanation. The purpose of § 25.143 is to verify that any operational maneuvers conducted within the operational envelope can be accomplished smoothly with average piloting skill and without encountering a stall warning or other characteristics that might interfere with normal maneuvering, or without exceeding any airplane structural limits. Control forces should not be so high that the pilot cannot safely maneuver the airplane. Also, the forces should not be so light that it would take exceptional skill to maneuver the airplane without over-stressing it or losing control. The airplane response to any control input should be predictable to the pilot and pitch and roll control force sensitivity and displacement sensitivity must be compatible, so that normal inputs on one control axis will not cause significant unintentional inputs on the other. Many modern aircraft employ Envelope Protection Functions to limit excursions of one or more measured flight parameters. § 25.144 provides general regulations for such functions. The purpose of § 25.144 is to ensure that Envelope Protection Functions support safe operation and do not interfere with required maneuvering in normal and emergency operations and in forseeable atmospheric conditions.

(1) The maximum forces given in the table in § 25.143(d) for pitch and roll control for short term application are applicable to maneuvers in which the control force is only needed for a short period. For conventional control wheels, whereWhere the maneuver is such that the pilot will need to use one hand to operate other controls (such as during the landing flare or a go-around, or during changes of configuration or power/thrust resulting in a change of control force that needs to be trimmed out) the single-handed maximum control forces will be applicable. In other cases (such as takeoff rotation, or maneuvering during en route flight), the two-handed maximum forces will apply.

The maximum short term and long term forces in the table in § 25.143(d) are based upon conventional control wheel and side stick installations (with adjustable arm/elbow rest), where their location relative to the pilot Design Eye Point (DEP) and range of motion are consistent with the standard design practice for flight deck ergonomics that accommodate the full pilot population range specified by § 25.777(c). Where non-conventional control wheel or side stick installations or other controller types (e.g., center-sticks) are used, the short and long term forces in the § 25.143(d) table and the maximum and minimum control forces specified in Subpart B and this AC may not be appropriate.

(2) Short-term and long-term forces should be interpreted as follows:

(a) Short-term forces are the initial stabilized control forces that result from maintaining the intended flight path following configuration changes and normal transitions from one flight condition to another, or from regaining control following a failure. It is assumed that the pilot will take immediate action to reduce or eliminate such forces by re-trimming or changing configuration or flight conditions, and consequently short-term forces are not considered to exist for any significant duration. They do not include transient force peaks that may occur during the configuration change, change of flight conditions, or recovery of control following a failure.

(b) Long-term forces are those control forces that result from normal or failure conditions that cannot readily be trimmed out or eliminated.

(3) In conducting the controllability and maneuverability tests to show compliance with § 25.143 at speeds between V_{MO}/M_{MO} and V_{FC}/M_{FC}, the airplane should be trimmed at V_{MO}/M_{MO}.

(4) Modern wing designs can exhibit a significant reduction in maximum lift capability with increasing Mach number. The magnitude of this Mach number effect depends on the design characteristics of the particular wing. For wing designs with a large Mach number effect, the maximum bank angle that can be achieved while retaining an acceptable stall margin can be significantly reduced. Because the effect of Mach number can be significant, and because it can also vary greatly for different wing designs, the multiplying factors applied to V_{SR} may be insufficient to ensure that adequate maneuvering capability exists at the minimum operating speeds. To address this issue, § 25.143(h) was added by Amendment 25-108 to require a minimum bank angle capability in a coordinated turn without encountering stall warning or any other characteristic (including the envelope protection features of fly-by-wire flight control systems or automatic power or thrust increases) that might interfere with normal maneuvering. The maneuvering requirements consist of the minimum bank angle capability the FAA deems adequate for the specified regimes of flight combined with additional bank angle capability to provide a safety margin for various operational factors. These operational factors include both potential environmental conditions (e.g., turbulence, wind gusts) and an allowance for piloting imprecision (e.g., inadvertent overshoots). The FAA considers the automatic application of power or thrust by an envelope protection feature to be a feature that might interfere with normal maneuvering because it will result in a speed increase and flight path deviation, as well as potentially increasing crew workload due to the unexpected power or thrust increase.

b. General Test Requirements.

(1) Compliance with § 25.143 (a) through (g) and (k) is primarily a qualitative determination by the pilot during the course of the flight test program. The control forces required and airplane response should be evaluated during changes from one flight condition to another and during maneuvering flight. The forces required should be appropriate to the flight condition being evaluated. For example, during an approach for landing, the forces should be light and the airplane responsive in order that adjustments in the flight path can be accomplished with a minimum of workload. In cruise flight, the combination of control forces~~, and~~ airplane response and any envelope protection functions that are included should be such that inadvertent control input does not result in exceeding limits or in undesirable maneuvers. Longitudinal control forces should be evaluated during accelerated flight to ensure a positive stick force with increasing normal acceleration. If a load factor limiting envelope protection function that prevents exceedance of design limits is not installed, pitch control forces~~Forces~~ should be heavy

enough at the limit load factor to prevent inadvertent excursions beyond the design limit. Sudden engine failures should be investigated during any flight condition or in any configuration considered critical, if not covered by another section of part 25. Control forces considered excessive should be measured to verify compliance with the maximum control force limits specified in § 25.143(d). Allowance should be made for delays in the initiation of recovery action appropriate to the situation.

(2) Since § 25.143(h) involves a target speed, bank angle, and maximum value of thrust/power setting, not all flight test conditions to demonstrate compliance will necessarily result in a constant-altitude, thrust-limited turn. In cases with positive excess power or thrust, a climbing condition at the target bank and speed is acceptable. Alternately, if desired, the power or thrust may be reduced to less than the maximum allowed, so that compliance is shown with a completely stabilized, constant-altitude turn. With the airplane stabilized in a coordinated turn, holding power or thrust and speed, increase bank angle at constant airspeed until compliance is shown. For cases with negative excess power or thrust (e.g., the landing configuration case), a constant-altitude slow-down maneuver at the target bank angle has been shown to be a suitable technique. With the airplane descending at V_{REF} in wings-level flight on a three degree glide path, trim and throttle position are noted. The airplane is then accelerated to V_{REF} + 10 to 20 knots in level flight. The original trim and throttle conditions are reset as the airplane is rolled into a constant-altitude slow-down turn at the target bank angle. Throttles can be manipulated between idle and the marked position to vary slow-down rate as desired. Compliance is shown when the airplane decelerates through V_{REF} in the turn without encountering a stall warning or other characteristic that might interfere with normal maneuvering.

(3) If stall warning is provided by an artificial stall warning system, the effect of production tolerances on the stall warning system should be considered when evaluating compliance with the maneuvering capability requirements of § 25.143(h). See paragraph 29f(2)(f) of this AC for more information.

c. Controllability Following Engine Failure. Section 25.143(b)(1) requires the airplane to be controllable following the sudden failure of the critical engine. To show compliance with this requirement, the demonstrations described in paragraphs (1) and (2), below, should be made with engine failure (simulated by fuel cuts) occurring during straight, wings level flight. To allow for likely in-service delays in initiating recovery action, no action should be taken to recover control for two seconds following pilot recognition of engine failure. The recovery action should not necessitate movement of the engine, propeller, or trim controls, and should not result in excessive control forces. Additionally, the airplane will be considered to have reached an unacceptable attitude if the bank angle exceeds 45 degrees during the recovery. These tests may be conducted using throttle slams to idle, with actual fuel cuts repeated only for those tests found to be critical.

(1) At each takeoff flap setting at the initial all-engine climb speed (e.g., V_2 + 10 knots) with:

(a) All engines operating at maximum takeoff power or thrust prior to failure of the critical engine;

(b) All propeller controls (if applicable) in the takeoff position;

(c) The landing gear retracted; and

(d) The airplane trimmed at the prescribed initial flight condition.

(2) With the wing flaps retracted at a speed of 1.23 V_{SR} with:

(a) All engines operating at maximum continuous power or thrust prior to failure of the critical engine;

(b) All propeller controls in the en route position;

(c) The landing gear retracted; and

(d) The airplane trimmed at the prescribed initial flight condition.

d. Pilot Induced Oscillations (PIO).

(1) Explanation.

(a) Section 25.143(a) and (b) require that the airplane be safely controllable and maneuverable without exceptional piloting skill and without danger of exceeding the airplane limiting load factor under any probable operating conditions. In addition, Section 25.143(k) requires that unsuitable pilot-in-the-loop control characteristics not be encountered during precision path control tasks, including while in expected levels of turbulence. Service history events have indicated that modern transport category airplanes can be susceptible to airplane-pilot coupling under certain operating conditions and would not meet the intent of this requirement.

(b) The classic PIO is considered to occur when an airplane's response is approximately 180 degrees out of phase with the pilot's control input. However, PIO events with 180 degrees phase relationships are not the only conditions in which the airplane may exhibit closed-loop (pilot-in-the-loop) characteristics that are unacceptable for operation within the normal, operational, or limit flight envelopes. Others include unpredictability of the airplane's response to the pilot's control input. This may be due to nonlinearities in the control system, actuator rate or position limiting not sensed by the pilot through the flight controls, or changing pitch response at high altitude as the airplane maneuvers into and out of Mach buffet. Artificial trim and feel systems which produce controllers with too small a displacement and light force gradients may also lead to severe over control. This is especially true in a dynamic environment of high altitude turbulence or upsets in which the autopilot disconnects. This places the airplane in the hands of the unsuspecting pilot in conditions of only a small g or airspeed margin to buffet onset and with very low aerodynamic damping. These characteristics, while not a classic 180° out of phase PIO per se, may be hazardous and should be considered under the more general description of airplane-pilot coupling tendencies

(c) Some of the PIO tendency characteristics described in paragraph (b) above are attributes of transport airplanes (e.g., low frequency short period, large response lags) that are recognized by part 25. Limits are placed on some of these individual attributes by part 25 (e.g., stick force per g, heavily damped short period) to assure satisfactory open-loop characteristics. However, service reports from recent years have indicated that certain operating envelope conditions, combined with triggering events, can result in airplane-pilot coupling incidents. Some of the conditions that have led to these PIOs include fuel management systems that permit extended operations with a c.g. at or near the aft limit, operating at weight/speed/altitude conditions that result in reduced margins to buffet onset combined with tracking tasks such as not exceeding speed limitations and severe buffet due to load factor following an upset, and control surface rate or position limiting.

(d) This service experience has shown that compliance with only the quantitative, open-loop (pilot-out-of-the loop) requirements does not guarantee that the required levels of flying qualities are achieved. Therefore, in order to ensure that the airplane has achieved the flying qualities required by § 25.143(a), (b) and (k~~b~~), the airplane should be evaluated by test pilots conducting high-gain (wide-bandwidth), closed-loop tasks to determine that the potential of encountering adverse PIO tendencies is minimal.

(e) For the most part, these tasks should be performed in actual flight. However, for conditions that are considered too dangerous to attempt in actual flight (i.e., certain flight conditions outside of the operational flight envelope, flight in severe atmospheric disturbances, flight with certain failure states, etc.), the closed loop evaluation tasks may be performed using a motion base high fidelity simulator if it can be validated for the flight conditions of interest.

(2) Special Considerations.

(a) The certification team should understand the flight control system and airplane design.

(b) The applicant should explain why the design is not conducive to a PIO problem and how this is to be shown in both developmental and certification flight tests.

(c) The applicant should explain what has been done during the development flight test experience and any design changes that were required for PIO problems.

(d) The certification flight test program should be tailored to the specific airplane design and to evaluate the airplane in conditions that were found to be critical during its development program and PIO analytical assessment.

(e) The FAA flight test pilots should also continuously evaluate the airplane for PIO tendencies during the certification program in both the airplane and simulator. This evaluation should include both normal and malfunction states; all certification flight test points; transitions between and recoveries from these flight test points; and normal, crosswind, and offset landing task evaluations.

(f) Since the evaluation of flying qualities under § 25.143(a) and (b) is basically qualitative, especially evaluations of PIO susceptibility, the high-gain tasks discussed herein should be accomplished by at least three test pilots. Use of other pilots can provide additional insights into the airplane handling qualities, but for the purpose of demonstrating compliance with this requirement the evaluation pilots should be trained test pilots.

(3) Procedures (Flight Test).

(a) Evaluation of the actual task performance achieved, e.g., flight technical error, is not recommended as a measure of proof of compliance. Only the pilot's rating of the PIO characteristics is needed as described in paragraph 20d(6). The tasks are used only to increase the pilot's gain, which is a prerequisite for exposing PIO tendencies. Although task performance is not used as proof of compliance, task performance should be recorded and analyzed to insure that all pilots seem to be attempting to achieve the same level of performance.

(b) Tasks for a specific certification project should be based on operational situations, flight testing maneuvers, or service difficulties that have produced PIO events. Task requirements for a specific project will be dictated by the particular airplane and its specific areas of interest as determined by the tailored flight test program mentioned above. Some of these include high altitude upset maneuvers, encounters with turbulence at high altitude in which the autopilot disconnects, crosswind/crossed control landings with and without one engine inoperative, and offset landings to simulate the operational case in which the airplane breaks out of instrument meteorological conditions (IMC) offset from the glideslope and/or localizer beam and the pilot makes a rapid alignment correction. Tests should be conducted at or near the critical altitude/weight/c.g. combinations.

(c) Tasks described here may be useful in any given evaluation and have proven to be operationally significant in the past. It is not intended that these are the only tasks that may be used or may be required depending on the scope and focus of the individual evaluation being conducted. Other tasks may be developed and used as appropriate. For example, some manufacturers have used formation tracking tasks successfully in the investigation of these tendencies. For all selected tasks, a build-up approach should be used and all end points should be approached with caution. Capture tasks and fine tracking tasks share many common characteristics but serve to highlight different aspects of any PIO problem areas that may exist. In some cases, depending on individual airplane characteristics, it may be prudent to look at capture tasks first and then proceed to fine tracking tasks or combined gross acquisition (capture) and fine tracking tasks as appropriate.

(4) Capture Tasks.

(a) Capture tasks are intended to evaluate handling qualities for gross acquisition as opposed to continuous tracking. A wide variety of captures can be done provided the necessary cues are available to the pilot. Pitch attitude, bank angle, heading, flight path angle, angle-of-attack, and g captures can be done to evaluate different aspects of the airplane response. These capture tasks can give the pilot a general impression of the handling qualities of the airplane, but because they do not involve closed-loop fine tracking, they do not expose all of the problems that may arise in fine tracking tasks. Capture tasks should not be used as the only evaluation tasks.

(b) For pitch captures, the airplane is trimmed for a specified flight condition. The pilot aggressively captures 5 degrees pitch attitude (or 10 degrees if the airplane is already trimmed above 5 degrees). The pilot then makes a series of aggressive pitch captures of 5 degree increments in both directions, and then continues this procedure with ten degree increments in both directions. An airplane with more capability can continue the procedure with larger pitch excursions. If possible, the initial conditions for each maneuver should be such that the airplane will remain within ± 1,000 feet and ± 10 knots of the specified flight condition during the maneuver; however, large angle captures at high-speed conditions will inevitably produce larger speed and altitude changes. If the airplane should get too far from the specified condition during a task, it should be re-trimmed for the specified condition before starting the next maneuver.

(c) The other kinds of captures are usually done in a similar manner, with some minor differences. G captures can be done from a constant-g turn or pull ups and pushovers using ± 0.2 g and ± 0.5 g. Heading captures can be used to evaluate the yaw controller alone (usually small heading changes of 5 degrees or less).

(d) Bank angle captures are also commonly done using bank-to-bank rolls. Starting from a 15 degree bank angle, the pilot aggressively rolls and captures the opposite 15 degree bank angle (total bank angle change of 30 degrees). The pilot then rolls back and captures 15 degrees bank in the original direction. This procedure should continue for a few cycles. The procedure is then repeated using 30 degree bank angles, and then repeated again using 45 degree bank angles. A variation of this is to capture wings-level from the initial bank condition.

(e) Where suitable, combined conditions could be used as described in the task shown in paragraph (f), below, in which a target g and bank angle are tightly tracked until the target pitch attitude and heading are captured.

(f) The following upset and/or collision avoidance maneuvers have been found to be effective in evaluating PIO susceptibility when the airplane is flying at high altitude under conditions of low g to buffet onset, typically 0.3g. This emphasis on cruise susceptibility stems from operational experiences, but should not be interpreted as placing less emphasis on other flight phases.

<u>1</u> Trim for level flight at long range cruise Mach number. Initiate a slight climb and slow the aircraft while leaving power/thrust set. Push the nose over and set up a descending turn with 30 to 40 degrees of bank and approximately 10 degrees nose below the horizon, or as appropriate, to accelerate to the initial trim speed. At the initial trim airspeed initiate a 1.5 g to 1.67 g (not to exceed deterrent buffet) pull up and establish a turn in the opposite direction to a heading which will intercept the initial course on which the airplane was trimmed. Establish a pitch attitude which will provide a stabilized climb back to the initial trim altitude. The pilot may use the throttles as desired during this maneuver and should pick a target

g, bank angle, heading, and pitch attitude to be used prior to starting the maneuver. The target g and bank angle should be set and tightly tracked until the target pitch attitude and heading are obtained respectively. The stabilized steady heading climb should be tightly tracked for an adequate amount of time to allow the pilot to assess handling qualities, even through the initial trim altitude and course if required. The pilot should qualitatively evaluate the airplane during both the gross acquisition and fine tracking portions of this task while looking for any tendency towards PIO in accordance with the criteria in paragraph 20d(6).

2 This maneuver should be repeated in the nose-down direction by accelerating to M_{MO} from the trim condition 10 degrees nose down and then recover as above.

3 Trim for level flight as above. Initiate a 1.5 g to 1.67 g (not to exceed deterrent buffet) pull-up and approximately a 30 degree bank turn. Once the target g is set, transition the aircraft to approximately a 0.5 g pushover and reverse the turn to establish an intercept heading to the initial course. Using power or thrust as required, set up a stabilized steady heading descent to intercept the initial course and altitude used for the trimmed condition. The pilot may continue the heading and descent through the initial conditions to allow more tracking time if needed. Attempt to precisely set and track bank angle, g, heading, and pitch attitude as appropriate. The pilot should qualitatively evaluate the airplane during both the gross acquisition and fine tracking portions of this task while looking for a PIO tendency in accordance with paragraph 20d(6).

(5) Fine Tracking Tasks.

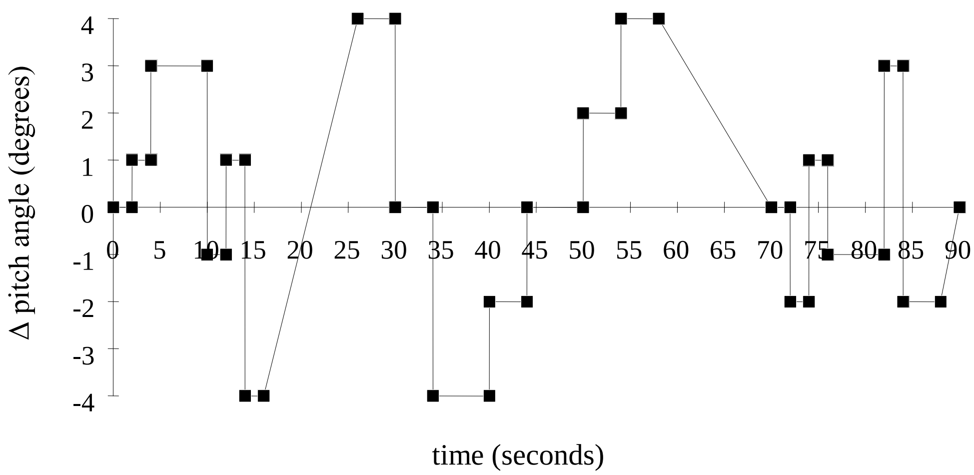
(a) These tasks may be used to assess the airplane's PIO susceptibility when flying in turbulent atmospheric conditions. In this task, a tracking target is displayed which commands pitch and roll changes for the evaluation pilot to follow. Whatever visual cue is used (e.g., head up display (HUD), flight director, etc.), it should present the tracking task without filtering, smoothing, or bias. The pitch and roll commands should be combinations of steps and ramps. The sequence of pitch and roll commands should be designed so as to keep the airplane within ± 1,000 feet of the test altitude and within ±10 knots of the test airspeed. The sequence should be long enough and complex enough that the pilot cannot learn to anticipate the commands. The unfamiliarity is intended to help keep the test pilot's gain high and to preclude inadvertent pilot compensation while accomplishing the task. Such compensation, along with reduced gains, could mask any PIO tendencies.

(b) Even though these fine tracking tasks will provide insight into PIO susceptibility of a conventional airplane when flying in turbulence, other considerations apply to augmented airplane types. For example, structural load alleviation systems that use the same flight control surface as the pilot will limit the pilot's control authority in turbulent atmospheric conditions. Under these circumstances of rate or position limiting, PIO tendencies will be more critical as previously discussed. Therefore, specific evaluations for turbulent atmospheric conditions with these systems operating are necessary for these airplane types.

(c) For single axis tasks, it has been found that aural commands given in a timed sequence provide an adequate cue in the event it is not possible to modify the flight director to display the pitch commands.

(d) Based on PIO events seen in service, high altitude tracking tasks (with up to approximately ± 4° pitch excursions from trim occurring at varying intervals of approximately 2 to 5 seconds) have been effective in evaluating PIO susceptibility. These tasks have been used where the airplane is flying under conditions of low g margin to buffet onset. The following time history is a pictorial representation of a sample task in MIL-STD-1797A that has the desired attributes for high altitude PIO evaluations:

Figure 20-1. Sample Pitch Tracking Task



(6) <u>PIO Assessment Criteria</u>.

(a) The evaluation of an airplane for PIO susceptibility will be conducted using the FAA handling qualities rating method (HQRM) (See Appendix 5 for more information on the HQRM.). Tasks should be designed to focus on any PIO tendencies that may exist. Figure 20-2 contains the descriptive material associated with PIO characteristics and its relationship to the PIO Rating Scale called out in the U.S. Military Standard.

(b) Figure 20-2 provides the FAA handling qualities (HQ) rating descriptions of airplane motions that may be seen during the conduct of specific PIO tasks or during tests throughout the entire certification flight test program. The *italicized* phrases highlight major differences between rating categories in the table.

Figure 20-2. PIO Rating Criteria and Comparison To MIL Standard

FAA HQ RATING	PIO CHARACTERISTICS DESCRIPTION	MIL 1797A STD. PIO RATING SCALE
SAT	No tendency for pilot to induce undesirable motion.	1
	Undesirable motions (overshoots) *tend to occur* when pilot initiates abrupt maneuvers or attempts tight control. These motions can be prevented or eliminated by pilot technique. (*No more than minimal pilot compensation is required*.)	2
ADQ	Undesirable motions (unpredictability or over control) *easily induced* when pilot initiates abrupt maneuvers or attempts tight control. These motions can be prevented or eliminated but only at sacrifice to task performance or through *considerable* pilot attention and effort. (*No more than extensive pilot compensation is required.*)	3
CON	*Oscillations tend to develop* when pilot initiates abrupt maneuvers or attempts tight control. Adequate performance is not attainable and pilot has to reduce gain to recover. (Pilot can recover by merely reducing gain.)	4
UNSAT	*Divergent oscillations* tend to develop when pilot initiates *abrupt maneuvers* or attempts tight control. Pilot has to open control loop by releasing or freezing the controller.	5
	Disturbance or *normal pilot control* may cause divergent oscillation. Pilot has to open control loop by releasing or freezing the controller.	6

SAT = Satisfactory
ADQ = Adequate
CON = Controllable
UNSAT = Unsatisfactory or Failed

(c) The acceptable HQ ratings for PIO tendencies is shown in Figure 9 of Appendix 5. As described in that appendix, the minimum HQ rating, and consequently the pass/fail criteria, varies with the flight envelope, atmospheric disturbance considered, and failure state. For example, Figure 20-3 below shows a handling qualities matrix for a tracking task with the airplane at aft c.g. trimmed in flight conditions giving 1.3 g to buffet onset.

Figure 20-3. Example of Acceptable HQ Rating For PIO Tendencies

Airplane at aft c.g. trimmed in conditions giving 1.3 g to buffet onset

AIRSPEED	M_{LRC}	M_{LRC}	M_{LRC}	M_{LRC}
LOAD FACTOR RANGE	0.8 TO 1.3	-1.0 TO 2.5	0.8 TO 1.3	-1.0 TO 2.5
BUFFET LEVEL	ONSET	DETERRENT	ONSET	DETERRENT
TURBULENCE	LIGHT	LIGHT	LIGHT	LIGHT
FAILURE	NONE	NONE	IMPROBABLE FAILURE OF SAS	IMPROBABLE FAILURE OF SAS
FLIGHT ENVELOPE	NFE	LFE	NFE	LFE
MINIMUM PERMITTED HQ RATING	SAT	ADQ	ADQ	CON

SAT = Satisfactory ADQ = Adequate CON = Controllable

NFE = Normal flight envelope LFE = Limit flight envelope

SAS = Stability augmentation system

M_{LRC} = Long range cruise Mach number

e. Maneuvering Characteristics - § 25.143(g).

(1) General. An acceptable means of compliance with the requirement that stick forces may not be excessive when maneuvering the airplane with the flight control systems operating normally is to demonstrate that, in a turn for 0.5g incremental normal acceleration (0.3g above 20,000 feet) at speeds up to V_{FC}/M_{FC}, the average stick force gradient does not exceed 120 pounds per g for a control conventional wheel or 55 pounds per g for a side stick. This gradient should be evaluated in flight conditions where it is possible to achieve the specified load factor without engagement of stall warning or envelope protections (e.g., high angle of attack limiting)..

(2) Interpretive Material.

(a) AnThe objective of § 25.143(g) is to ensure that the limit strength of any critical component on the airplane would not be exceeded in maneuvering flight. with the flight control systems operating normally; however, this requirement is satisfied if the maximum achievable load factor is limited to the design limits by a load factor envelope protection function that is shown to comply with § 25.144 and is shown to have an improbable failure rate (less than 10-5 per flight hour).. In much of the structure, the load sustained in maneuvering flight can be assumed to be directly proportional to the load factor applied. However, this may not be the case for some parts of the structure (e.g., the tail and rear fuselage). Nevertheless, it is accepted that the airplane load factor will be a sufficient guide to the possibility of exceeding limit strength on any critical component if a structural investigation is undertaken whenever the design positive limit maneuvering load factor is closely approached. If flight testing indicates that the positive design limit maneuvering load factor could be exceeded in steady maneuvering flight with a 50 pound stick force for a conventional control wheel or 25 pounds for a side stick, the airplane structure should be evaluated for the anticipated load at this pitch controla 50 pound stick force level. The airplane will be considered to have been overstressed if limit strength has been exceeded in any critical component. For the purposes of this evaluation, limit strength is defined as the lesser of either the limit design loads envelope increased by the available margins of safety, or the ultimate static test strength divided by 1.5.

(b) Minimum Stick Force to Reach Limit Strength. Unless a load factor envelope protection function is installed, the following applies:

1 A stick force of at least 50 pounds for a conventional control wheel or 25 pounds for a side stick to reach limit strength in steady maneuvers or wind-up turns is considered acceptable to demonstrate adequate minimum force at limit strength in the absence of deterrent buffeting. If heavy buffeting occurs before the limit strength condition is reached, a somewhat lower stick force at limit strength may be acceptable. The acceptability of the lowera stick force of less than 50 pounds at the limit strength condition will depend upon the intensity of the buffet, the adequacy of the warning margin (i.e., the load factor increment between the heavy buffet and the limit strength condition), and the stick force characteristics. In determining the limit strength condition for each critical component, the contribution of buffet loads to the overall maneuvering loads should be taken into account.

2 This minimum stick force applies in the en route configuration with the airplane trimmed for straight flight, at all speeds above the minimum speed at which the limit strength condition can be achieved without stalling. No minimum stick force is specified for other configurations, but the requirements of § 25.143(g) are applicable in these conditions.

(c) Stick Force Characteristics.

1 At all points within the buffet onset boundary determined in accordance with § 25.251(e), but not including speeds above V_{FC}/M_{FC}, the stick force should increase progressively with increasing load factor. Any reduction in stick force gradient with change of load factor should not be so large or abrupt as to impair significantly the ability of the pilot to maintain control over the load factor and pitch attitude of the airplane.

2 Beyond the buffet onset boundary, hazardous stick force characteristics should not be encountered within the permitted maneuvering envelope as limited by paragraph

20e(2)(c)3. It should be possible, by use of the primary longitudinal control alone, to rapidly pitch the airplane nose down so as to regain the initial trimmed conditions. The stick force characteristics demonstrated should comply with the following:

(aa) For normal acceleration increments of up to 0.3g beyond buffet onset, where these can be achieved, local reversal of the stick force gradient may be acceptable, provided that any tendency to pitch up is mild and easily controllable.

(bb) For normal acceleration increments of more than 0.3g beyond buffet onset, where these can be achieved, more marked reversals of the stick force gradient may be acceptable. It should be possible to contain any pitch-up tendency of the airplane within the allowable maneuvering limits, without applying push forces to the control column and without making a large and rapid forward movement of the control column.

3 In flight tests to satisfy paragraphs 20e(2)(c)(1) and (2), the load factor should be increased until either:

(aa) The level of buffet becomes sufficient to provide a strong and effective deterrent to any further increase of the load factor; or

(bb) Further increase of the load factor requires a stick force in excess of 150 pounds for a conventional control wheel or 70 pounds for a side stick (or in excess of 100 or 45 pounds, respectively, when beyond the buffet onset boundary) or is impossible because of the limitations of the control system; or

(cc) The positive limit maneuvering load factor established in compliance with § 25.337(b) is achieved.

(d) Negative Load Factors. It is not intended that a detailed flight test assessment of the maneuvering characteristics under negative load factors should necessarily be made throughout the specified range of conditions. An assessment of the characteristics in the normal flight envelope involving normal accelerations from 1g to zero g will normally be sufficient. Stick forces should also be assessed during other required flight testing involving negative load factors. Where these assessments reveal stick force gradients that are unusually low, or that are subject to significant variation, a more detailed assessment, in the most critical of the specified conditions, will be required. This may be based on calculations, provided they are supported by adequate flight test or wind tunnel data.

f. Thrust or Power Setting for Maneuver Capability Demonstrations. The effect of thrust or power on maneuver capability is normally a function of only the thrust-to-weight ratio. Therefore, for those configurations in which the WAT-limited thrust or power setting is prescribed, it is usually acceptable to use the thrust or power setting that is consistent with a WAT-limited climb gradient at the test conditions of weight, altitude, and temperature. However, if the maneuver margin to stall warning (or other characteristic that might interfere with normal maneuvering) is reduced with increasing thrust or power, the critical conditions of both thrust or power and thrust-to-weight ratio should be taken into account when demonstrating the required maneuvering capabilities.

g. General Requirements for Envelope Protection Functions - § 25.144.

(1) Background - § 25.144.

(a) General. Many modern aircraft employ Envelope Protection Functions (EPFs) to limit the achievable range of one or more measured flight parameters. Such functions are typically implemented by control laws in an electronic flight control system. Envelope Protection Functions are intended to reduce the likelihood of excursions, either commanded or uncommanded, to unintended or potentially hazardous aircraft operating states. As a consequence of preventing excursions, these functions can also restrict aircraft maneuver capability and introduce non-traditional behavior. The purpose of § 25.144 is to ensure that EPFs support safe operation and do not interfere with required maneuvering in normal and emergency operations and forseeable atmospheric conditions. The description above refers to "measured flight parameters" because EPFs typically rely on closed-loop control of one or more flight parameters that may be measured directly or inferred from other measurements. In general, any flight control function that limits one or more flight parameters to a smaller range than would be achieved by traditional usage of the control surfaces should be considered an Envelope Protection Function. For example, a maneuver-command control law such as a g-command law may act as an EPF if the maximum command is less than the aircraft capability in some conditions. However, control laws or devices that simply limit control authority as a function of flight condition (such as rudder ratio changers, elevator travel limits or hinge moment limiters) and depend on aerodynamic stability to limit parameter excursions are generally not considered EPFs even if they are implemented as an element of an electronic flight control system.

(b) Overrideability of Envelope Protection Functions by Pilot Force Input. EPFs may be non-overrideable (also called an envelope limiting function), meaning that the pilot cannot command the aircraft beyond the parameter limit regardless of how much force is applied to the primary controller for that axis; or overrideable, meaning that while the function is intended to deter the pilot from commanding the aircraft beyond the parameter limit, a pilot input of sufficiently large force on the primary controller for that axis can command the aircraft beyond the parameter limit. Whether a particular EPF should be non-overrideable depends on the flight parameter being protected, and how rapidly the aircraft could enter a potentially unsafe flight condition due to intuitive but possibly inappropriate pilot action. High-angle of attack limiting functions (HALF) that are used for compliance with § 25.202 must be non-overrideable to successfully demonstrate the maneuvers specified by that regulation. Maneuver protection functions (i.e. load factor limiting) must be non-overrideable if the protection function is used to show compliance to § 25.143(g) in lieu of sufficiently large controller force characteristics, or is used to establish a reduced structural design load factor per § 25.337(d). Overrideability considerations for some other protection functions are addressed on a case-by-case basis in Paragraph 20.g.(2) below.

(c) Disconnect of Envelope Protection Functions. If the capability is provided to disconnect any or all EPFs by means of a switch(es) or similar device, that means should not be associated with the primary controller(s) for the flight parameter in question, and should not be likely to be invoked intuitively by the pilot in event the envelope protection limit is encountered.

(d) Use of Simulation for Evaluation In some situations it is appropriate to use a suitable flight simulation to demonstrate the function of an EPF, particularly for situations that are difficult to demonstrate in flight, such as performance in large atmospheric disturbances, or when a flight test could be hazardous. The guidance in Paragraph 3.a.(1)(f) regarding characteristics of a suitable simulation should be followed for simulation evaluations used to show compliance to § 25.144.

(2) Maneuverability in the Presence of Envelope Protection Functions - § 25.144(a).

(a) General § 25.144(a) states that "Envelope protection functions must not unduly limit the maneuver capability of the aircraft nor interfere with its ability to perform maneuvers required for normal and emergency operations." Guidance is provided below for evaluating envelope protection functions (EPFs) for several flight parameters, namely normal load factor, roll and pitch attitude, and high airspeed. Additional regulations applicable to high angle of attack limiting functions are provided in § 25.202 and § 25.204; associated guidance material is included in Paragraph 29. In addition to the guidelines presented in this section, a qualitative assessment of aircraft maneuverability and dynamic response in the presence of EPFs should be performed by pilot evaluation of handling qualities throughout flight test, including conditions showing compliance to the general requirements of § 25.143(a). EPFs should not interfere with maneuver capability required for safe operation during emergency and non-normal maneuvers such as emergency descent, aborted landings, collision avoidance, terrain avoidance, Means of showing compliance for emergency maneuvers is discussed in Section g.(2)(f) of this paragraph. Effect of EPFs on control during atmospheric disturbances and recovery from windshear is addressed by § 25.144(d), with guidance provided in Paragraph 20.g.(5) of this paragraph.

(b) Normal Load Factor Protection

1 Explanation.

(aa) General. This guidance applies to aircraft employing control laws and protection functions that command and regulate pitch maneuver capability. Control laws or devices that simply limit pitch control authority as a function of flight condition (such as elevator travel limits or hinge moment limiters) and depend on aerodynamic stability to limit load factor excursions are generally not considered normal load factor protection functions. There is no requirement that a pitch maneuver command function must limit the achievable load factor to less than structural limits; however, if a maneuver command limit (i.e., a normal load factor protection function) is used to provide compliance with § 25.143(g) in lieu of suitably high pitch controller forces, the load factor protection function must not be overrideable by pilot force, and the function should have suitable reliability as discussed in Paragraph 20.e(2)(a). Control laws that regulate normal load factor are likely to also affect achievable pitch rate and/or g rate. Pitch up and pitch down response must be satisfactory while initiating and recovering from aggressive pitch maneuvers.

(bb) Positive Load Factors. Unless positive maneuver capability is limited by airframe characteristics (e.g. wing lift, deterrent buffet, or pitch control power), or by other protection functions that serve specific flight characteristics design purposes (e.g., high-angle-of-attack protection or pitch attitude protection), the positive load factor command limit with the flight controls operating normally and the airplane in its normal trim state for the flight condition should not be less than:

- 2.5 g with the high-lift devices retracted, and
- 2.0 g with the EFCS functioning in its normal mode and with the high-lift devices extended.

A reduced positive limiting load factor that decreases gradually from 2.5 g at Vmo/Mmo to 2.25 g at Vd/Md has been considered acceptable on aircraft with negative pitch attitude protection and high-speed protection, provided it does not hinder overspeed recovery (§ 25.335b(1)).

(cc) Negative Load Factor. Unless negative maneuver capability is limited by airframe characteristics (e.g. wing lift, deterrent buffet, or pitch control power), or by other protection functions that serve specific flight characteristics design purposes (e.g., high speed protection, low-angle-of-attack protection or pitch attitude protection), the negative limiting load factor command with the EFCS functioning in its normal mode should be equal to or more negative than:

- -1.0 g with the high-lift devices retracted; or
- 0 g with the high-lift devices extended.

Maximum negative load factor command may be further limited by flight control system characteristics or flight envelope protections, provided that:

- pitch down responsiveness is satisfactory, and
- from trimmed level flight, 0 g can be commanded or a satisfactory trajectory change is readily achievable at operational speeds.

It has also been considered acceptable for the control law to initially restrict negative load factor to approximately 0 g with high-lift devices retracted to reduce the risk of inadvertent brief negative-g maneuvers, with the load factor limit increasing gradually to approximately -1.0 g within a reasonable time.

2 Procedures.

(aa) Positive Load Factors. Compliance for positive load factor command capability may be shown in a pullup or in turning flight, at a speed/weight/cg combination at which the specified load factor is achievable, supported by design review of the control law to show that it does not limit inappropriately at other conditions. A pullup may be initiated from a pushover or descent condition to avoid excessive positive pitch attitudes during the pullup. If a turning maneuver is used to demonstrate maneuver command capability, pitch response in a pullup should be shown to be acceptably prompt.

(bb) Negative Load Factors. Compliance for negative load factor limits may be shown in a pushover to 0 g at a weight/speed/cg combination at which the aircraft is capable of achieving that load factor, supported by design review of the control law to show that it does not limit inappropriately at other conditions. The pushover may be initiated from a pullup or climb condition to avoid excessive negative pitch attitude and potential overspeed.

(c) Pitch Attitude Protection

1 Explanation.

(aa) General. Pitch attitude limits may be employed to protect the aircraft from achieving attitude states that could lead to undesired changes in airspeed or energy or could contribute to pilot disorientation. Pitch attitude protection may also be used in concert with other protection functions such as high angle of attack protection or high speed protection to achieve a flight characteristics objective. There is no requirement that pitch attitude protection be provided, but if it is provided, it should not interfere with the airplane's ability to perform maneuvers required for normal and emergency operations. This guidance is provided in support of the requirement of 25.144(a) to "not unduly limit" airplane capability, and is not intended to evaluate how well a pitch attitude limiting function serves its intended function of protection against undesired changes in energy. Non-interference of pitch attitude protection can generally be evaluated in the course of showing compliance to other Subpart B requirements, although it may be necessary to consider conditions that result in extremes of pitch attitude in addition to the typical conditions that result in extremes of performance or other flight characteristics. Inservice experience with pitch limit values on similar aircraft may be considered in establishing acceptable limit values.

(bb) Positive Attitudes. A pitch attitude protection function should not impede attaining positive (nose-up) pitch angles up to the maximum required for normal maneuvering, including a normal all-engines operating takeoff or go-around, plus a suitable margin to allow for satisfactory speed control. Pitch attitude protection should not prevent attaining the pitch attitude necessary for emergency maneuvering such as terrain avoidance and collision avoidance. The possible effects of pitch attitude limiting on windshear escape and atmospheric disturbances are addressed under § 25.144(d). If pitch attitude protection is available on or near the ground, it should not interfere with adequate pitch control during takeoffs and landings, including aborted landings.

(cc) Negative Attitudes. A pitch attitude protection function should not impede attaining negative pitch attitudes required for normal operations nor interfere with recovery from high angle of attack, collision-avoidance capability, or with attaining and maintaining speeds appropriate for emergency descent plus a suitable margin for speed control.

2 Procedures.

(aa) Positive Attitudes. Demonstrations of aircraft employing pitch attitude protection functions need to show that the function does not interfere with normal operation, including normal all-engines takeoff and go-around. A takeoff and climb should be demonstrated in the condition that results in the smallest margin between climbout attitude and the pitch attitude limit, typically a high T/W condition. If takeoff procedures call for establishing a target speed during climb, an acceptable means to show that the pitch attitude margin allows for satisfactory speed control is to demonstrate the ability to change speed approximately 5 kt below the target speed without changing thrust. If takeoff procedures for some conditions (typically high T/W) involve targeting or not exceeding a specific pitch attitude, it is sufficient for those conditions to demonstrate a takeoff that achieves the specified target attitude and show that the margin between the target atttude and the pitch attitude limit allows for adequate flight path control. Similarly, acceptable speed control or nose-up attitude control during a go-around should be demonstrated with the configuration that results in the smallest pitch attitude margin using recommended go-around procedures. If it is not practical to demonstrate the critical cases for takeoff or go-around in flight due to limitations on minimum weight of the test article, a flight demonstration should be performed as close as practical to the critical case, and a simulator evaluation should be performed at the critical condition. Analysis may be used in lieu of flight or simulator demonstration if it can be shown that the margin between airplane attitude and the pitch attitude limits are clearly large enough to ensure no interference with normal operation in the maneuvers described above, including allowance for speed control and flight path control. The effect of pitch attitude limits on takeoff flare and landing flare will generally be assessed adequately during normal and abuse takeoff and landing conditions performed to show compliance with other Subpart B requirements. Means of showing non-interference in wind shear is discussed in Section (d) of this paragraph.

(bb) Negative Attitudes. It should be shown that normal and emergency operations are not impeded by a negative pitch attitude limit. The condition that typically requires the greatest nose-down attitude is an idle descent with speedbrakes deployed at light weight at Vmo/Mmo. If an alternate speed or target attitude is recommended for emergency descent the evaluation may be performed at that speed/attitude. It should be possible to perform this task with a suitable pitch attitude margin remaining for speed or flight path control. Compliance may be shown by analysis if the margin between the limit and the attitude required to perform the descent is sufficiently large. If a flight demonstration is employed, this evaluation may require a dedicated condition at light weight since the critical condition for showing compliance with emergency descent cabin pressure regulations is typically at heavy weight. Flight at Vfe with landing flaps, gear down, idle thrust at light weight could result in negative pitch attitudes and should be considered; suitable maneuverability should be available consistent with § 25.143(a). Possible effects of negative pitch attitude protection during recovery from high angles of attack should be evaluated during tests performed to show compliance with § 25.145(a). It is acceptable for pitch attitude protection to be active during the recovery provided the acceleration to trim speed is judged to be prompt. Collision avoidance capability can be established as part of the general maneuverability assessments of § 25.143(a).

(d) Roll Attitude Protection

1 Explanation. Roll attitude protection may be employed to reduce the risk of unintended or excessive roll excursions, possibly due to pilot disorientation or atmospheric disturbances. However, roll attitudeprotection must not interfere with the pilot's ability to perform reasonably rapid changes in flight path. This guidance is provided in support of the requirement of 25.144(a) to "not unduly limit" airplane capability, and is not intended to evaluate how well a roll attitude protection function serves its intended function of protection against excessive roll excursions.

(aa) Roll attitude limits of approximately 66 deg flaps up within the Vmo/Mmo boundary and approximately 60 deg flaps down have been considered acceptable. These bank angles correspond to steady turns of 2.5 g and 2.0 g, respectively. It should be possible to achieve these roll angles without requiring excessive pilot skill or strength. A modest reduction in roll attitude limit at high angle of attack and at speeds above Vfc/Mfc has been considered acceptable, as discussed in (bb) and (cc) below.

(bb) A reduced roll attitude limit has been accepted at high angle of attack conditions to provide protection against low speed roll. The aircraft should be able to perform coordinated turns as per § 25.143(h). A roll attitude limit of approximately 45 degrees at high angle of attack conditions has been considered acceptable.

(cc) A reduced roll attitude limit has been considered acceptable beyond the overspeed warning to provide protection against high-speed combined pitch and roll upsets. The aircraft should be able to perform operational turns at these speeds. A roll attitude limit of approximately 30 degrees at Vdf/Mdf has been considered acceptable.

2 Procedures. Compliance with the requirement that a roll attitude protection function not interfere with required operations can be shown by demonstrating that the airplane can achieve the roll attitudes identified in Section g.2.(d)1 above without undue pilot effort. This can typically be achieved during maneuvers (windup turns or steep turns) performed to show maneuver characteristics, or during maneuvers performed to demonstrate load factor command limits described above in Section 20.g.2.(b)2(aa). Non-interference of roll attitude limits should be demonstrated in flight in each configuration or flight regime that invokes a different limit. A reduced roll attitude limit that may be utilized at high angle of attack can be judged not to interfere with operations by showing compliance with § 25.143(h) and with stall characteristics or high-angle-of-attack characteristics requirements as appropriate.

(e) High Speed Protection

1 Explanation.

(aa) The High-Speed Protection Functions (HSPF) addressed in this section are intended to provide protection from excursions beyond the normal speed (or Mach) envelope due to an atmospheric disturbance, flight path upset, trim shift, or inadvertent pilot input. While the intent of an HSPF is to limit speed excursions, it should not interfere with normal or emergency operations near Vmo/Mmo nor cause difficulty in controlling the aircraft for larger speed excursions.

(bb) An HSPF should not impede attainment of speeds anticipated in normal operation or impede the pilot's ability to easily maintain flight path in the presence of modest speed excursions beyond Vmo/Mmo. Activation of the HSPF associated with modest excursions beyond Vmo/Mmo due to pilot inputs or atmospheric upsets should come in smoothly and the flight path should be easily controlled. Demonstrating controllability during a speed excursion to overspeed warning is generally considered sufficient to show compliance. It should also be ensured that an HSPF does not interfere with performing an emergency descent procedure.

2 Procedures.

(aa) To demonstrate that the HSPF does not interfere during modest speed excursions beyond Vmo/Mmo, it is sufficient to trim the airplane near Vmo/Mmo, accelerate out to the overspeed warning, stabilize briefly at that speed, then return smoothly to within the Vmo/Mmo boundary. Speed may be changed either by altering thrust while maintaining altitude or by initiating a mild descent to increase speed and a mild climb if necessary to recover to Vmo/Mmo. It should be possible for the pilot to maintain the desired flight path (either level flight or constant descent profile) without significant effort. If the aircraft flight envelope is limited by Mach number at high altitude, this evaluation should be performed in both the Mach-limited regime and also at a lower altitude in the speed-limited regime. Since the HSPF behavior is largely determined by the control law, not aerodynamic characteristics, it is sufficient to perform this demonstration at a representive en-route weight and cg.

(3) Onset Characteristics - § 25.144(b)

(a) Explanation. § 25.144(b) says "Onset characteristics of each envelope protection function must be appropriate to the phase of flight and type of maneuver, and must not conflict with the ability of the pilot to satisfactorily control the airplane flight path, speed, or attitude." The intent of § 25.144(b) is to ensure that when envelope protection functions become active they do not create undesirable or unexpected handling qualities that interfere with the pilot's ability to perform tasks that involve controlling the aircraft in proximity to the onset point or the limit.

(b) Procedures. Flight test conditions should be demonstrated that involve approaching each limit in a fashion that allows the pilot to assess the handling and control characteristics associated with onset of the function. In most cases this may be done in conjunction with other required testing; for example, onset characteristics of a high angle-of-attack limiting function may be evaluated during the demonstrations of § 25.202; onset characteristics of a roll attitude limit may be evaluated during the demonstration of maneuver characteristics under § 25.143(g), and onset characteristics of a high-speed protection function may be evaluated during evaluation of high speed characteristics under § 25.253. If the limits are set at a position that is not approached during normal certification demonstrations it is acceptable to adjust the limit so the onset characteristics can be safely demonstrated in flight, or to show the characteristics in a simulator with the limits set to the normal position.

(4) Margin to Unsafe Characteristics - § 25.144(c)

(a) Explanation. § 25.144(c) states "Excursions of a limited flight parameter beyond its nominal design limit value due to dynamic maneuvering, airframe and system tolerances, and non-steady atmospheric conditions must not result in unsafe flight characteristics or conditions." If an envelope protection function serves to prevent the aircraft from reaching a flight condition that could result in unknown or potentially unsafe flight characteristics, the applicant should show that the performance of the function is sufficient to prevent excursion to a potentially unsafe regime as a result of foreseeable aircraft dynamics, non-steady atmospheric conditions, and system tolerances, in any appropriate combination. This regulation addresses flight characteristics and therefore primarily applies to parameters where aerodynamic characteristics may change significantly for moderate variations in the parameter beyond the limit. Such parameters may include angle of attack and airspeed/Mach number.

(b) Procedures. For an airplane with a high angle of attack limiting function that complies with §§ 25.202 and 25.204, the demonstrations that show compliance with those regulations address the effects of dynamic maneuvers, tolerances, and atmospheric disturbances, and are considered sufficient to satisfy 25.144(b). For an airplane utilizing a high speed protection function, the demonstrations showing compliance to §§ 25.253 and 25.255 at Vdf/Mdf address controllability in the presence of excursions of airspeed and Mach beyond the steady limit values due to dynamics and atmospheric conditions or upsets, and are considered sufficient to satisfy 25.144(b).

(5) Operation in Atmospheric Disturbances and Windshear- § 25.144(d)

(a) Explanation. § 25.144(d) states "Operation of envelope protection functions must not adversely affect aircraft control during expected levels of atmospheric disturbances, nor impede the application of recovery procedures in case of wind-shear." This regulation differs from § 25.144(c) in that (c) specifically addresses characteristics associated with parameter excursions beyond the nominal limit, whereas (d) addresses the potential interference with normal control tasks caused by activation of the EPF due to atmospheric disturbances in conditions where it would not normally be active. Adverse interaction with envelope protection functions is most likely to occur when the airplane is operated in proximity to a protection boundary such as an angle-of-attack limit or a high speed protection limit. These effects should be evaluated in "heavy turbulence". Since it is not practical to find such conditions during a flight test program, the evaluation should be done in an appropriate flight simulator. Evaluation of protection functions in wind shear is called out specifically because wind shear escape procedures typically involve operating at relatively high angle-of-attack. The wind shear profiles described in AC120-41 or another acceptable model may be used for the purpose of showing compliance to this regulation. Additional guidelines for showing compliance with the effect of turbulence on the performance of a high angle-of-attack limiting function are presented in Paragraph 29.d.(3) of this document in conjunction with the means of compliance for § 25.202 and § 25.204.

(b) Procedure.

1 The behavior of the airplane in heavy turbulence in operational tasks should be demonstrated in flight or in an appropriate means of simulation or analysis using an adequate turbulence model If high angle of attack protection is present, suggested evaluation tasks involve a simulated engine-out takeoff at heavy weight, and an approach and landing at the minimum approach speed appropriate for the level of turbulence, including a 30 deg banked turn. If high speed protection is present the suggested task is a descent at Vmo/Mmo. Obviously the turbulence itself increases the difficulty of the task. The standard for evaluation is that when the airplane is operated in turbulence, the EPFs do not introduce unexpected behaviors or create

undue difficulty in controlling the flight path. Analysis may be used in lieu of flight test or piloted simulation if the margin to activation of an EPF is sufficiently large that the EPF will not become active due to turbulence in relevant tasks.

2 The effect of EPFs in windshear escape should be evaluated in an appropriate flight simulator using the wind shear profiles described in AC120-41 or another acceptable model. These evaluations may be conducted at the same time as evaluations of windshear warning and guidance systems. The airplane configuration and flight condition should be selected with consideration of what is most likely to cause an adverse effect of envelope protection. This configuration or condition may be different from the critical condition required to evaluate other aspects of the windshear warning and guidance system, in which case the evaluation may need to be repeated specifically to assess the EPF. It is acceptable for EPFs to be active during the maneuver, but the resultant airplane performance must be acceptable.

(6) Priority and Interaction of Protection Functions- § 25.144(e)

(a) Explanation. § 25.144(e) states "Simultaneous action of envelope protection functions must not result in adverse coupling or adverse priority." EFCS control laws may regulate multiple parameters during a maneuver, introducing the potential of inappropriate priority or undesired interaction among protection functions or between protection functions and other control law functions. In showing compliance to § 25.144(e) the applicant must show that the EPFs are prioritized or coordinated so simultaneous action of EPFs results in the proper priority of functions and does not cause hazardous or confusing behaviors. § 25.144(e) is specifically intended to address cases where multiple protection functions are at or near their limits at the same time, particularly if the actions are potentially in conflict. Cross-axis effects should be considered when applicable. It is also essential that envelope protection functions not display adverse interactions or inappropriate priority with other flight control functions such as basic command augmentation or load relief functions. However, these types of interactions are likely to be observed during the basic evaluations of each protection function and are not the subject of § 25.144(e).

(b) Procedures. The applicant should identify through design review if there are any conditions where multiple protection functions could be active, particularly if they are in conflict, and should explain the prioritization scheme employed in these situations. Airplane behavior should be demonstrated for representative scenarios if envelope protection functions could be in conflict or have potentially undesired interaction. The demonstration may be performed in an appropriate flight simulation. The behavior of the airplane should be conducive to the pilot retaining control and retreating safely from the limits.

(7) Excursions Beyond Protected Boundaries- § 25.144(f)

(a) Explanation. § 25.144 (f) states " In case of abnormal attitude or excursion of any flight parameters outside the protected boundaries, the operation of the EFCS, including the automatic envelope protection functions, must not hinder airplane recovery." This regulation is intended to ensure that the design of an EFCS and any envelope protection functions consider the possibility that the airplane could experience excursions well beyond the intended operating regime due to unforseen events. The full range of potential pilot inputs or strategies for recovery should be considered. It should be shown that for aircraft states well beyond the protection boundaries, the aircraft will either respond in a conventional manner to large pilot inputs, or will recover automatically to within the protected envelope regardless of pilot input.

(b) Procedure. For every protected parameter, an excursion well beyond the protection boundary should be considered. Compliance to § 25.144(f) may be shown by a design review of the control law behavior in these conditions.

21. Longitudinal Control - § 25.145.

a. Explanation.

(1) Section 25.145(a) requires that there be adequate longitudinal control to promptly pitch the airplane nose down from at or near the stall, or the angle of attack achieved at full aft control input (the AOA limit) when a High Angle-of-Attack Limiting Function is installed and compliance is shown with §§ 25.202 & 25.204, to return to the original trim speed. The intent is to ensure that there is sufficient pitch control for a prompt recovery if inadvertently slowed to the minimum achievable airspeed, including to the point of stall identification if normally achievable. Although this requirement must be met with power off and at maximum continuous thrust or power, there is no intention to require stall demonstrations with thrust or power above that specified in § 25.201(a)(2). Instead of performing a full stall at maximum continuous power or thrust with airplanes for which compliance is shown to § 25.207, compliance with § 25.145(a), ~~compliance~~ may be assessed by demonstrating sufficient static longitudinal stability and nose down control margin when the deceleration is ended at least one second past stall warning during a one knot per second deceleration. The static longitudinal stability during the maneuver and the nose down control power remaining at the end of the maneuver must be sufficient to assure compliance with the requirement.

(2) Section 25.145(b) requires changes to be made in flap position, power or thrust, and speed without undue effort when re-trimming is impractical. The purpose is to ensure that any of these changes are possible assuming that the pilot finds it necessary to devote at least one hand to the initiation of the desired operation without being overpowered by the primary airplane controls. The objective is to show that an excessive change in trim does not result from the application or removal of power or thrust or the extension or retraction of wing flaps. The presence of gated positions on the flap control does not affect the requirement to demonstrate full flap extensions and retractions without changing the trim control. Compliance with § 25.145(b) also requires that the relation of control force to speed be such that reasonable changes in speed may be made without encountering very high control forces.

(3) Section 25.145(c) contains requirements associated primarily with attempting a go-around maneuver from the landing configuration. Retraction of the high-lift devices from the landing configuration should not result in a loss of altitude if the power or thrust controls are moved to the go-around setting at the same time that flap/slat retraction is begun. The design features involved with this requirement are the rate of flap/slat retraction, the presence of any flap gates, and the go-around power or thrust setting. The go-around power or thrust setting should be the same as is used to comply with the approach and landing climb performance requirements of §§ 25.121(d) and 25.119, and the controllability requirements of §§ 25.145(b)(3), 25.145(b)(4), 25.145(b)(5), 25.149(f), and 25.149(g). The controllability requirements may limit the go-around power or thrust setting.

(4) Section 25.145(d) provides requirements for demonstrating compliance with § 25.145(c) when gates are installed on the flap selector. Section 25.145(d) also specifies gate design requirements. Flap gates, which prevent the pilot from moving the flap selector through

the gated position without a separate and distinct movement of the selector, allow compliance with these requirements to be demonstrated in segments. High lift device retraction must be demonstrated beginning from the maximum landing position to the first gated position, between gated positions, and from the last gated position to the fully retracted position.

(a) If gates are provided, § 25.145(d) requires the first gate from the maximum landing position to be to be located at a position corresponding to a go-around configuration. If there are multiple go-around configurations, the following criteria should be considered when selecting the location of the gate:

1 The expected relative frequency of use of the available go-around configurations.

2 The effects of selecting the incorrect high-lift device control position.

3 The potential for the pilot to select the incorrect control position, considering the likely situations for use of the different go-around positions.

4 The extent to which the gate(s) aid the pilot in quickly and accurately selecting the correct position of the high-lift devices.

(b) Regardless of the location of any gates, initiating a go-around from any of the approved landing positions should not result in a loss of altitude. Therefore, § 25.145(d) requires that compliance with § 25.145(c) be demonstrated for retraction of the high-lift devices from each approved landing position to the control position(s) associated with the high-lift device configuration(s) used to establish the go-around procedure(s) from that landing position. A separate demonstration of compliance with this requirement should only be necessary if there is a gate between an approved landing position and its associated go-around position(s). If there is more than one associated go-around position, conducting this test using the go-around configuration with the most retracted high-lift device position should suffice, unless there is a more critical case. If there are no gates between any of the landing flap positions and their associated go-around positions, the demonstrations discussed in paragraph 21a(4) above should be sufficient to show compliance with this provision of § 25.145(d).

b. Procedures. The following test procedures outline an acceptable means for demonstrating compliance with § 25.145. These tests may be conducted at an optional altitude in accordance with § 25.21(c). Where applicable, the conditions should be maintained on the engines throughout the maneuver.

(l) Longitudinal control recovery, § 25.145(a).

(a) Configuration:

1 Maximum weight, or a lighter weight if more critical.

2 Critical c.g. position.

3 Landing gear extended.

4 Wing flaps retracted and extended to the maximum landing position.

5 Engine power or thrust at idle and maximum continuous.

(b) Test procedure: The airplane must be trimmed at the speed for each configuration as prescribed in § 25.103(b)(6). The airplane should then be decelerated at 1 knot per second with wings level. For tests at idle power or thrust, the applicant must demonstrate that the nose can be pitched down from any speed between the trim speed and the stall. identification or the AOA limit if a High Angle-of-Attack Limiting Function is installed and compliance is shown with §§ 25.202 & 25.204. Typically, with airplanes for which compliance is shown to § 25.201. Typically, the most critical point is at the stall when in stall buffet. The rate of speed increase during the recovery should be adequate to promptly return to the trim point. Data from the stall characteristics testing (§25.201) or high AOA handling demonstrations (§25.202), as appropriate, can be used to evaluate this capability at the stall. For tests at maximum continuous power or thrust, the maneuver need not be continued for more than one second beyond the onset of stall warning. with airplanes for which compliance is shown to § 25.207.. However, the static longitudinal stability characteristics during the maneuver, and the nose down control power remaining at the end of the maneuver, must be sufficient to assure that a prompt recovery to the trim speed could be attained if the airplane is slowed to the point of stall identification.

(2) Longitudinal control, flap extension, § 25.145(b)(1).

(a) Configuration:

1 Maximum landing weight or a lighter weight if considered more critical.

2 Critical c.g. position.

3 Wing flaps retracted.

4 Landing gear extended.

5 Engine power or thrust at flight idle.

(b) Test procedure: The airplane must be trimmed at a speed of 1.3 V_{SR}. The flaps must be extended to the maximum landing position as rapidly as possible while maintaining approximately 1.3 V_{SR} for the flap position existing at each instant throughout the maneuver. The control forces must not exceed 50 poundslbs. (the maximum force for short term application that can be applied readily by one hand) for a conventional control wheel or 35 pounds for a side stick controller throughout the maneuver without changing the trim control.

(3) Longitudinal control, flap retraction, § 25.145(b)(2) & (3).

(a) Configuration:

1 Maximum landing weight or a lighter weight if considered more critical.

2 Critical c.g. position.

3 Wing flaps extended to the maximum landing position.

4 Landing gear extended.

5 Engine power or thrust at flight idle and the go-around power or thrust setting.

(b) Test procedure: With the airplane trimmed at 1.3 V_{SR}, the flaps must be retracted to the full up position while maintaining approximately 1.3 V_{SR} for the flap position existing at each instant throughout the maneuver. The longitudinal control force must not exceed 50 pounds for a conventional control wheel or 35 pounds for a side stick controller~~lbs.~~ throughout the maneuver without changing the trim control.

(4) Longitudinal control, power or thrust application, § 25.145(b)(4) & (5).

(a) Configuration:

1 Maximum landing weight or a lighter weight if considered more critical.

2 Critical c.g. position.

3 Wing flaps retracted and extended to the maximum landing position.

4 Landing gear extended.

5 Engine power or thrust at flight idle.

(b) Test procedure: The airplane must be trimmed at a speed of 1.3 V_{SR}. Quickly set go-around power or thrust while maintaining the speed of 1.3 V_{SR}. The longitudinal control force must not exceed 50 pounds for a conventional control wheel or 35 pounds for a side stick controller throughout the maneuver without changing the trim control.

(5) Longitudinal control, airspeed variation, § 25.145(b)(6).

(a) Configuration:

1 Maximum landing weight or a lighter weight if considered more critical.

2 Most forward c.g. position.

3 Wing flaps extended to the maximum landing position.

4 Landing gear extended.

5 Engine power or thrust at flight idle.

(b) Test Procedure: The airplane must be trimmed at a speed of 1.3 V_{SR}. The speed should then be reduced to V_{SW}, or to the higher airspeed of V_{REF} - 5 knots CAS and the minimum airspeed free of a caution or warning alert in accordance with § 25.1322 if a High Angle-of-Attack Limiting Function is installed and compliance is shown with §§ 25.202 and 25.204. The airspeed should then be increased to 1.6 V_{SR}, or the maximum flap extended speed, V_{FE}, whichever is lower. The longitudinal control force must not be greater than 50 pounds for a conventional control wheel or 35 pounds for a side stick controller.~~lbs.lbs.~~ Data from the static longitudinal stability tests in the landing configuration at forward c.g., § 25.175(d), may be used to show compliance with this requirement.

(6) Longitudinal control, flap retraction and power or thrust application, § 25.145(c).

(a) Configuration:

1 Critical combinations of maximum landing weights and altitudes.

2 Critical c.g. position.

3 Wing flaps extended to the maximum landing position and gated position, if applicable.

4 Landing gear extended.

5 Engine power or thrust for level flight at a speed of 1.08 V_{SR} for propeller driven airplanes, or 1.13V_{SR} for turbojet powered airplanes.

(b) Test procedure. With the airplane stable in level flight at a speed of 1.08 V_{SR} for propeller driven airplanes, or 1.13 V_{SR} for turbojet powered airplanes, retract the flaps to the full up position, or the next gated position, while simultaneously setting go-around power or thrust. Use the same power or thrust as is used to comply with the performance requirement of § 25.121(d), as limited by the applicable controllability requirements. It must be possible, without requiring exceptional piloting skill, to prevent losing altitude during the maneuver. Trimming is permissible at any time during the maneuver. If gates are provided, conduct this test beginning from the maximum landing flap position to the first gate, from gate to gate, and from the last gate to the fully retracted position. If there is a gate between any landing position and its associated go-around position(s), this test should also be conducted from that landing position through the gate to the associated go-around position. If there is more than one associated go-around position, this additional test should be conducted using the go-around position corresponding to the most retracted flap position, unless another position is more critical. Keep the landing gear extended throughout the test.

(7) Longitudinal control, out-of-trim takeoff conditions, §§ 25.107(e)(4) and 25.143(a)(1). See paragraphs 10b(9)(c)3 and 4.

Section 5. Stability

25. General - § 25.171. [Reserved]

a. Explanation. Section 25.171 requires the airplane to exhibit suitable stability characteristics around all three axes and through all parts of the flight envelope. While there are specific flight and loading conditions called out for compliance to specific stability requirements, 25.171 requires the airplane to exhibit suitable characteristics throughout the flight envelope, and that the stability characteristics allow normal piloting tasks without requiring exceptional pilot strength, skill or attention.

(1) Section 25.171 requires that the stability and the control feel be suitable in any condition normally encountered in service including those not specified in 25.173 through 25.177. Section 25.171 refers to both longitudinal and lateral/directional characteristics and both static and dynamic conditions including those not included in 25.181 (e.g. phugoid motions) and including those resulting from control systems operation.

(2) The stability (e.g. disturbance rejection) characteristics must be suitable in both hands off flight and during maneuvering.

b. Procedures. The general stability and the control feel of the airplane should be evaluated continuously in the course of flying the airplane for certification. Provided that there are no marginal compliance aspects, no specific test conditions are required for 25.171 beyond those already specified for compliance to other 14 CFR 25 requirements.

26. Static Longitudinal Stability and Demonstration of Static Longitudinal Stability - §§ 25.173, and 25.175 and 25.176..

a. Explanation. The regulation accommodates flight phases which provide classical longitudinal static (speed) stability and those which do not. This is done via a "branching" construct in the regulation which specifies that airplanes must meet either 25.173 and 175 or 25.176. This compliance branching is available on a flight phase-by-flight phase basis as long as the other requirements (e.g. smooth transitions between configurations, 25.143) are also demonstrated.

a. Explanation.

(1) Section 25.173 - Static Longitudinal Stability.

(a) Compliance with the general requirements of § 25.173 is determined from a demonstration of static longitudinal stability under the conditions specified in § 25.175.

(b) The requirement is to have a pull force to obtain and maintain speeds lower than trim speed, and a push force to obtain and maintain speeds higher than trim speed. There may be no force reversal at any speed that can be obtained, except lower than the minimum for steady, unstalled flight or, higher than the landing gear or wing flap operating limit speed or V_{FC}/M_{FC}, whichever is appropriate for the test configuration. The required trim speeds are specified in § 25.175.

(c) When the control force is slowly released from any speed within the required test speed range, the airspeed must return to within 10 percent of the original trim speed in the climb, approach, and landing conditions, and return to within 7.5 percent of the trim speed in the cruising condition specified in § 25.175 (free return).

(d) The average gradient of the stick force versus speed curves for each test configuration may not be less than one pound for each 6 knots for a conventional control wheel, or one pound for each 9 knots for a side stick controller, for the appropriate speed ranges specified in § 25.175. This average slope is intended to be assessed within the speed range before any included envelope protections or low/high speed cueing functions engage, if they increase the apparent speed stability of the airplane above that provided within the normal operational speed range. Therefore, after each curve is drawn, draw a straight line from the intersection of the curve and the required maximum speed, or the maximum speed before a high speed protection or cueing function engages, to the trim point. Then draw a straight line from the intersection of the curve and the required minimum speed ~~to the trim point.~~, or the minimum speed before a low speed protection or cueing function or High Angle-of-Attack Limiting Function engages, to the trim point. ~~to the trim point.~~ The slope of these lines must be at least the minimum value specified for the type of pitch controller. ~~one pound for each 6 knots.~~ The local slope of the curve must remain stable for this range.

(2) Section 25.175, Demonstration of Static Longitudinal Stability, specifically defines the flight conditions, airplane configurations, trim speed, test speed ranges, and power or thrust settings to be used in demonstrating compliance with the longitudinal stability requirements.

(3) Section 25.176 - Static Longitudinal Stability - Alternate.

(a) With the implementation of certain flight control laws, it has been found that airplane configurations which do not exhibit classical speed stability as demonstrated in § 25.173 can be acceptable. In order to appropriately compensate for the lack of conventional speed stability, § 25.176 requires these airplanes to exhibit a number of additional features. These features are considered to be a package, all of which are required to compensate for the lack of conventional stability. Since compliance to 25.176 depends on these control laws and features, compliance with §§25.671 and 25.672 is required per § 25.21(e).

(b) The demonstration of classical stability using the requirements of § 25.173 and § 25.175 ensures that other characteristics are also acceptable including: pitch attitude and flight path dynamics, workload during maneuvering, controller friction, command resolution, awareness of airspeed changes, stability during unattended operation and disturbance rejection.

In the absence of classical stability, § 25.176 ensures that these elements are provided through other means.

(c) When control laws are used to replace unaugmented stability with the desired augmented stability, evaluation of the augmentation in the presence of gusts and turbulence is important for several reasons: the response to pilot commands may have different characteristics than the response to disturbances, the disturbance could saturate the rate or authority capability of the augmentation and the cueing and protection systems must be effective for disturbances. Therefore, § 25.176 requires an evaluation of characteristics in turbulence.

(d) Section 25.176(a) specifies requirements on longitudinal characteristics beyond the low and high speeds boundaries of the normal flight envelope. A small margin in speed between Vmo/Mmo and the start of strong stability is acceptable but this stability must begin before Vfc/Mfc. In the speed range for strong stability, control forces must not be allowed to be trimmed so that the speed awareness is not removed and the airplane will promptly recover towards normal operating speeds when the controller is released.

(e) Section 25.176(b) lists four specific characteristics which must be present to provide suitable static longitudinal characteristics although these may not be the only characteristics needed. General evaluations of handling qualities, pilot workload and pilot compensation must be made.

(f) Section 25.176(c) requires that the airplane provide adequate alerting to the pilot of a low energy (low speed/low thrust/low height) state. "Adequate alerting" means alerting information must be provided to alert the crew of unsafe operating conditions and to enable them to take appropriate corrective action.

b. Procedures.

(1) Stabilized Method for § 25.173 and § 25.175.

(a) For the demonstration of static longitudinal stability, the airplane should be trimmed in smooth air at the conditions required by the regulation. Aft c.g. loadings are generally most critical. After stabilizing at the trim speed, apply a light pull force and stabilize at a slower speed. Continue this process in increments, the size of the speed increment being dependent on the speed spread being investigated, until reaching the minimum speed for steady, unstalled flight or the minimum speed appropriate for the configuration. A continuous pull force should be used from the trim speed on each series of test points to eliminate hysteresis effects. At the end of the required speed range, the force should be gradually relaxed to allow the airplane to return slowly toward the trim speed and zero stick force. Depending on the amount of friction in the control system, the eventual speed at which the airplane stabilizes will normally be less than the original trim speed. The new speed, called the free return speed, must meet the requirements of § 25.173.

(b) Starting again at the trim speed, and with the airplane in trim, push forces should be gradually applied and gradually relaxed in the same manner as described in paragraph (a), above.

(c) The above techniques result in several problems in practice. One effect of changing airspeed is a change of altitude, with a corresponding change in Mach number and power or thrust output. Consequently, a reasonably small altitude band, limited to ±3,000 ft., should be used for the complete maneuver. If this altitude band is exceeded, regain the original trim altitude by changing the power or thrust setting and flap and gear position as necessary, but without changing the trim setting. Then continue the push or pull maneuver in the original configuration. Testing somewhat beyond the required speed limits in each direction assures that the resulting data covers at least the required speed ranges. It will also be noted in testing that while holding force constant at each data point, the airspeed and instantaneous vertical speed vary in a cyclic manner. This is due to the long period (phugoid) oscillation. Care should be exercised in defining and evaluating the data point, since it may be biased by this phugoid oscillation. Averaging these oscillating speeds at each data point is an acceptable method of eliminating this effect. Extremely smooth air improves the quality of the test data. In-bay and cross-bay wing fuel shift is another issue experienced in some airplanes. In-bay fuel shift occurs rapidly with pitch angle; therefore, consideration should be given to testing with fuel loadings that provide the maximum shift since it is generally destabilizing. Slower, cross-bay fuel shift, or burn from an aft tank, can influence the measured stability but usually only because of the time required to obtain the data points. This testing induced instability should be removed from the data before evaluating the slope of the stick force versus speed.

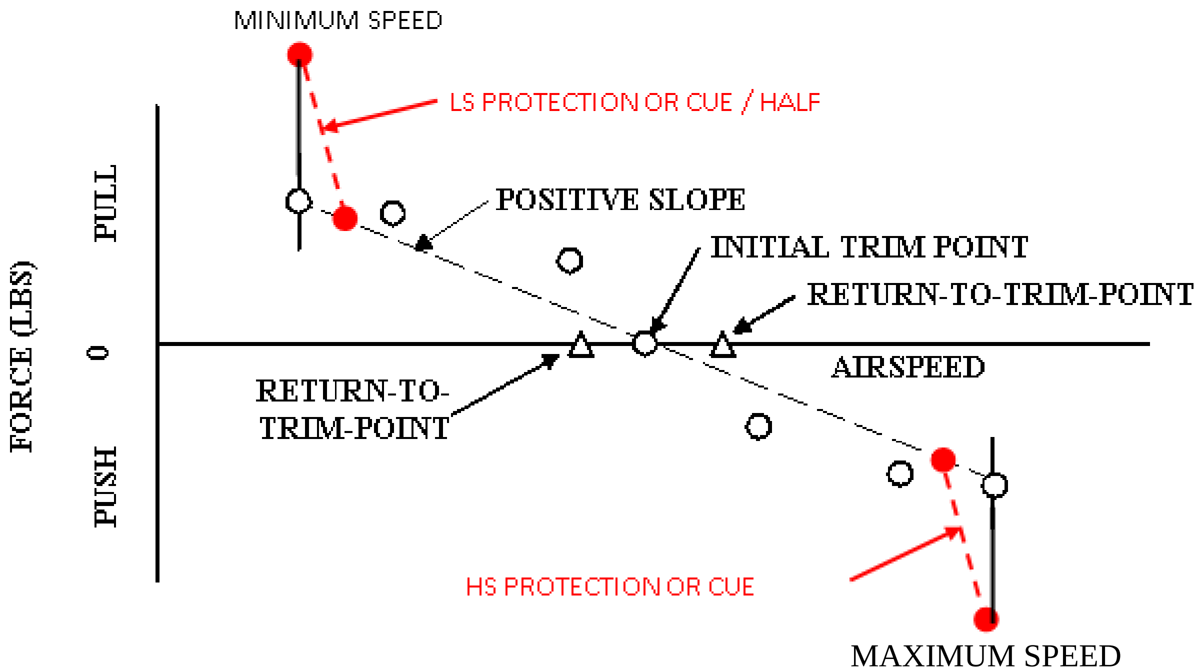
(2) Acceleration-Deceleration Method for § 25.173 and § 25.175.

(a) Trim at the desired airspeed and note the power or thrust setting. Without changing pitch trim, increase power or thrust to accelerate the airplane to the extreme speed of the desired data band. Using elevator control as needed, maintain approximately a constant altitude. Then, without changing pitch trim, quickly reset the power or thrust to the original power setting and allow the airplane to decelerate at a constant altitude back to the original trim speed. Obtain longitudinal static stability data during the deceleration to trim speed with the power and the pitch trim position the same as the original trim data point.

(b) Obtain data below the trim speed in a similar manner, by reducing power or thrust to decelerate the airplane to the lowest speed in the data band. Using elevator control as needed without changing pitch trim, maintain approximately a constant altitude. Then, without changing pitch trim, quickly reset the power to the original power setting, and record the data during the level flight acceleration back to trim speed. If, because of thrust/drag relationships, the airplane has difficulty returning to the trim conditions, small altitude changes within ± 2,000 feet can also be used to coax an airplane back to trim speed. Level flight is preferred, if possible. Obtain speed and elevator stick force data approximately every 10 knots of speed change.

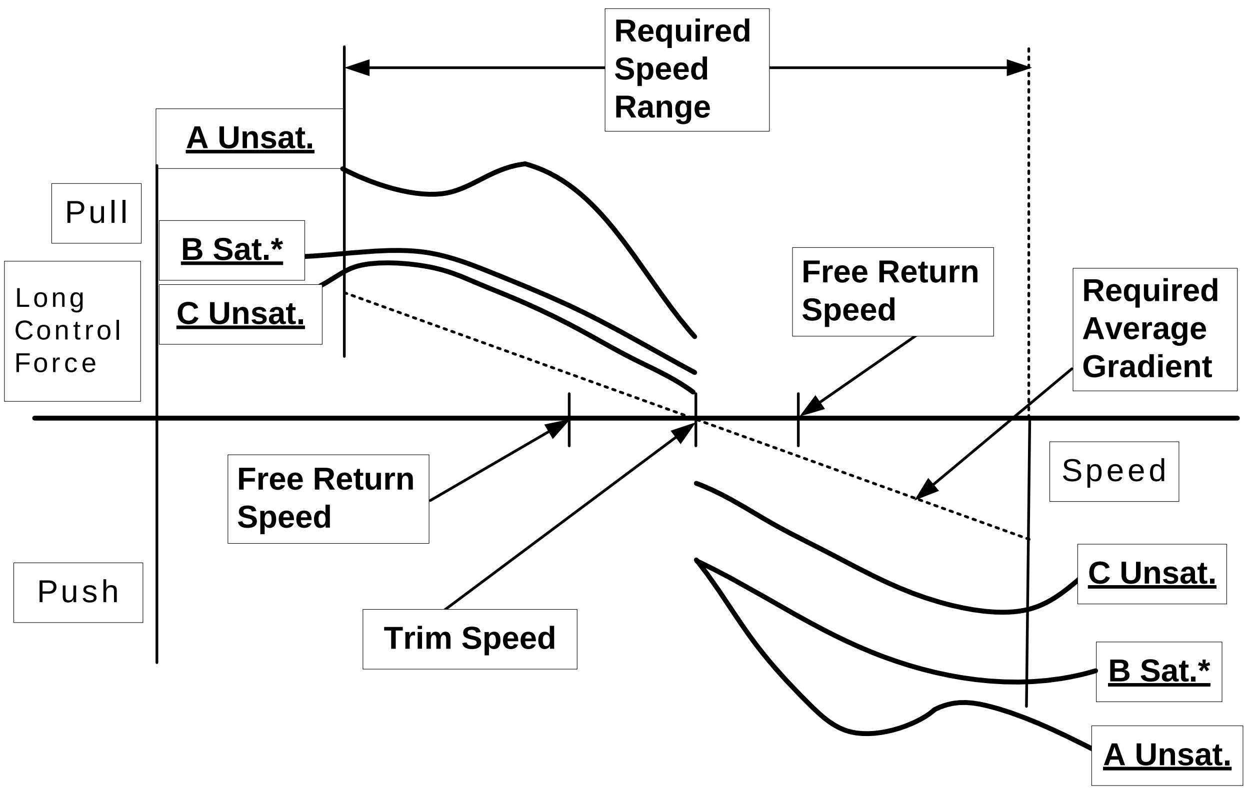
(3) The resulting pilot longitudinal force test points should be plotted versus airspeed to show the positive stable gradient of static longitudinal stability and that there are no "local" reversals in the stick force vs. airspeed relationship over the range of airspeeds tested. The average slope should be shown for the speed range up to the point at which any included envelope protection or cueing functions engage, if they increase the apparent speed stability of the airplane above that provided within the normal operational speed range. This plot should also show the initial trim point and the two return-to-trim points to evaluate the return-to-trim characteristics (see Figure 26-1).

Figure 26-1. Longitudinal Static Stability



(4) Examples of "local reversals" are given in Figure 26-2. Curves A and C depict a local gradient reversal within the required speed range. Even though it might be argued that the "average gradient" meets the minimum~~one pound in six knots~~ criterion, the gradient reversals would render these characteristics unacceptable. Curve B depicts a situation in which the gradient reverses, but only outside the required speed range. In addition, Curve B demonstrates a situation in which the local gradient does not always meet the minimum criterion~~required one pound in six knots~~, even though the average gradient does.

Figure 26-2. Local Reversal



* zero slope at end of speed range

(5) Static Longitudinal Stability – Alternate, § 25.176. Effects of external disturbances on the stability of the airplane should be assessed. For this purpose, it has been found acceptable to perform continuous qualitative evaluations throughout the flight test campaign. Since the airplane will likely be exposed to different levels of atmospheric disturbance during the course of a flight test program, attention should be given in each flight to the aspects of pilot workload, pilot compensation, control feel and the overall suitability of the static longitudinal characteristics of the airplane. This continuous evaluation should be complemented by dedicated flight tests, analysis or simulation whenever a marginal characteristic is found.

(6) Strong Static Longitudinal Stability at Envelope Boundaries, § 25.176(a). Experience has shown that strong positive static longitudinal stability is provided by at least 1 pound/6 knots stick force for a side stick controller. Comparable force gradient for a conventional wheel/column is 1 pound/4 knots. A higher force gradient is needed where speed is limited by Mmo/Md. These slopes are measured in the speed range where the applicable envelope protection or cueing functions are engaged.

(7) Static Longitudinal Characteristics, § 25.176(b).

(a) Precise control of speed and flight path should be accessed. For this purpose, it has been found acceptable to perform a continuous qualitative evaluation throughout the course of the flight test program, with attention to pilot workload while acquiring or maintaining small changes in speed, altitude or flight path. Especially relevant to this matter are AEO and OEI takeoff tests, approach and landing and go-around tests, flight level changes, configuration changes and the steady state trim required before or after a variety of flight test maneuvers in different combinations of weight, CG and power setting. It is not the intent of this regulation to require dedicated flight tests. However, this continuous evaluation should be complemented by dedicated flight tests, analysis or simulation whenever a marginal characteristic is found.

(b) Envelope protection: High Angle of Attack Limiting Function (HALF) that complies with 25.202 and 25.204 is an acceptable envelope protection. The high speed protection should include the strong positive stability described in 25.176(a) in both the altitude range limited by Vmo as well as Mmo. Evaluation of envelope protection functions include the requirements of 25.144.

(8) Low Energy Awareness, § 25.176(c)

[Contents for this section have not been sufficiently reviewed by the FTHWG.]

27. Static Directional and Lateral Stability - § 25.177.

a. Explanation.

(l) Static Directional Stability. Positive static directional stability is defined as the tendency to recover from a skid with the directional control~~rudder~~ free. This requirement returned at Amendment 25-135. Prior to Amendment 25-72, a separate demonstration of positive static directional stability was required by § 25.177(a) for any landing gear and flap position and symmetrical power or thrust condition at speeds from 1.13 V_{SR1} up to V_{FE}, V_{LE}, or V_{FC}/M_{FC}, as appropriate for the airplane configuration.

(2) Static Lateral Stability. Positive static lateral stability is defined as the tendency to raise the low wing in a sideslip with hands off the roll controls. This requirement returned at Amendment 25-135. Prior to Amendment 25-72, a separate demonstration was required by § 25.177(b) to show that static lateral stability was not negative in any landing gear and flap position and symmetrical power or thrust condition at speeds from 1.13 V_{SR1} to V_{FE}, V_{LE}, or V_{MO}/M_{MO}, as appropriate for the airplane configuration. At speeds from V_{MO}/M_{MO} to V_{FC}/M_{FC}, negative static lateral stability was permitted by § 25.177(b), if the divergence is:

(a) Gradual;

(b) Easily recognizable by the pilot; and

(c) Easily controllable by the pilot.

(3) Steady Straight Sideslips.

(a) Section 25.177(c) requires, in steady, straight sideslips throughout the range of sideslip angles appropriate to the operation of the airplane, that the directional~~aileron and rudder~~ control movements and forces be substantially proportional to the angle of sideslip. Also, the factor of proportionality must lie between limits found necessary for safe operation. The factor of proportionality is the slope of control movements and forces with respect to the angle of sideslip. During these straight, steady sideslips, necessary lateral control movements and forces must not be in the unstable sense with the exception of speeds above Vmo/Mmo per § 25.177(b)(2). Section 25.177(c) also states that that the range of sideslip angles evaluated must include those sideslip angles resulting from the lesser of: (1) one-half of the available directional~~rudder~~ control input; and (2) a directional~~rudder~~ control force of 180 pounds. This means that if using one-half of the available directional~~rudder~~ control input takes less than 180 pounds of force, then compliance must be based on using one-half of the available directional~~rudder~~ control input. If application of 180 pounds of directional~~rudder~~ control force results in using less than one-half of the available directional~~rudder~~ control input, then compliance must be based on applying 180 pounds of directional~~rudder~~ control force. By cross-reference to § 25.177(a), § 25.177(c) requires that these steady, straight sideslip criteria must be met for all landing gear and flap positions and symmetrical power or thrust conditions at speeds from 1.13 V_{SR1} to V_{FE}, V_{LE}, or V_{FC}/M_{FC}, as appropriate for the configuration.

(b) Experience has shown that an acceptable method for determining the appropriate sideslip angle for the operation of a transport category airplane is provided by the following equation:

$$ß = \arcsin (30/V)$$

where ß = Sideslip angle, and
V = Airspeed (KTAS)

Recognizing that smaller sideslip angles are appropriate as speed is increased, this equation provides sideslip angle as a function of airspeed. The equation is based on the theoretical sideslip value for a 30-knot crosswind, but has been shown to conservatively represent (i.e., exceed) the sideslip angles achieved in maximum crosswind takeoffs and landings and minimum static and dynamic control speed testing for a variety of transport category airplanes. Experience has also shown that a maximum sideslip angle of 15 degrees is generally appropriate for most transport category airplanes even though the equation above may provide a higher sideslip angle. However, limiting the maximum sideslip angle to 15 degrees may not be appropriate for airplanes with low approach speeds or high crosswind capability.

(c) A lower sideslip angle than that provided in paragraph 27a(3)(b) may be used if it is substantiated that the lower value conservatively covers all crosswind conditions, engine failure scenarios, and other conditions where sideslip may be experienced within the approved operating envelope. Conversely, a higher value should be used for airplanes where test evidence indicates that a higher value would be appropriate to the operation of the airplane.

(d) For the purpose of showing compliance with the requirement out to sideslip angles associated with the lesser of: (1) one-half of the available directional~~rudder~~ control input;

and (2) a directional~~rudder~~ control force of 180 pounds, there is no need to consider a directional~~rudder~~ control input beyond that corresponding to full available rudder surface travel. Some directional~~rudder~~ control system designs may limit the available rudder surface deflection such that full deflection for the particular flight condition, or the maximum commanded sideslip angle for the flight condition, is reached before the directional~~rudder~~ control reaches one-half of its available travel. In such cases, further directional~~rudder~~ control input is unnecessary as it would not result in a higher sideslip angle, and therefore would not affect compliance with the rule.

(4) Full Directional Control~~Rudder~~ Sideslips.

(a) At sideslip angles greater than those appropriate for normal operation of the airplane, up to the sideslip angle at which full directional~~rudder~~ control input is used or a directional~~rudder~~ control force of 180 pounds is obtained, § 25.177(d) requires that the directional (~~rudder~~ pedal) control forces may not reverse and increased rudder deflection must be needed for increased angles of sideslip. The goals of this higher-than-normal sideslip angle test are to show that at full directional~~rudder~~ control input, or at maximum expected pilot effort: (1) the directional~~rudder~~ control force does not reverse, and (2) increased rudder deflection must be needed for increased angles of sideslip, thus demonstrating freedom from rudder lock or fin stall, and adequate directional stability for maneuvers involving large rudder inputs.

(b) Compliance with this requirement should be shown using straight, steady sideslips. However, if full lateral control input is reached before full directional~~rudder~~ control travel or a directional~~rudder~~ control force of 180 pounds is reached, the maneuver may be continued in a non-steady heading (i.e., rolling and yawing) maneuver. Care should be taken to prevent excessive bank angles that may occur during this maneuver.

(c) Section 25.177(d) states that the criteria listed in paragraph 27a(4)(a) must be met at all approved landing gear and flap positions for the range of operating speeds and power conditions appropriate to each landing gear and flap position with all engines operating. The range of operating speeds and power conditions appropriate to each landing gear and flap position with all engines operating should be consistent with the following:

1 For takeoff configurations, speeds from V_2+xx (airspeed approved for all-engines-operating initial climb) to V_{FE} or V_{LE}, as appropriate, and takeoff power/thrust;

2 For flaps up configurations, speeds from 1.23 V_{SR} to V_{LE} or V_{MO}/M_{MO}, as appropriate, and power from idle to maximum continuous power/thrust;

3 For approach configurations, speeds from 1.23 V_{SR} to V_{FE} or V_{LE}, as appropriate, and power from idle to go-around power/thrust; and

4 For landing configurations, speeds from V_{REF}-5 knots to V_{FE} or V_{LE}, as appropriate, with power from idle to go-around power/thrust at speeds from V_{REF} to V_{FE}/V_{LE}, and idle power at V_{REF}-5 knots (to cover the landing flare).

b. Procedures. The test conditions should include each flap and landing gear configuration as described in paragraphs 27a(1) through 27a(4) at an altitude appropriate to each configuration.

(1) Basic Tests for Static Directional and Lateral Stability.

(a) Static Directional Stability. To check static directional stability with the airplane in the desired configuration and stabilized at the trim speed, the airplane is slowly yawed in both directions while maintaining the wings level with the lateral~~roll~~ controls. When the directional control~~rudder~~ is released, the airplane should tend to return to straight flight.

(b) Static Lateral Stability. To check lateral stability with a particular configuration and trim speed, conduct steady, straight sideslips at the trim speed by maintaining the airplane heading with directional control~~rudder~~ and banking with the lateral~~roll~~ controls. When the lateral~~roll~~ controls are released, with the directional control~~rudder~~ held fixed, and the low wing tends~~should tend~~ to return to level. Initial bank angle should be appropriate to type; however, it is recommended that it should not be less than 10 degrees or that necessary to maintain the steady, straight sideslip with one-half directional control~~rudder~~ deflection, whichever occurs first. If lateral control deflection is needed during the straight, steady sideslip, lateral~~ Roll~~ control centering by the pilot should not be permitted during this evaluation (only a control release).~~.~~ The intent of this testing is to evaluate the short-term response of the airplane; therefore long-term effects, such as those due to spanwise fuel movement, need not be taken into account.

(2) Steady, Straight Sideslips. Steady, straight sideslips should be conducted in each direction to show that the directional~~aileron and rudder~~ control movements and forces are substantially proportional to the angle of sideslip in a stable sense, and that the factor of proportionality is within the limits found necessary for safe operation. Also, the necessary lateral control movements and forces must not be in the unstable sense with the exception of speeds above Vmo/Mmo per § 25.177(b)(2).These tests should be conducted at progressively greater sideslip angles up to the sideslip angle appropriate to the operation of the airplane (see paragraph 27a(3)(b)) or the sideslip angle associated with one-half of the available directional~~rudder~~ control input (as limited by a directional~~rudder~~ control force of 180 pounds), whichever is greater.

(a) When determining the lateral~~rudder~~ and directional~~aileron~~ control forces, the controls should be relaxed at each point to find the minimum force needed to maintain the control surface deflection. If excessive friction is present, the resulting low forces will indicate the airplane does not have acceptable stability or proportionality characteristics.

(b) In lieu of conducting each of the separate qualitative tests described in paragraph 27b(1), the applicant may use recorded quantitative data showing lateral~~aileron~~ and directional~~rudder~~ control force and position versus sideslip (left and right) to the appropriate limits in the steady heading sideslips conducted to show compliance with § 25.177(c). If the control force and position versus sideslip indicates appropriate lateral stability~~positive dihedral effect~~ and positive directional stability, compliance with § 25.177(a) and (b) will have been successfully demonstrated.

(3) Full Directional Control~~Rudder~~ Sideslips.

(a) Rudder lock is that condition where the rudder over-balances aerodynamically and either deflects fully with no additional pilot input or does not tend to return to neutral when the pilot input is released. It is indicated by a reversal in the directional~~rudder~~ control force as sideslip angle is increased. Full directional control~~rudder~~ sideslips are conducted to determine the directional~~rudder~~ control forces and deflections out to sideslip angles associated with full directional~~rudder~~ control input (or as limited by a directional~~rudder~~ control force of 180 pounds) to investigate the potential for rudder lock and lack of directional stability.

(b) To check for positive directional stability and for the absence of rudder lock, conduct steady heading sideslips at increasing sideslip angles until obtaining full directional~~rudder~~ control input or a directional~~rudder~~ control force of 180 pounds. If full lateral control is reached before reaching the directional~~rudder~~ control limit or 180 pounds of directional~~rudder~~ control force, continue the test to the directional control~~rudder~~ limiting condition in a non-steady heading sideslip maneuver.

(4) Control Limits. The control limits approved for the airplane should not be exceeded when conducting the flight tests required by § 25.177.

(5) Flight Test Safety Concerns. In planning for and conducting the full directional control~~rudder~~ sideslips, items relevant to flight test safety should be considered, including:

(a) Inadvertent stalls,

(b) Effects of sideslip on stall protection systems,

(c) Actuation of stick pusher, including the effects of sideslip on angle-of-attack sensor vanes,

(d) Heavy buffet,

(e) Exceeding flap loads or other structural limits,

(f) Extreme bank angles,

(g) Propulsion system behavior (e.g., propeller stress, fuel and oil supply, and inlet stability),

(h) Minimum altitude for recovery,

(i) Resulting roll rates when the sideslip at the lateral control~~aileron~~ limit is exceeded, and

(j) Position errors and effects on electronic or augmented flight control systems, especially when using the airplane's production airspeed system.

(k) Rudder loads, particularly those that may occur with dynamic rudder inputs.
(l) Cross-axis control system considerations.

28. Dynamic Stability - § 25.181.

a. Explanation. While the purpose of 25.173-177 are to ensure that the airplane exhibits satisfactory static stability and control feel characteristics, the purpose of 25.181 is to ensure that the dynamics of any motion resulting from control input or from external disturbances is satisfactory, such that the motion does not impede the pilot's ability to achieve precise attitude control. Therefore, 25.181 requires that longitudinal short period dynamics be heavily damped and the lateral-directional dynamics be positively damped and controllable without exceptional strength or skill. Evaluation of dynamic stability characteristics should include the response to turbulence and gusts. Nonlinear effects should also be considered such as authority or rate limits and EFCS mode transitions or nonlinear feedback.

~~a. Explanation.~~

(1) The dynamic stability tests described in this section should be conducted over the speed range of 1.13 V_{SR} to V_{FE}, V_{LE} or V_{FC}/M_{FC}, as appropriate.

(2) Dynamic Longitudinal Stability.

(a) The classic short period oscillation is the first oscillation the pilot sees after disturbing the airplane from its trim condition with the pitch control (as opposed to the long period (phugoid)). Care should be taken that the control movement used to excite the motion is not too abrupt.

(b) Heavily damped means that the oscillation has decreased to 1/10 the initial amplitude within approximately two cycles after completion of the control input.

(c) Short period oscillations must be heavily damped, both with controls free and controls fixed.

(3) Dynamic Lateral-Directional Stability. The evaluation of the dynamic lateral-directional stability should include any combined lateral-directional oscillation (classically "~~(~~"Dutch roll") occurring over the speed range appropriate to the airplane configuration. This oscillation must be positively damped with controls free and must be controllable with normal use of the primary controls without requiring exceptional piloting skill.

(4) EFCS and SAS Characteristics. The use of a closed-loop EFCS or SAS has the potential to introduce additional dynamic modes, whose character may be distinct from or a modification of the classical short period or "Dutch roll" oscillatory modes. Any

dynamic motion, whether stemming from the aerodynamic short period or Dutch roll modes or generated by closed loop systems interactions should be evaluated under 25.181 for adequate stability characteristics. The frequency range of interest for these modes of motion is one in which dynamic modes affect the pilot's control of the airplane.

b. Procedures.

(1) Dynamic Longitudinal Stability.

(a) The test for longitudinal dynamic stability is accomplished by a rapid movement or pulse of the longitudinal control in a nose up and nose down direction at a rate and degree necessary to obtain a short period pitch response from the airplane. The best way to excite a particular mode of motion is via a doublet input at the target frequency. Appropriate frequencies for excitation should be selected after reviewing the frequencies of the augmented and unaugmented airplane, and its control system.

(b) Dynamic longitudinal stability should be checked at a sufficient number of points in each configuration to assure compliance at all operational speeds.

(2) Dynamic Lateral--Directional Stability.

(a) A typical test for lateral-directional dynamic stability is accomplished by a directional controlrudder doublet or triplet input at a rate and amplitude that will excite the lateral-directional response (i.e., Dutch roll). The control input should be in phase with the airplane's oscillatory response.

(b) Dynamic lateral--directional stability should be checked under all conditions and configurations. If critical, special emphasis should be placed on adverse wing fuel loading conditions.

(3) Airplanes Equipped with a Closed Loop EFCS or Stability Augmentation Systems (SAS). In the event a closed loop control system SAS is operating while demonstratingrequired for the airplane to show compliance with § 25.181(a) or (b), it must also meet the requirements of §§ 25.671 and 25.672. The potential for additional dynamic modes of motion should be considered and investigated in their axes and at their critical frequencies with the systems operating normally. Additionally:

(a) If a single failure of the EFCS/SAS can degrade dynamic stability characteristics, such as for an airplane (a) If the airplane is equipped with only one SAS (i.e., a single strand system), in accordance with § 25.672, compliance with the dynamic stability requirements of § 25.181(a) or (b), as applicable, must be shown throughout the normal operating flight envelope to be certificated with the EFCS/SAS operating normally, and in a reduced, practical operating flight envelope that will permit continued safe flight and landing with the single EFCS/SAS failureinoperative.

(b) If the airplane is equipped with more than one SAS, the resulting effects of SAS failure should be considered when determining whether or not the primary and any redundant SAS should be operating simultaneously for showing compliance with the dynamic stability requirements of § 25.181(a) or (b). If the primary and redundant SAS are dissimilar, the functional capability (i.e., control authority) of the redundant SAS should be considered with regard to restricting the operating envelope after failure of the primary SAS. At the applicant's option, however, compliance with § 25.181(a) or (b) may still be demonstrated to a reduced flight envelope with no SAS operating as described in paragraph 28b(3)(a), above.

(c) Regardless of the EFCS/SAS redundancy, following any single failure or combination of failures not shown to be extremely improbable~~SAS redundancy~~, the airplane should be safely controllable at the point of system failure or malfunction anywhere in the approved operating flight envelope of the airplane. Accordingly, it should be demonstrated that the airplane remains controllable during transition from the operating SAS to any redundant SAS, and during transition from anywhere in the normal operating envelope to the reduced practical operating envelope of § 25.672(c), if applicable. Airplane controllability should be demonstrated to meet the following levels as defined by the FAA HQRM. (The FAA HQRM is described in Appendix 5 of this AC.)

1 In the normal operating flight envelope with the SAS operating, the handling qualities should be "satisfactory" (SAT) as defined by the FAA HQRM.

2 At the point of SAS failure in the normal operating envelope, the airplane should be "controllable" (CON), as defined by the FAA HQRM, during the short term transitory period required to attain a speed and configuration that will permit compliance with paragraph 3, below.

3 During transition from the primary SAS to a redundant SAS, or from the normal operating envelope to a reduced, practical operating envelope (where applicable), the handling qualities should be "adequate" (ADQ) as defined by the HQRM.

4 In the reduced, practical operating flight envelope that will permit continued safe flight and landing, the handling qualities should be "satisfactory" (SAT) as defined by the HQRM.

Section 6. Stalls

29. Stall Testing.

a. The applicable Code of Federal Regulations (CFR) are as follows:

Section 25.21(c) Proof of Compliance

Section 25.103 Reference Stall Speed

Section 25.143 Controllability and Maneuverability (General)

Section 25.201 Stall Demonstration

Section 25.202 Handling demonstrations for high angle-of-attack limiting functions

Section 25.203 Stall Characteristics

Section 25.204 Flight characteristics for high angle-of-attack limiting functions

Section 25.207 Stall Warning

b. Explanation.

(1) The purpose of stall or high angle-of-attack testing is threefold:

(a) To define the reference stall speeds and how they vary with weight, altitude, and airplane configuration.

(b) To demonstrate that handling qualities are adequate to allow a safe recovery from the highest angle-of-attack attainable in normal flight. ~~(stall characteristics).~~

(c) When stall warning is required, to~~To~~ determine that there is adequate pre-stall warning (either aerodynamic or artificial) to allow the pilot time to recover from any probable high angle-of-attack condition without inadvertently stalling the airplane.

(2) During this testing, the angle-of-attack should be increased at least to the point where either, (a) the behavior of the airplane gives the pilot a clear and distinctive indication through the inherent flight characteristics or the characteristics resulting from the operation of a stall identification device (e.g., a stick pusher) that the airplane is stalled ,or (b) the airplane has reached a stabilized flight condition at the AOA-limit with the longitudinal control at the aft stop with a High Angle-of-Attack Limiting Function (HALF) installed. In addition, if compliance is to be shown to §§ 25.202 & 25.204 in lieu of §§25.201 & 25.203 with a HALF installed, high angle of attack testing beyond the AOA-limit up to the angle of attack corresponding to V_{SR} or the peak angle of attack achieved during dynamic maneuvers to the AOA-limit is required with the High Angle-of-Attack Limiting Function deactivated or adjusted, at the option of the applicant.

c. Stall Demonstration - § 25.201.

(1) The airplane is considered to be fully stalled when any one or a combination of the characteristics listed below occurs to give the pilot a clear and distinctive indication to cease any

further increase in angle-of-attack, at which time recovery should be initiated using normal techniques.

(a) The pitch control reaches the aft stop and is held full aft for two seconds, or until the pitch attitude stops increasing, whichever occurs later. In the case of turning flight stalls, recovery may be initiated once the pitch control reaches the aft stop when accompanied by a rolling motion that is not immediately controllable (provided the rolling motion complies with § 25.203(c)).

(b) An uncommanded, distinctive, and easily recognizable nose down pitch that cannot be readily arrested. This nose down pitch may be accompanied by a rolling motion that is not immediately controllable, provided that the rolling motion complies with § 25.203(b) or (c), as appropriate.

(c) The airplane demonstrates an unmistakable, inherent aerodynamic warning of a magnitude and severity that is a strong and effective deterrent to further speed reduction. This deterrent level of aerodynamic warning (i.e., buffet) should be of a much greater magnitude than the initial buffet ordinarily associated with stall warning. An example is a large transport airplane that exhibits "deterrent buffet" with flaps up and is characterized by an intensity that inhibits reading cockpit instruments and would require a strong determined effort by the pilot to increase the angle-of-attack any further.

(d) The activation point of a stall identification device that provides one of the characteristics listed above. See paragraph 228 of this AC for additional guidance material on demonstrating compliance with the regulatory requirements of part 25 for stall identification systems.

(2) It should be recognized that the point at which the airplane is considered stalled may vary, depending on the airplane configuration (e.g., flaps, gear, c.g., and gross weight). In any case, the angle-of-attack should be increased until one or more of these characteristics is reached for all likely combinations of variables.

d. Handling demonstrations for high angle-of-attack limiting functions - § 25.202. If a High Angle-of-Attack Limiting Function (HALF) is installed that meets the capability and reliability requirements of § 25.202(a), the applicant may choose to show compliance with § 25.202 in lieu of § 25.201.

(1) Section 25.202(a)(1) requires consistent application of the alternative requirements of §§ 25.202 and 25.204 for HALF equipped airplanes to all normal flap and landing gear configurations. If a HALF is used to prevent stall for any normal flap and landing gear configuration under the criteria of §§ 25.202 and 25.204, the airplane must comply with the requirements of §§ 25.202 and 25.204 in all normal flap and landing gear configurations up to the maximum altitude approved for flaps down operation. Above these altitudes, the HALF must be shown to prevent stall for flaps and gear up configuration in low entry rate maneuvers up to the maximum altitude expected in operation in accordance with § 25.21(c) as described in paragraph 29h(2)(g) of this AC.

(2) Section 25.202(a)(2) requires that the airplane not encounter a stall during the maneuvers prescribed in § 25.202(b)-(d) in icing and non-icing conditions. Airplane behavior that is considered indicative of stall includes:

(a) Abnormal or abrupt nose-up pitching;

(b) Uncommanded nose-down pitching (i.e., not commanded by the pilot or the HALF);

(c) Uncommanded lateral or directional motion; or

(d) Buffeting of a magnitude and severity that would act as a deterrent from completing the specified maneuvers.

(3) Section 25.202(a)(3) requires that the airplane be protected from stalling and that the High Angle-of-Attack Limiting Function not adversely interfere with or affect airplane control in expected levels of atmospheric disturbances. Compliance with this requirement can be shown using a combination of piloted simulation evaluations and an evaluation throughout the test program during elevated levels of turbulence and gusts, including crosswind takeoff and landing flight testing. It is not intended that flight testing at the AOA limit be conducted in elevated levels of turbulence or gusts. Instead, simulation evaluations should include assessments of level flight in moderate turbulence to assure that stall AOA is not encountered when operating at an airspeed associated with the AOA limit (full aft control input) or if so equipped; at the minimum airspeed free of a continuous and non-cancellable low speed/energy caution or warning alert in accordance with §25.1322 (or equivalent); or activation of a low speed/energy protection system or high AOA alert (e.g. stick shaker)). §25.202(a)(3) also requires that the airplane be protected from stalling and that the High Angle-of-Attack Limiting Function not impede the application of recovery procedures in case of wind shear. Simulation testing (fixed base is considered sufficient) or suitable engineering analysis with wind-shear encounters during takeoff and landing where the airplane may be flown at, or very near, the AOA limit should also be evaluated to assure the HALF does not adversely interfere with recovery and a stall is not encountered when the recovery is flown in accordance with the applicant's recommended procedure. The wind-shear profiles provided in FAA AC120-41 may be used for this assessment. Alternatively, the maneuvers to the AOA limit for compliance with §25.202(d)(4), including rapid application of go-around thrust for approach and landing configurations (if more critical), can be used to show compliance with the requirements of §25.202(a)(3) in case of wind-shear. In order for these flight test results to be considered acceptable for this purpose, it must be assured that the airplane response to pilot inputs demonstrated during the maneuvers to the AOA limit for compliance with §25.202(d)(4) in still air are representative of the pitch response and AOA control at the AOA limit expected during a wind-shear encounter.

(4) Section 25.202(a)(4) requires that the HALF be provided and be capable of preventing stall in each abnormal configuration of the high lift system resulting from probable failures (on the order of 1E-5/flt-hr or greater). Improbable failures of the high lift system that would result in the HALF being either ineffective or inoperative would be permissible under the requirement of §25.202(a)(4)&(5), provided that a suitable stall warning is provided that complies with the requirements of §25.207(j).

(5) Section 25.202(a)(5) establishes the failure probability requirement for a High Angle-of-Attack Limiting Function as improbable. Consistent with §25.1309 criteria, this is interpreted to mean a maximum failure rate on the order of 1E-5/flt-hr or less. In addition, the High Angle-of-Attack Limiting Function and its supporting airplane systems must comply with § 25.1309, consistent with identified hazards for failure of the High Angle-of-Attack Limiting Function appropriate for the airplane.

e. Reference Stall Speeds - § 25.103.

(1) Background. Since many of the regulations pertaining to performance and handling qualities specify trim speeds and other variables that are functions of reference stall speeds, it is desirable to accomplish the reference stall speed testing early in the program, so the data are available for subsequent testing. Because of this interrelationship between the reference stall speeds and other critical performance parameters, it is essential that accurate measurement methods be used. Most standard airplane pitot-static systems are unacceptable for stall speed determination. These tests require the use of properly calibrated instruments and usually require a separate test airspeed system.

(2) Configuration.

(a) Reference stall~~Stall~~ speeds should be determined for all aerodynamic configurations to be certificated for use in the takeoff, en route, approach, and landing configurations.

(b) The c.g. positions to be used should be those that result in the highest reference stall speeds for each weight (forward c.g. in most cases).

(c) Sufficient testing should be conducted to determine the effects of weight on reference stall speed. Altitude effects (compressibility, Reynolds Number) may also be considered if credit for variations in these parameters is sought by the applicant. If reference stall speeds are not to be defined as a function of altitude, then all reference stall speed testing should be conducted at a nominal altitude no lower than 1,500 ft. above the maximum approved takeoff and landing altitude. (See paragraph 29e~~29d~~(5)(g).)

(3) Procedures.

(a) The airplane should be trimmed for hands-off straight flight at a speed 13 percent to 30 percent above the anticipated V_{SR}, with the engines at idle and the airplane in the configuration for which the reference stall speed is being determined. Then, using only the primary longitudinal control for speed reduction, maintain a constant deceleration (entry rate) until the airplane has achieved one of the criteria established by § 25.103(c). The airplane should then be recovered using normal techniques. Engine~~is stalled, as defined in § 25.201(d) and paragraph 29c(1) of this AC. Following the stall, engine~~ power or thrust may be used as desired to expedite recovery.

(b) A sufficient number of maneuvers~~stalls~~ (normally four to eight) should be accomplished at each critical combination of weight, altitude, c.g., and external configuration. The intent is to obtain enough data to determine the reference stall speed at an entry rate not exceeding 1.0 knot/second. During the maneuver for determining reference stall speeds, the flight controls should be operated smoothly in order to achieve good data quality rather than trying to maintain a constant entry rate because experience has shown that adjusting the flight controls to maintain a constant entry rate leads to fluctuations in load factor and significant data scatter.

(c) During the reference stall speed testing, the flight~~stall~~ characteristics of the airplane must also satisfy the requirements of § 25.203(a) and (b) , or § 25.204(f), as appropriate.~~).~~

(d) For airplanes that have stall identification devices for which the angle-of-attack for activation is biased by angle-of-attack rate, some additional considerations are necessary. The reference stall speeds are normalized against an average airspeed deceleration rate, as described in paragraph 29e~~29d~~(5)(e). However, stall identification systems generally activate at a specific angle-of-attack, biased by an instantaneous angle-of-attack rate. Therefore, longitudinal control manipulation by the pilot during the stall maneuver, close to the stall identification system activation point, can advance or delay its activation without appreciably affecting the average stall entry airspeed rate. To minimize scatter in the reference stall speed versus entry rate data, the pilot should attempt to maintain a stable angle-of-attack rate or pitch rate (not necessarily a fixed airspeed deceleration rate), until the stall identification system activates. The resulting time-history of angle-of-attack data should be smooth and without discontinuities. A cross plot of airspeed deceleration rate, as defined in paragraph 29e~~29d~~(5)(e), versus angle-of-attack rate for all related test points, will show the general trend of this relationship for each flap setting. Any points that do not follow this general trend should not be used in establishing the reference stall speed.

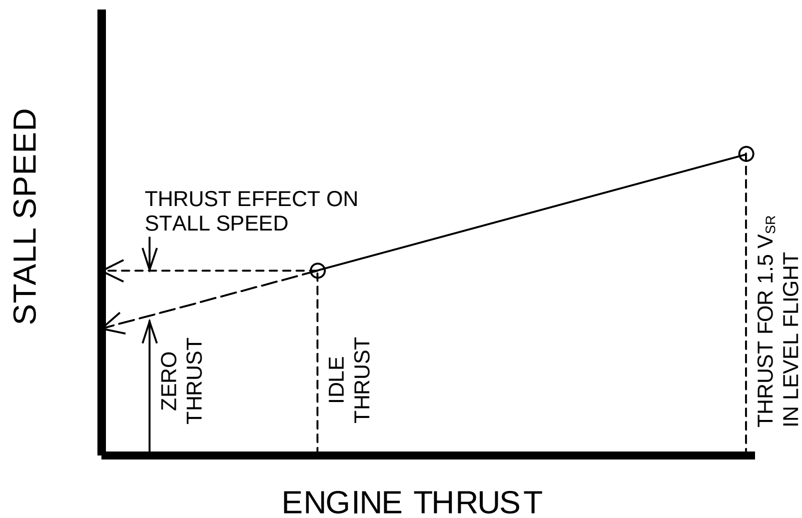
(4) Thrust Effects on Reference Stall Speed.

(a) Reference stall~~Stall~~ speeds are typically determined with the thrust levers at idle; however, it is necessary to verify by test or analysis that engine idle thrust does not result in appreciably lower reference stall speeds than would be obtained at zero thrust. Prior to Amendment 25-108, a negative idle thrust at the stall, which slightly increases stall speeds, was considered acceptable, but applicants were not required to base stall speeds on idle thrust. With the adoption of Amendment 25-108, it became a requirement to base reference stall speeds on idle thrust, except where that thrust level results in a significant decrease in reference stall speeds. If idle thrust results in a significant decrease in reference stall speeds, then reference stall speeds cannot be based on more than zero thrust.

(b) To determine whether thrust effects on reference stall speed are significant, at least three maneuvers~~stalls~~ should be conducted at one flap setting, with thrust set to approximately the value required to maintain level flight at 1.5 V_{SR} in the selected configuration.

(c) These data may then be extrapolated to a zero thrust condition to determine the effects of idle thrust on reference stall speeds (see Figure 29-1). If the difference between idle thrust and zero thrust reference stall speed is 0.5 knots or less, the effect may be considered insignificant.

Figure 29-1. Thrust Effect On Stall Speed



(d) The effects of engine power on reference stall speeds for a turbopropeller airplane can be evaluated in a similar manner. Reference stall~~Stall~~ speed flight tests should be accomplished with engines idling and the propellers in the takeoff position. Engine torque, engine r.p.m., and estimated propeller efficiency can be used to predict the thrust associated with this configuration.

(5) Data Reduction and Presentation. The following is an example of how the data obtained during the reference stall speed testing may be reduced to standard conditions. Other methods may be found acceptable.

(a) Record the indicated airspeed from the flight test airspeed system throughout the maneuver~~stall~~, and correct these values to equivalent airspeed. Also record load factor normal to the flight path. Typically, the load factor data would be obtained from a sufficient number of accelerometers capable of resolving the flight path load factor. It *may* be possible to obtain acceptable data using one accelerometer aligned along the expected 1-g stall pitch angle. More likely, it will take at least two accelerometers, one aligned along the fuselage longitudinal axis and one aligned at 90 degrees to that axis, as well as a means to determine the angle between the flight path and the fuselage longitudinal axis.

(b) Calculate the airplane lift coefficient (C_L) from the equation given below and plot it as a time history throughout the ~~stall~~ maneuver.

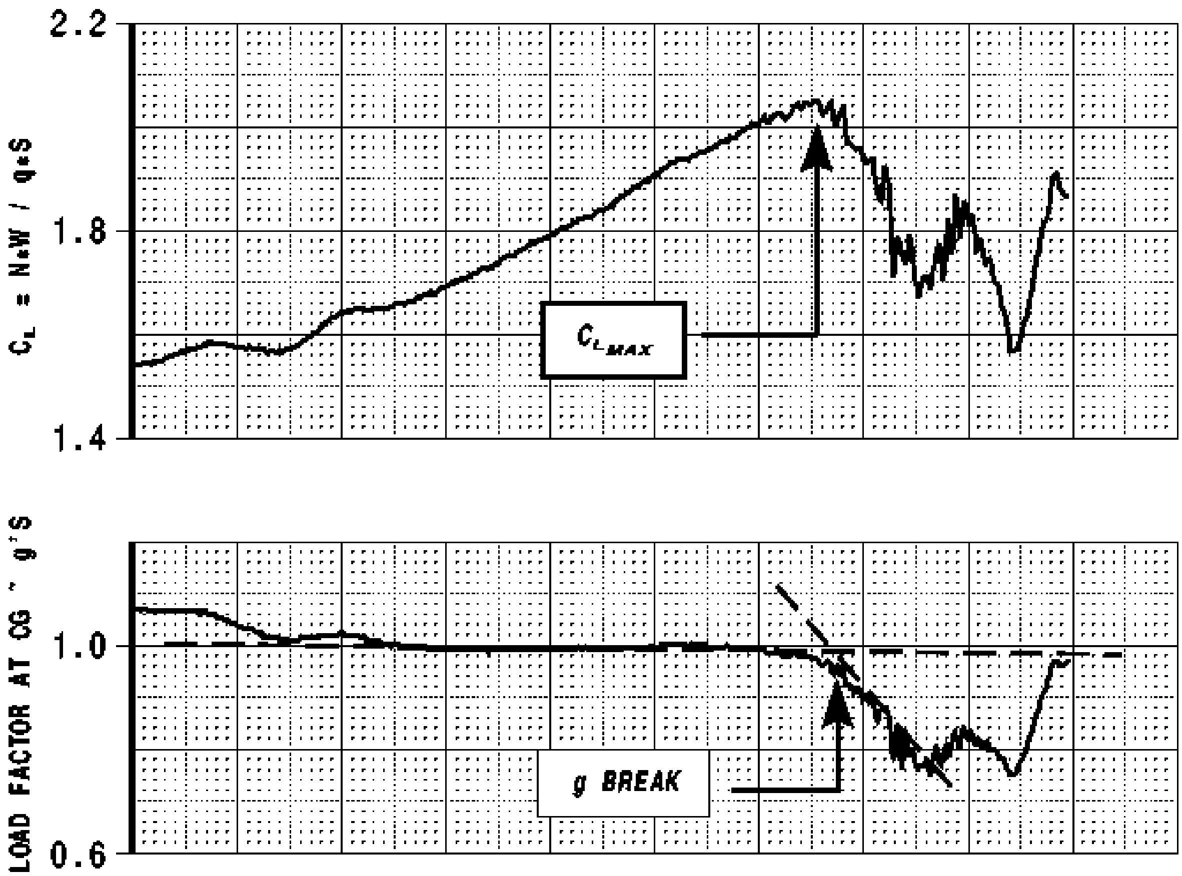
$$C_L = \frac{n_{zw}W}{qS} = \frac{295.37 n_{zw}W}{V_e^{\,2}S}$$

Where: n_{zw} = airplane load factor normal to the flight path

W = airplane test weight - lbs.
q = dynamic pressure - lbs./ft.^{2}
S = reference wing area - ft.^{2}
V_e = knots equivalent airspeed.

(c) The maximum lift coefficient (C_{LMAX}) is defined as the maximum value of C_L achieved during the test. At the option of the applicant this testing need only extend to the angle-of-attack and CL at which the reference stall speed is to be established, except when a stick pusher is installed where testing should extend to the activation of the stick pusher such that compliance with § 25.103(d) can be shown.~~stall test.~~ Where the time history plot of C_L exhibits multiple peak values, C_{LMAX} normally corresponds to the first maximum. However, the peak corresponding to the highest C_L achieved may be used for C_{LMAX}, provided it represents usable lift, meaning that it does not occur after deterrent buffet or other stall identification cue (ref. § 25.201(d)). There should also typically be a noticeable break in a plot of the load factor normal to the flight path near the point at which C_{LMAX} is reached. The analysis to determine C_{LMAX} should disregard any transient or dynamic increases in recorded load factor, such as might be generated by abrupt control inputs that do not reflect the lift capability of the airplane. The load factor normal to the flight path should be maintained at nominally 1.0 until C_{LMAX} is reached. (See Figure 29-2.)

Figure 29-2. C_{LMAX} and Load Factor



(d) Correct the $C_{L_{MAX}}$ obtained for each maneuver~~stall~~, if necessary, from the test c.g. position to the targeted c.g. position, and for any thrust effects, using the equation:

$$C_{L_{MAX}} = C_{L_{MAX}\,(\text{test c.g. position})}[1 + (MAC/l_t)(CG_{std} - CG_{test})] - \Delta C_{L_T}$$

Where: MAC = Wing mean aerodynamic chord length - inches.

l_t = Effective tail length, measured between the wing 25 percent MAC and the stabilizer 25 percent MAC - inches.

CG_{std} = C.G. position resulting in the highest value of reference stall speed (normally the forward c.g. limit at the pertinent weight) - percent MAC/100.

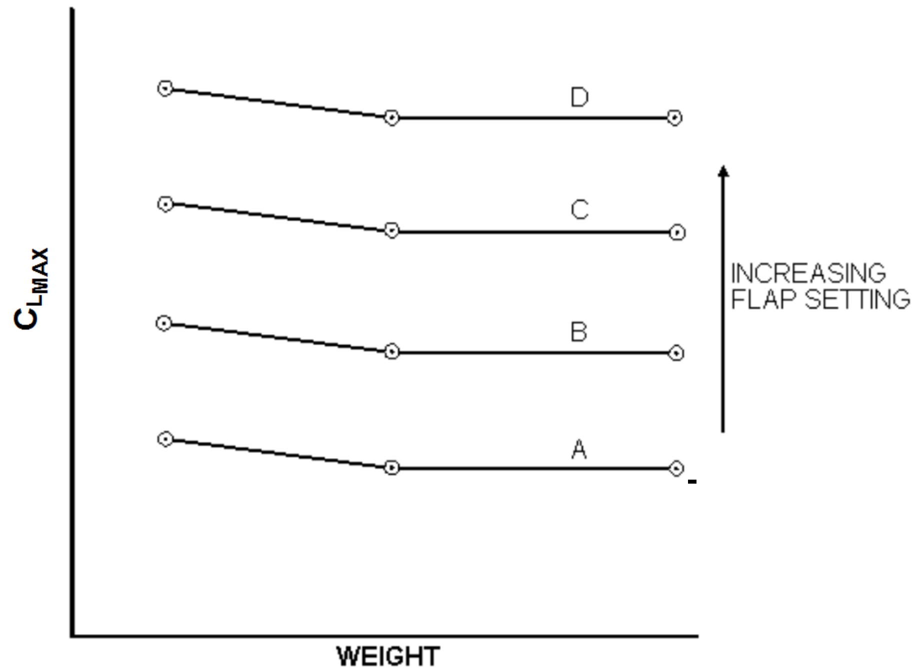
CG_{test} = Actual test c.g. position - percent MAC/100.

ΔC_{L_T} = Change in C_L due to engine thrust (if effect of idle thrust is greater than 0.5 knots in stall speed).

(e) Determine the ~~stall~~ entry rate, which is defined as the slope of a straight line connecting the reference stall speed and an airspeed 10 percent above the reference stall speed, for each ~~stall~~ test. Because C_{LMAX} is relatively insensitive to ~~stall~~ entry rate, a rigorous investigation of entry rate effects should not be necessary.

(f) For each approved configuration, construct a plot of $C_{L_{MAX}}$ versus weight (see Figure 29-3.)

Figure 29-3. $C_{L_{MAX}}$ vs Weight and Flap Setting



(g) Flight test safety concerns usually dictate the lowest test altitude for determining stall speeds. The test data should then be expanded to lower altitudes, and hence lower Mach numbers, to cover the operational envelope of the airplane. Since $C_{L_{MAX}}$ usually increases as the Mach number is reduced, simple expansion of the flight test data could result in extrapolating to a higher $C_{L_{MAX}}$ than tested. The expansion of $C_{L_{MAX}}$ versus Mach number data is only permitted up to the highest $C_{L_{MAX}}$ demonstrated within the range of W/δ's tested, unless the continuation of the trend of higher $C_{L_{MAX}}$ with decreasing Mach number is substantiated with other test data. For example, data obtained at a more aft c.g. position or with power on can be used for this purpose if c.g. and thrust effects can be accounted for. Data from another airplane in the same family with the same wing and showing the same general trend of $C_{L_{MAX}}$ versus Mach (e.g., a lighter weight variant) may also be used if shown to be applicable.

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

$$V_{SR} \geq \frac{V_{CL_{MAX}}}{\sqrt{n_{zw}}}$$

Where: $V_{C_{L_{MAX}}} = \sqrt{295.37(n_{ZW})(W)/(C_{L_{MAX}}S)} + \Delta V_C$. If the stalling maneuver is limited by a device that commands an abrupt nose down pitch (i.e.g., a stick pusher), $C_{L_{MAX}}$ may not be less than the speed existing at the instant the device operates.

ΔV_C = compressibility correction (i.e., the difference between equivalent airspeed and calibrated airspeed).

W = airplane weight - lbs.

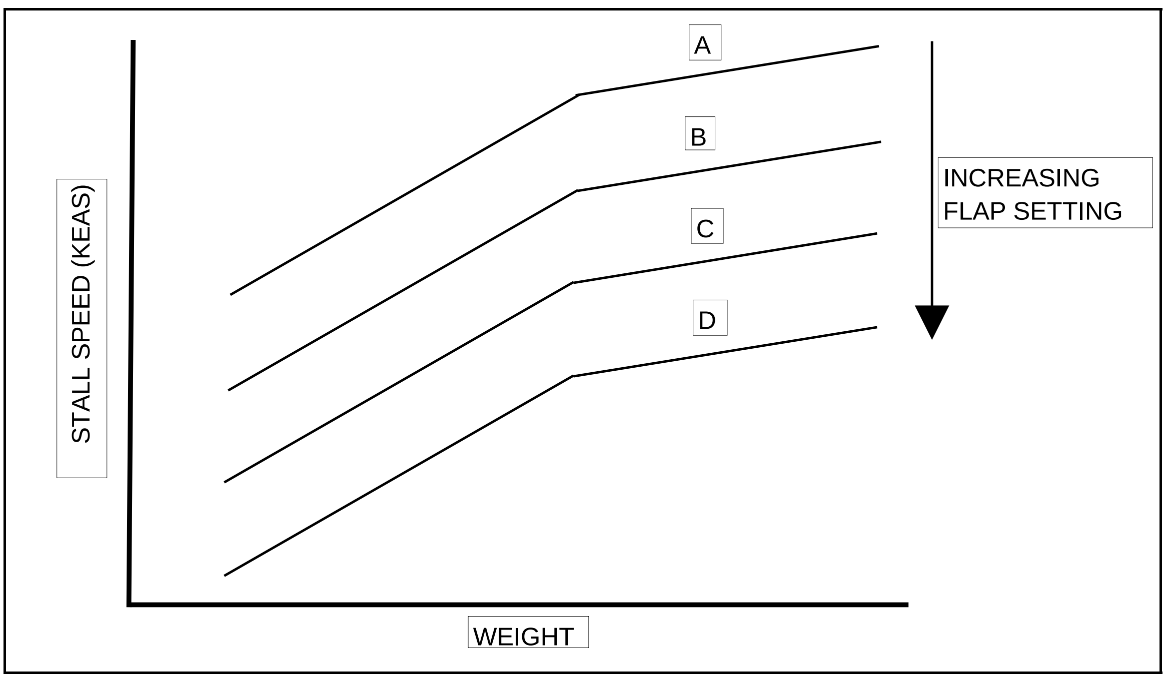
n_{zw} = airplane load factor normal to the flight path.

$C_{L_{MAX}}$ = value of $C_{L_{MAX}}$ corresponding to the chosen weight (see Figure 29-4).

S = reference wing area - ft.^{2}

(i) Construct a plot of reference stall speed versus weight for each flap/gear configuration. (See Figure 29-4).

Figure 29-4. Stall Speed vs Weight and Flap Setting



(j) For airplanes equipped with a device that abruptly pushes the nose down at a selected angle-of-attack (i.e.g., a stick pusher), V_{SR} must not be less than the greater of 2 knots or 2 percent above the speed at which the device activates (§ 25.103(d)).

(k) In showing compliance with § 25.103(d) for airplanes equipped a device that abruptly pushes the nose down at a selected angle-of-attack (i.e.g., a stick pusher), the speed at which the device operates need not be corrected to 1 g. Requiring a load factor correction of the device activation speed to the 1-g condition would unnecessarily increase the stringency of § 25.103(d). For example, it would be possible for the device activation speed to be assessed as higher than V_{SR} (or at least closer to V_{SR} than would be obtained without correcting to the 1 g condition). Test procedures should be in accordance with paragraph 29d(3)(a) to ensure that no abnormal or unusual pilot control input is used to obtain an artificially low speed at which the device first activates.

f. Minimum Steady Flight Speed - § 25.103(e).

(1) Background. With a High Angle-of-Attack Limiting Function (HALF) installed, the one-g minimum steady flight speed, V_{MIN1g}, must be established if it is used to determine compliance with a required performance standard or other requirements demonstrations. Otherwise, determination of V_{MIN1g} is at the option of the applicant. V_{MIN1g} is defined as the minimum calibrated airspeed at which the airplane can develop a lift force (normal to the flight path) equal to its weight, while stabilized the limit angle of attack achieved with the High Angle-of-Attack Limiting Function operating normally. If V_{MIN1g} is to be established, it should be determined by flight test as the final stabilized calibrated airspeed obtained when the airplane is decelerated in straight flight until the longitudinal control is on its stop with the HALF operating normally, in such a way that the entry rate does not exceed 1 knot per second.

(2) Configuration.

(a) One-g minimum steady flight speeds, V_{MIN1g}, must be determined for all aerodynamic configurations for which it is to be used to show compliance with a required performance standard or other requirement (e.g., takeoff, en route, approach, and landing configurations).

(b) The c.g. positions to be used should be those that result in the highest V_{MIN1g} for each weight (forward c.g. in most cases).

(c) Sufficient test data should be available to determine the effects of weight on V_{MIN1g}. Altitude effects (compressibility, Reynolds number) may also be considered if credit for variations in these parameters is sought by the applicant.

(3) Procedures.

(a) V_{MIN1g} should be determined by dedicated flight testing if it is used to determine compliance with a required performance standard or other requirements demonstration. If V_{MIN1g} is not used in this manner, it is acceptable to determine V_{MIN1g} by analysis or simulation, provided it is shown to be conservative by comparison to other flight testing required for compliance with §§ 25.103, 25.202 & 25.204.

(b) The airplane should be trimmed for straight flight at a speed 13 percent (or the minimum trim speed, if higher than 1.13 V_{MIN1g}) to 30 percent above the anticipated V_{MIN1g}, with the engines at idle and the airplane in the configuration for which the minimum flight speed is being determined. Then, using only the primary longitudinal control for speed reduction, maintain a constant deceleration (entry rate) not exceeding 1 knot per second until the longitudinal control reaches the aft stop. The control should be maintained at the aft stop until the airplane has reached a stabilized flight condition from which V_{MIN1g} can be determined. Some airspeed variation while maintaining full aft control may occur and data analysis should be used to establish the one-g minimum steady speed.

(c) The High Angle-of-Attack Limiting Function is expected to provide repeatable minimum steady speeds for a particular flight condition. A sufficient number of maneuvers should be accomplished at each critical combination of weight, altitude, c.g., and external configuration to assure that is the case.

(d) During the minimum steady flight speed testing, the flight characteristics of the airplane must also satisfy the requirements of § 25.204(b).

(4) Data Reduction and Presentation. Analysis to determine the one-g minimum steady flight speed should be conducted in a manner similar to that for the reference stall speeds (Paragraph 29e(5) of this AC).

g. Stall Characteristics - § 25.203.

(1) Background. If a High Angle-of-Attack Limiting Function that meets the requirements of §§ 25.202 and 25.204 is not installed, the stall characteristics requirements of § 25.203 must be met. ~~(1) Background.~~ To assure a safe and expeditious recovery from an unintentional stall, it should not require any unusual piloting technique to successfully demonstrate compliance with § 25.203, nor should it require exceptional skill or repeated practice by the test pilot. The behavior of the airplane during the stall and recovery must be easily controllable using normally expected pilot reactions.

(2) Configuration.

(a) Stall characteristics should be investigated with wings level and in a 30-degree banked turn, with both power or thrust on and power or thrust off in all configurations approved for normal operations.

(b) The test configurations for stall characteristics should include deployed deceleration devices for all flap positions, unless limitations against the use of those devices with particular flap positions are imposed. 'Deceleration devices' include spoilers used as airbrakes, and thrust reversers approved for inflight use. Stall demonstrations with deceleration devices deployed should normally be carried out with power or thrust off, except where deployment of the deceleration devices with power or thrust on would likely occur in normal operations (e.g., extended spoilers during landing approach).

(c) Stall characteristics should be investigated with any systems or devices that may alter the stalling behavior of the airplane in their normal functioning mode. Unless the design of the airplane's automatic flight control system precludes its ability to operate beyond the stall warning angle-of-attack, stall characteristics and the adequacy of stall warning should be evaluated when the airplane is stalled under the control of the automatic flight control system.

(d) Power-off stalls should be conducted at flight idle for the appropriate configuration. For propeller-driven airplanes, the propeller should be set in the normal low pitch (high r.p.m.) position.

(e) For power-on stalls, power or thrust should be set to the value required to maintain level flight at a speed of 1.5 V_{SR} at the maximum landing weight with flaps in the approach position, and the landing gear retracted. The approach flap position referred to is the maximum flap deflection used to show compliance with § 25.121(d), which specifies a configuration in which the reference stall speed does not exceed 110 percent of the reference stall speed for the related landing configuration.

(f) Stall characteristics testing is normally done at the aft c.g. limit, which is typically the most adverse; however, if the stall speed tests at forward c.g. indicate that marginal stall recovery characteristics may exist at forward c.g., compliance with § 25.203 should be shown for the most critical loading.

(g) In accordance with § 25.21(c), stalls must be demonstrated up to the maximum approved operating altitude to determine if there are any adverse compressibility effects on stall characteristics. These tests should be flown with gear and flaps up at the most adverse c.g. Power or thrust may be set, as required, to maintain approximately level flight and a 1 knot/second deceleration. A slight descent rate is permissible as long as the stall occurs at approximately the maximum approved altitude. Characteristics should be checked during a wings level stall and in a 30-degree banked turn.

(h) For abnormal aerodynamic configurations covered by AFM procedures, high angle-of-attack characteristics should be evaluated down to the speed reached one second after stall warning in a one knot/second deceleration with the wings level and at idle power or thrust. If there are no adverse characteristics and there is adequate controllability, it is not necessary to stall the airplane. Adequate controllability means that it is possible to produce and to correct pitch, roll, and yaw by unreversed use of the flight controls, and that there are no uncommanded airplane motions due to aerodynamic flow breakdown. The applicant should also demonstrate that the airplane is safely controllable and maneuverable when flown at the recommended operating speed.

(i) Stall characteristics should also be demonstrated with the maximum allowable asymmetric fuel loading. Requirements are as specified in § 25.203(a) and (c).

(3) <u>Procedures</u>.

(a) The airplane should be trimmed for hands-off flight at a speed 13 percent to 30 percent above the reference stall speed, with the appropriate power or thrust setting and configuration. Then, using only the primary longitudinal control, establish and maintain a deceleration (stall entry rate) consistent with that specified in § 25.201(c)(1) or (c)(2), as appropriate, until the airplane is stalled. Both power/thrust and pilot selectable trim should remain constant throughout the stall and recovery (to where the angle-of-attack has decreased to the point of no stall warning).

(b) The same trim reference (for example, 1.23 V_{SR}) should be used for both the stall speeds and characteristics testing. For all stall testing, the trim speed is based on the stall speeds provided in the AFM.

(c) During the approach to the stall, the longitudinal control pull force should increase continuously as speed is reduced from the trimmed speed to the onset of stall warning. Below that speed some reduction in longitudinal control force is acceptable, provided it is not sudden or excessive.

(d) Section 25.203(b) states that "the roll occurring between the stall and the completion of the recovery may not exceed approximately 20 degrees" for level wing stalls. In level wing stalls the bank angle may exceed 20 degrees occasionally, provided that lateral control is effective during recovery.

(e) Section 25.203(c) requires the action of the airplane, following the 30 degrees bank turning stalls, "not be so violent or extreme..." such that a prompt recovery would be difficult and require more than normal piloting skill. The maximum bank angle that occurs during the recovery should not exceed approximately 60 degrees in the original direction of the turn, or 30 degrees in the opposite direction.

(f) The intent of evaluating the 3 knot per second deceleration rate required under § 25.201(c)(2) is to demonstrate safe characteristics at higher rates of increase in angle-of-attack than are obtained from the 1 knot per second stalls. The specified airspeed deceleration rate, and associated angle-of-attack rate, should be maintained up to the point at which the airplane stalls. The maximum bank angle that occurs during the recovery should not exceed approximately 90 degrees in the original direction of the turn, or 60 degrees in the opposite direction.

(g) For those airplanes where stall is defined by full nose-up longitudinal control for both forward and aft c.g., the time at full aft stick during characteristics testing should be not less than that used for stall speed determination. For turning flight stalls, however, recovery may be initiated once the pitch control reaches the aft stop when accompanied by a rolling motion that is not immediately controllable (provided the rolling motion complies with § 25.203(c)).

(h) As required by § 25.203(a), normal use of the lateral control must produce (or correct) a roll, and normal use of the directional control must produce (or correct) a yaw in the applied direction up to the point where the airplane is considered stalled. It must be possible to prevent or recover from a stall by normal use of the controls.

(i) If wind tunnel tests have indicated an airplane may be susceptible to deep stall penetration (i.e., that area beyond the stall angle-of-attack from which recovery may be difficult or impossible), substantiation should be provided that there is adequate recovery control available at, and sufficiently beyond, the stall angle-of-attack.

h. Flight characteristics for high angle-of-attack limiting functions - § 25.204.

(1) Background. § 25.204 is applicable in lieu of § 25.203 for airplane designs that include a High Angle-of-Attack Limiting Function that meets the capability and reliability requirements of §25.202(a). It should not require any unusual piloting technique to successfully demonstrate compliance with § 25.204, nor should it require exceptional skill or repeated practice by the test pilot. The behavior of the airplane during the maneuvers to the AOA-limit and recovery must be easily controllable using conventional pilot control inputs.

(2) Configuration.

(a) Characteristics to the AOA-limit should be investigated with wings level and in a 30-degree banked turn as prescribed by § 25.202(b)(c) in all configurations approved for normal operations.

(b) The test configurations should include deployed deceleration devices for all flap positions, unless limitations against the use of those devices with particular flap positions are imposed. 'Deceleration devices' include spoilers used as airbrakes, and thrust reversers approved for inflight use. Demonstrations with deceleration devices deployed should normally be carried out with power or thrust off, except where deployment of the deceleration devices with power or thrust on would likely occur in normal operations (e.g., extended spoilers during landing approach).

(c) Characteristics to the AOA-limit should be investigated with the High Angle-of-Attack Limiting Function operating normally, except with the AOA-limit adjusted to the highest value when considering airframe and system tolerances, unless shown to be insignificant. Any other systems or devices that may alter the behavior of the airplane during the maneuvers should also be in their normal functioning mode, except that automatic thrust increase functions should be disabled as specified in §25.202(b)(1). Unless the design of the airplane's automatic flight control system precludes its ability to operate near the AOA-limit, characteristics should be evaluated when the airplane is flown to the AOA-limit under the control of the automatic flight control system.

(d) Engines idling conditions should be conducted at flight idle for the appropriate configuration. For propeller-driven airplanes, the propeller should be set in the normal low pitch (high r.p.m.) position.

(e) For power-on maneuvers, power or thrust should be set to the value required to maintain level flight at a speed of 1.5 V_{SR} at the maximum landing weight with flaps in the approach position, and the landing gear retracted. The approach flap position referred to is the maximum flap deflection used to show compliance with § 25.121(d), which specifies a configuration in which the reference stall speed does not exceed 110 percent of the reference stall speed for the related landing configuration.

(f) Testing is specified in § 25.202(c) to be conducted at the most adverse c.g. and weights throughout the range to be certified. The design of the High Angle-of-Attack Limiting Function and any pitch axis EFCS control law active prior to engagement of the HALF, may result in a critical weight and c.g. condition not traditionally expected. Sufficient weight and c.g. combinations should be tested to ensure that the airplane is compliant throughout the weight and c.g. envelope to be approved. Alternatively, analysis or simulation that has been shown to be valid may be used to identify critical conditions.

(g) In accordance with the intent of § 25.21(c), characteristics to the AOA-limit must be demonstrated up to the maximum approved operating altitude to determine if there are any adverse compressibility effects on characteristics. This high altitude assessment is intended to assure that stall is prevented during slow, near 1g decelerations at altitudes up to the maximum approved operating altitude. It is not required that the HALF be evaluated at Mach numbers associated with cruise conditions where an AOA-limit may only be achievable in maneuvering flight at elevated load factor. Tests to the AOA limit should be flown with gear and flaps up at the most adverse c.g. Power or thrust may be set, as required, to maintain approximately level flight and a 1 knot/second deceleration. A slight descent rate is permissible as long as the AOA-limit is achieved at approximately the maximum approved altitude. Characteristics should be checked during wings level and in a 30-degree banked turn maneuvers.

(h) For abnormal high-lift configurations covered by AFM procedures and where the High Angle-of-Attack Limiting Function remains operational and not annunciated as inoperative, characteristics should be evaluated to the AOA-limit with the wings level in a -1 kt/sec deceleration at idle power or thrust (§25.202(a)(4)). It should be possible to produce and to correct pitch, roll, and yaw by unreversed use of the flight controls, and there should be no uncommanded airplane motions due to aerodynamic flow breakdown. The applicant should also demonstrate that the airplane is safely controllable and maneuverable when flown at the recommended operating speed. Alternatively, if the HALF is disabled or annunciated to the flight crew as inoperative due to an improbable failure that results in an abnormal high-lift condition, compliance with 25.207(j) is required.

(i) Characteristics should be demonstrated with the maximum allowable asymmetric fuel loading unless it can be shown that it will not change the results of the test.

(3) Procedures.

(a) The airplane should be trimmed for hands-off flight at the all-engine minimum normal operating speed appropriate for the configuration (e.g., V_2+10, V_{REF}, 1.23V_{SR}), with the appropriate power or thrust setting and configuration. The airplane should then be accelerated as necessary to a speed that provides an angle of attack sufficiently below the AOA-limit to ensure that a steady rate of speed reduction can be established. Then, using only the primary longitudinal control, establish and maintain a steady deceleration consistent with that specified in § 25.202(d)(1) or (d)(4), as appropriate, until the control reaches the aft stop (see paragraph 29h(3)(d) below). Recovery to the initial trim airspeed must be possible using normal recovery techniques. No change in power/thrust or pilot selectable trim should be made throughout the deceleration to the AOA-limit and recovery (except as done as part of the HALF robustness maneuvers with application simultaneous go-around thrust or power).

(b) The same trim reference (e.g., 1.23 V_{SR}) should be used for both the reference stall speeds and high angle-of-attack characteristics testing.

(c) During the approach to the AOA-limit, the longitudinal control pull force should increase continuously as speed is reduced from the trimmed speed to the AOA-limit subject to the allowances for neutral speed stability of § 25.176. For rates of entry not more than 1 kt/sec to the AOA-limit, there may be no uncommanded airplane response that would be indicative of aerodynamic stall as required by §25.204(b).

(d) Once the longitudinal control stop is reached, the control must be maintained at the stop until the airplane has reached a stabilized flight condition. This does not require steady level flight, but the angle-of-attack should be shown to remain reasonably steady while on the stop. Some level of residual pitch angle and airspeed variations may persist, but these should not present any indications of stall or any characteristics that would prevent the pilot from maintaining the control at the stop. It also must be shown while at the aft control stop that a satisfactory level of lateral and directional control is available to allow corrections to heading and bank angle (in coordinated flight) while at the AOA-limit. The application of small roll rates (10° of bank left and right at approximately 5°/sec) should also not present any indications of stall or any characteristics that would prevent the pilot from maintaining the control at the stop. (§25.202(d)(2) and §25.204(b)(3)). It must then be possible to recover the airplane to the trim condition through normal recovery techniques and use of the controls (§25.202(d)(3)).

(e) § 25.202(d)(4) requires that the high AOA handling demonstrations of § 25.202(b) and (c) also be shown with increased entry rates up to the maximum practical entry rate. For these maneuvers, some transient degradation in characteristics is acceptable, provided that the airplane does not exhibit hazardous characteristics and it is possible to readily correct any uncommanded response with conventional use of the controls. The maneuvers with increased entry rates up to the maximum practical entry rate are intended to demonstrate the robustness of the High Angle-of-Attack Limiting Function. The maximum practical entry rate can be defined according to the type of aircraft longitudinal controller and the corresponding control force characteristics:

(i) For a conventional control wheel and airplane design that complies with the minimum control force requirements of §25.143(g) as applied to airplanes without load factor limiting (refer to paragraph 20e(2)(b) of this AC) and §25.173(c), entry rates up to 3kt/sec have been found acceptable.

(ii) For sidestick controllers where the airplane design does not comply with the minimum control force requirements of §25.143(g) as applied to airplanes without load factor limiting (refer to paragraph 20e(2)(b) of this AC) or §25.173(c), the maximum practical entry rate has included those resulting from an abrupt longitudinal step input in the sidestick, as limited by the aircraft aerodynamics and/or system characteristics.

(iii) Applications with longitudinal controller types and force levels and/or force gradient schemes different than those described in items (i) and (ii) may choose to substantiate a different maximum practical rate between those specified in items (i) and (ii) through pilot-in-the-loop simulation, by similarity to a previous project, or by flight tests.

(iv) Maneuvers to demonstrate robustness of the High Angle-of-Attack Limiting Function (HALF) should include:

(A) At the conditions specified in §25.202(b), in wings level and 30 degree banked steady decelerations up to maximum practical rate defined according to (e)(i, ii, iii) above to the aft control stop until the angle-of-attack has reached a maximum and the airplane is shown to be constrained by the AOA limit.

(B) At the conditions specified in §25.202(b), except with the airplane trimmed and thrust set for level flight at 1.3Vsr, slowdown turns to the aft control stop with at least 1.5 g load factor and deceleration rates of at least 2 knots per second. Recovery should be delayed until 3 seconds after achieving the aft control stop.

(C) If dynamic application of go-around thrust combined with the maximum practical entry rate maneuver described in paragraph (A) above could result in a higher peak AOA than that experienced during the maneuvers with constant thrust setting, additional testing should be conducted in all normal approach and landing configurations. The airplane should be initially trimmed for a 3 degree glideslope at normal approach/landing speed. The longitudinal control should then be rapidly applied at a rate consistent with that applied per paragraph (A) above to full aft control input combined with rapid application of go-around thrust at the most critical time from initiation of the maneuver to the time at which the control reaches the aft stop. The maneuver should be continued until conditions noted in paragraph (v) below are achieved or the airplane is shown to be constrained by the AOA limit. The go-around power or thrust setting should be the same as is used to comply with the approach and landing climb performance requirements of § 25.121(d) and the controllability requirements of §§ 25.145(b)(3)-(5) and 25.149(f)(g).

(v) Flight testing of each of the HALF robustness maneuvers described in paragraph (iv) may not be necessary if it can be determined (e.g., by design review, analysis or simulation) that one or more of the maneuvers is less critical than another. The robustness maneuvers may be limited by other factors such as the achievement of unreasonable pitch attitude (e.g., beyond the threshold for unusual attitude primary display cues) or control force levels, or control system imposed pitch limits or pitch rate limits which would prevent continuation of the maneuver.

(f) § 25.204(e) requires that the airplane's response to pilot inputs while trimmed at speeds within the normal flight envelope (down to V_2 and V_{REF} as appropriate) not be unusually damped or sluggish in response. The intent is to assure reasonably expected corrective inputs to maintain airspeed or landing flare and go-around inputs by the pilot result in acceptable airplane response. This should be evaluated during the increased entry rate maneuvers required by §25.202(d)(4).

(g) § 25.202(e) requires testing be conducted up to the angle-of-attack corresponding to V_{SR} or the maximum angle-of-attack achieved during the dynamic maneuvers of § 25.202(d)(1)-(4), and the resulting characteristics shown to comply with the requirements of § 25.204(f). This is to be done wings-level and in 30 deg banked turns (for non-icing conditions only) with a deceleration from the trim speed of not more than 1 kt/sec, for all flap, landing gear and decelerations device combinations to be approved for operation. At the option of the applicant, this testing may be conducted with the High Angle-of-Attack Limiting Function deactivated (disabled) or adjusted to a higher AOA-limit to allow full development of the angle-of-attack described above in this paragraph. This testing is not intended to evaluate the AOA Limiting Function behavior at this increased AOA, but rather demonstrate that the AOA used to define the reference stall speed and that achieved during highly dynamic maneuvers can be achieved in a slow, steady entry without encountering hazardous or otherwise unacceptable characteristics. As such, airframe or system tolerances need not be considered when conducting this testing.

i ~~f~~. Stall Warning - § 25.207.

(1) Explanation. The purpose of these stall warning requirements is to provide an adequate spread between warning and stall to allow the pilot time to recover without inadvertently stalling the airplane. If a High Angle-of-Attack Limiting Function (HALF) is installed that meets the requirements of §§ 25.202 and 25.204, the ability to prevent stall has been achieved without the provision of natural or artificial stall warning. As such, compliance with §25.207(a)-(i) is not required for such designs. However, for all failures of the HALF not shown to be extremely improbable, the stall warning requirements of §25.207 (j) must be met following failure of the function.

(2) Background. To be acceptable, a stall warning must have the following features:

(a) Distinctiveness. The stall warning indication must be clear and distinct to a degree that will ensure positive pilot recognition of an impending stall.

(b) Timeliness. For one knot per second entry rate stalls, the stall warning must begin at a speed, V_{SW}, not less than five knots or five percent (whichever is greater) above the speed at which the stall is identified in accordance with § 25.201(d). For straight flight stalls, at idle power or thrust and with the c.g. at the position specified in § 25.103(b)(5), the stall warning must begin at a speed not less than three knots or three percent (whichever is greater) above the reference stall speed. These speed margins should be in terms of the same units of measurement as V_{SR} (i.e., calibrated airspeed).

(c) Consistency. The stall warning should be reliable and repeatable. The warning must occur with flaps and gear in all normally used positions in both straight and turning flight (§ 25.207(a)) and must continue throughout the stall demonstration until the angle-of-attack is reduced to approximately that at which the stall warning was initiated (§ 25.207(c)). The warning may be furnished naturally through the inherent aerodynamic characteristics of the airplane, or artificially by a system designed for this purpose. If artificial stall warning is provided for any airplane configuration, it must be provided for all configurations (§ 25.207(b)).

(d) An artificial stall warning indication that is a solely visual device which requires attention in the cockpit, inhibits cockpit conversation or, in the event of malfunction, causes distraction that would interfere with safe operation of the airplane, is not acceptable.

(e) For airplanes that use artificial stall warning systems, paragraph 228 of this AC presents guidance material for demonstrating compliance with the regulatory requirements of part 25.

(f) If the stall warning required by § 25.207 is provided by an artificial stall warning system (e.g., a stick shaker), the effect of production tolerances on the stall warning system should be considered when evaluating the stall warning margin required by § 25.207(c) through (f) and the maneuver capabilities required by § 25.143(h).

1 The stall warning margin required by § 25.207(c) through (f) should be available with the stall warning system set to the most critical setting expected in production. Unless another setting would provide a lesser margin, the stall warning system should be operating at its high angle-of-attack limit. For airplanes where V_{SR} is set by a device that abruptly pushes the nose down at a selected angle-of-attack (e.g., a stick pusher), the stall warning margin may be evaluated with both the stall warning and stall identification (e.g., stick pusher) systems at their nominal angle-of-attack settings unless a lesser margin can result from the various system tolerances.

2 The maneuver capabilities required by § 25.143(h) should be available assuming the stall warning system is operating on its nominal setting. When the stall warning system is operating at its low angle-of-attack limit, the maneuver capabilities should not be

reduced by more than 2 degrees of bank angle from those specified in § 25.143(h). A flight test, an acceptable analysis, or simulation can be used to make this assessment.

3 The stall warning margin and maneuver capabilities may be demonstrated by flight testing at the most critical settings specified above for the stall warning and, if so equipped, stall identification systems. Alternatively, compliance may be shown by applying adjustments to flight test data obtained at a different system setting if an acceptable method is used that takes into account all of the relevant variables.

(3) Procedures. Stall warning tests are normally conducted in conjunction with the stall testing required by § 25.103 (stall speeds), § 25.201 (stall demonstration), and § 25.203 (stall characteristics), including consideration of the prescribed bank angles, power or thrust settings, and c.g. position. The pilot technique in stalling the airplane should be consistent between the onset of stall warning and the point at which the stall is identified. That is, there should not be any deliberate attempt to reduce the load factor, change the deceleration, or use any other means to increase the stall warning margin. In addition, if the stall warning margin may be affected by a system (e.g., a stall warning or stick pusher system that modifies the stall warning or stall identification speed as a function of power or thrust, bank angle, angle-of-attack rate, etc.), compliance with § 25.207(c) should be demonstrated at the most critical conditions in terms of stall warning margin. However, for this case, bank angles greater than 40 degrees and power or thrust exceeding maximum continuous power or thrust need not be demonstrated. If the effect of the stall identification or stall warning system compensation is to increase the stall warning margin relative to the nominal values demonstrated during the testing required by §§ 25.103, 25.201, and 25.203, these additional stall warning margin demonstrations need not be done.

(4) Data Acquisition and Reduction. The stall warning speed and type and quality of warning should be noted. To determine if the required margin exits, compare the speed at which acceptable stall warning begins with (1) the stall identification speed, and (2) V_{SR} (for the conditions under which V_{SR} is defined). The stall warning margin comparisons should be made at a constant 1-g load factor when showing compliance with § 25.207(d).

jg. Accelerated Stall Warning.

(1) Explanation. Section 25.207(f) requires that, in slow-down turns with at least a 1.5g load factor normal to the flight path and an airspeed deceleration rate greater than 2 knots per second, sufficient stall warning is provided to prevent stalling when the pilot takes recovery action not less than one second after recognition of stall warning. The purpose of the requirement is to ensure that adequate stall warning exists to prevent an inadvertent stall under the most demanding conditions that are likely to occur in normal flight. The elevated load factor will emphasize any adverse stall characteristics, such as wing drop or asymmetric wing flow breakdown, while also investigating Mach and potential aeroelastic effects on available lift.

(2) Procedures.

(a) Trim at 1.3 V_{SR}. Once trimmed, accelerate to a speed that will allow enough time to set up and complete the maneuver at the specified load factor and airspeed deceleration rate. Set power or thrust appropriate to the power or thrust for level flight at 1.3 V_{SR} and do not adjust it during the maneuver. In a level flight maneuver, 1.5g equates to a bank angle of 48 degrees. To prevent an excessive deceleration rate (e.g., greater than 3 knots per second), a descent may be used. Conversely, if the deceleration rate is too low, the maneuver should be conducted in a climbing turn.

(b) After the onset of stall warning, continue the maneuver without releasing stick force for one second before attempting recovery. Normal low speed recovery techniques should be used. If any of the indications of a stall prescribed in § 25.201(d) (see paragraph 29c(1) of this AC) occur during the accelerated stall warning demonstration, compliance with § 25.207(f) will not have been demonstrated.

k~~h~~. Maneuver Margins. See paragraph 20 of this AC for guidance material associated with demonstrating compliance to the maneuvering capability requirements of § 25.143(h).

l~~i~~. Additional Considerations for Airplanes Equipped with Stall Identification Systems. A stall identification system is any system that is used to show compliance with § 25.201(d), which requires the airplane to give the pilot a clear and distinctive indication of stall. The stall identification system consists of everything from the sensing devices that supply inputs to the system to the activation of the system response that provides stall identification to the flightcrew. Section 25.1309(a) requires that such a system, when it is needed to show compliance with the stall-related requirements, must be designed to perform its intended function under any foreseeable operating condition.

(1) The applicant should verify that the stall identification system, considering system design features (e.g., filtering, phase advancing) and airplane and system production tolerances will not result in an unsafe diminishing of the margin between stall warning and stall identification, or between stall identification and any hazardous airplane flight characteristic in any foreseeable operating condition. This verification may be provided by a combination of analysis, simulation, and flight test. The following operating conditions should not result in unwanted activation of the stall identification system or in aerodynamic stall prior to, or close to, activation of the stall warning system: dynamic and accelerated stall entries, the effects of atmospheric turbulence, any foreseeable type of wing contamination (e.g., ice, frost, insects, dirt, anti-icing fluids), or wing leading edge damage within prescribed maintenance limits. Operation in windshear environments where the airplane will be flown at, or very near, stall warning, should also be considered, although, depending on the severity of the windshear, it may be impossible to ensure that there is no possibility of stall indication system operation. For wing contamination, the applicant should substantiate the critical height and density of the contaminant. Carborundum sandpaper no. 40 (that is, 40-grit carborundum sandpaper) has been used in past certification programs to represent residual ice or frost contamination.

(2) Stall characteristics testing should be performed with the following airplane and stall identification system production tolerances set to achieve the most adverse stall identification system activation condition for stall characteristics:

(a) Airframe build tolerances – the impact of wing angle of incidence variation relative to stall identification system vane angle; and

(b) Stall identification system tolerances (e.g., activation vane angles).

(3) If the combined root-sum-square (square root of the sum of the squares of each tolerance) effect of the tolerances identified above is less than ±1 knot, stall speeds testing can be performed and the stall speeds determined with the tolerances at their nominal values. If the combined root-sum-square effect is ±1 knot or greater, stall speed testing should be performed with the tolerances at the values that would result in the highest stall speeds.

mj. Reliability of Artificial Stall Warning and Stall Identification Systems. Additional guidance material related to the testing and approval of artificial stall warning and stall identification systems is presented in paragraph 228 of this AC.

n. Considerations for Airplanes Equipped with a High Angle-of-Attack Limiting Function. A High Angle-of-Attack Limiting Function (HALF) is a type of Flight Envelope Limiting System that operates directly and automatically on the airplane's flying controls to limit the maximum angle of attack that can be attained to a value below that at which an aerodynamic stall would occur. As such, the system consists of everything from the sensing devices that supply inputs to the system to the activation of the system commands to the cockpit controllers or control surfaces. Section 25.1309(a) requires that such a system, when it is used to show compliance with the high angle-of-attack related requirements, must be designed to perform its intended function under any foreseeable operating condition. Section 25.202(a) requires that the system meet availability requirements as explained in paragraph 29d(5) of this AC. In addition, § 25.207(j) specifies that a satisfactory stall warning "must be provided" for any failures of the HALF that are not shown to be extremely improbable. This regulation not only requires satisfactory stall warning if the HALF fails, but also requires that combined loss of HALF and an effective stall warning be extremely improbable. To acceptable, this stall warning must have the following features:

(1) Distinctiveness. The stall warning indication must be clear and distinct to a degree that will ensure positive pilot recognition of an impending stall.

(2) Timeliness. For one knot per second entry rate decelerations, the stall warning must begin at a speed with a sufficient margin to allow the deceleration to continue below the stall warning activation speed for the greater of 5 kts or 5% CAS without encountering stall or encountering unacceptable characteristics as defined by § 25.207(j)(4). For turning flight decelerations at entry rates up to 3 kt/sec, the stall warning must begin at a speed with sufficient margin to allow the pilot to prevent stall when the recovery input is initiated not less than 1 second after stall warning activation.

(3) Consistency. The stall warning should be reliable and repeatable. The warning must occur with flaps and landing gear in all normally approved positions in both straight and turning flight (§ 25.207(a)) and should continue throughout the recovery maneuver until the angle-of-attack is reduced to approximately that at which the stall warning was initiated (§ 25.207(j)(3)). The warning may be furnished naturally through the inherent aerodynamic characteristics of the

airplane, or artificially by a system designed for this purpose. If artificial stall warning is provided for any airplane configuration, it must be provided for all configurations (§ 25.207(b)).

(4) An artificial stall warning indication that is a solely visual device which requires attention in the cockpit, inhibits cockpit conversation or, in the event of malfunction, causes distraction that would interfere with safe operation of the airplane, is not acceptable.

(5) If the stall warning required by § 25.207(j) is provided by an artificial stall warning system, the effect of production tolerances on the stall warning system should be considered when evaluating the margins required by § 25.207(j)(1).

Section 7. Ground and Water Handling Characteristics

30. General.

a. Part 25 Regulations. The applicable regulations are §§ 25.231, 25.233, 25.235, 25.237, and 25.239 of the CFR.

b. Longitudinal Stability and Control - § 25.231.

(1) Explanation. Test program objectives would not be expected to demonstrate taxiing over rough surfaces at speeds high enough to approach structural design limits, nor is it expected that in the test program the airplane be landed harder or at higher sink rates than it will ever encounter in service. However, new or modified landing gear systems should be evaluated on rough surfaces that are representative of normal service, and landings should be conducted at various sink rates sufficient to identify any dangerous characteristics or tendencies. Variables to be considered are c.g. and taxi speed. The cockpit motion dynamics during ground handling should not impede control of the airplane, and pitching motion during bounce should not create static pitch control problems or pilot induced oscillation tendencies.

(2) Procedures. Ground handling tests at speeds normally expected in service should be conducted on smooth and rough surfaces that are likely to be encountered under normal operating conditions. Particular attention should be paid to the following:

(a) Brakes. The adequacy of the brakes when maneuvering on the ground and the tendency of the brakes to cause nosing-over should be investigated. Any bad tendency will normally be exaggerated when taxiing in a strong cross or tail wind.

(b) Seaplanes and Amphibians. The most adverse water conditions safe for taxiing, takeoff, and landing must be established per § 25.231(b). Procedure and limitations for using reverse thrust should be determined.

c. Directional Stability and Control - § 25.233.

(1) Explanation. None.

(2) Procedures. Taxi, takeoff, and landing should be conducted in all configurations under normal operating conditions.

(a) There may be no uncontrollable ground-looping tendency in 90-degree crosswinds, up to an averagea wind velocity of 20 knots or 0.2 V_{SR0}, whichever is greater (except that the wind velocity need not exceed 25 knots) at any speed at which the airplane may be expected to be operated on the ground. This may be shown while establishing the 90-degree crosswind component required by § 25.237.

(b) Landplanes must be satisfactorily controllable, without exceptional piloting skill or alertness in power-off landings at normal landing speed, without using brakes or engine power or thrust to maintain a straight path. This may be shown during power-off landings made in conjunction with other tests.

(c) The airplane must have adequate directional control during taxiing. This may be shown during taxiing prior to takeoffs made in conjunction with other tests.

d. Taxiing Condition - § 25.235. [Reserved]

e. Wind Velocities -§ 25.237.

(1) Explanation.

(a) Landplanes.

1 There must be a 90-degree crosswind component established that is shown to be safe for takeoff and landing on dry runways.

2 The airplane must exhibit satisfactory controllability and handling characteristics in 90-degree crosswinds at any ground speed at which the airplane is expected to operate.

(b) Seaplanes and Amphibians.

1 There must be a 90-degree crosswind component established that is shown to be safe for takeoff and landing in all water conditions that may reasonably be expected in normal operation.

2 There must be a wind velocity established for which taxiing is safe in any direction under all water conditions that may reasonably be expected in normal operation.

(c) Crosswind Demonstration. An averagedA 90-degree crosswind component at 10 meters (as required by § 25.21(f)) of at least 20 knots or 0.2 V_{SR0} (where V_{SR0} is for the maximum design landing weight), whichever is greater, except that it need not exceed 25 knots, must be demonstrated during type certification tests. At the same time, the maximum gusts encountered should be established and their effect on airplane handling characteristics in crosswind assessed. There are two results possible:

1 A crosswind component value may be established that meets the minimum requirements but is not considered to be a limiting value for airplane handling characteristics. This demonstrated value should be included as information in the AFM.

2 A crosswind component value may be established that is considered to be a maximum limiting value up to which it is safe to operate for takeoff and landing. This limiting value should be shown in the operating limitations section of the AFM.

(d) The crosswind component included in AFM, whether limiting or not, should be provided as a single gust included value i.e."XX kt (Gust included)". A set of two values, such as "Average XX kt with gusts up to YY kt", is acceptable although not preferred. Other formats, in particular those not providing information related to gusts, should not be used.

(2) Procedures.

(a) Configuration. These tests should be conducted in the following configurations:

1 At light weight and aft c.g. (This is desirable; however, flexibility should be permitted.)

2 Normal takeoff and landing flap configurations using the recommended procedures.

3 Normal usage of thrust reversers. Particular attention should be paid to any degradation of rudder effectiveness due to thrust reverser airflow effects.

4 Yaw dampers/turn coordinator On, or Off, whichever is applicable.

(b) Test Procedures. Three takeoffs and 3 landings, with at least one landing to a full stop, should be conducted in a 90-degree crosswind component of at least 20 knots or 0.2 V_{SR0}, whichever is greater, except that it need not exceed 25 knots. For each test condition, a qualitative evaluation by the pilot of airplane control capability, forces, airplane dynamic reaction in gusty crosswinds (if available), and general handling characteristics should be conducted. The airplane should be satisfactorily controllable without requiring exceptional piloting skill or strength. If thrust reversers are installed, these landings should be conducted with the thrust reversers deployed as per normal procedures and additional landings should be conducted at the critical reverse thrust/power level to verify that there are no unsatisfactory handling characteristics.

(c) Test data. Crosswind data may be obtained from a calibrated flight test wind measurement station, from an airfield wind reporting device, or from any other method acceptable to the FAA.

1 A calibrated flight test wind measurement station located in the vicinity of the liftoff or touchdown point generally provides the most accurate data and is preferable.

2 An airport wind reporting device may also be acceptable provided the device has been calibrated and is located near the runway being used for testing.

3 Crosswind data taken directly from a commercially available inertial or differential GPS based reference system may not be accurate in sideslips and is not accurate on the ground. During landing, filtering may introduce lags making the data incorrect due to wind shear with altitude (i.e., a higher wind value at altitude is "remembered"). Hence this method is considered unsuitable for accurately determining the crosswind during takeoff and landing.

4 Other methods based on the computation of the actual crosswind encountered by the airplane based on on-board measurements are also acceptable. For example, the crosswind can be computed by resolving the difference between true airspeed (from an ADC) and an accurate ground speed measurement (e.g., derived from IRS groundspeed) into the along runway and across runway heading taking into account the airplane heading, track angle and sideslip.

5 No matter which method is used, the wind should be continuously time-recorded throughout the takeoff from brake release (or any low speed above which all data necessary to the computation are available and of sufficient accuracy) to a height of 50 ft, and throughout the landing from a height of 50 ft to termination of the test event (e.g., full stop, touch-and-go, go-around) or any low speed above which all data necessary to the computation are available and of sufficient accuracy. The measured crosswind component should be corrected from the height of the measurement device to a height of 10 meters. The average crosswind at 90 degrees to the runway heading should then be calculated for the above time span. The maximum gust could also be derived during this process, based on the same time span.

6 With prior agreement from the FAA, it may also be permissible to obtain crosswind data from tower wind reports. However the use of this method should be carefully reviewed to ensure that the measurement sensor is properly calibrated to establish the measurement sensor reference height, to establish that the smoothing characteristics do not produce unacceptable filtering, and that the location of the measurement sensor is appropriate for the takeoff and landing runway(s). Such a method has the disadvantage of not being able to provide the gust value during takeoff and landing.

7 With the exception of the method described in 6 where the following is not applicable:

- the averaged value of wind should be understood as a mathematical average obtained from:

Landing	Take-off
$\dfrac{\int_{t_{50ft}}^{t_{last\_valid\_data}} Vw_y . dt}{t_{last\_valid\_data} - t_{50ft}}$	$\dfrac{\int_{t_{first\_valid\_data}}^{t_{50ft}} Vw_y . dt}{t_{50ft} - t_{first\_valid\_data}}$

where Vwy is the wind component corrected to 10m height as per § 25.21(f) and perpendicular to the runway axis.

- the maximum gust derived from test analysis should be of a duration sufficient to interfere with airplane handling characteristics in crosswind. It should be obtained from a centered moving average applied to the test data. The centered moving average should not be of less than 3 seconds in order to be consistent with the filtering standard applied by airports to communicate the gust value. Note however that a 3 second moving average applied on the data collected during the tests may not necessarily provide the same result as airport reported gusts due to differences in data acquisition and reduction methodologies in between flight tests systems and airport system. This filtering also introduces some conservatism in the gust determination to account for the variability of gusts profiles as compared to the ones encountered in flight tests.

- If an applicant wants to use a centered moving average below 3 seconds, this should be substantiated on a case by case basis. The moving average should not go below 1 second.

8 If demonstrated crosswind is not considered limiting, an applicant may use a separate and distinctively identified portion of the AFM to provide "unapproved" data regarding airplane crosswind capability beyond the demonstrated level.

f. Spray Characteristics, Control, and Stability on Water - § 25.239.

(1) Explanation. These characteristics should be investigated at the most adverse weight/c.g. combinations.

(2) Procedures.

(a) The spray characteristics and, in particular, the pilot view during the initial takeoff run, should allow sufficient view in order to maintain a reasonable track over the water. Since not all seaplane operations are on open lakes or bays, but can be on rivers or channels, the directional control and view should be sufficient enough to stay within the channel confines.

(b) The tendency of the wing floats or sponsons to submerge and/or cause waterloops should be evaluated during the crosswind testing. During the step taxiing evaluations, the floats should also be evaluated for any tendency to bury and either cause waterlooping or damage. The procedures used to avoid undesirable characteristics should be included in the AFM.

(c) During low speed taxi, the effectiveness of the water rudders and/or asymmetric power or thrust should be evaluated in view of the types of maneuvering to be expected in service. If reverse thrust is to be used, it too should be evaluated in terms of ease of accomplishment and crew coordination.

(d) If an amphibian is intended to be "beached" or run up a ramp, the handling characteristics and ability to maneuver onto the ramp should be evaluated. Forward c.g. is generally more critical. The procedures should be included in the AFM. There should be no undue tendency to damage the bow or other structure.

(e) Engine failure of the critical engine at any time during the takeoff run should be evaluated. No dangerous porpoising, swerving, or waterlooping should result.

(f) There should be no undue tendency to porpoise and no extraordinary skill or alertness should be required to control porpoising.

(g) Spray impingement on the airframe (control surfaces, etc.) should be evaluated to assure the resulting loads are within acceptable limits.

(h) The above evaluations should be performed in the airplane on the water rather than by analysis or model testing. Analysis and/or model testing may be used to point out the problem areas but should not be substituted for actual testing.

Section 8. Miscellaneous Flight Requirements

31. Vibration and Buffeting - § 25.251.

a. Explanation.

(1) The testing required by subpart C of part 25 covers the vibration extremes expected in service. The applicant's flight tests should assure that the regulatory limits are not exceeded. Flight testing should not be conducted beyond where structural (subpart C) tests and calculations have been completed.

(2) For § 25.251(b) and (c), vibration and buffeting are considered excessive when it is determined that it:

(a) May cause structural damage or, if sustained over an extended period of time, could lead to structural fatigue;

(b) May cause pilot fatigue or annoyance that interferes with operation of the airplane or management of the airplane systems; or

(c) Interferes with flight instrument readability.

(3) No perceptible buffeting is permitted in the cruise configuration as required by § 25.251(d). Weight and/or altitude AFM limitations may need to be imposed to comply with this criterion. Reasonable buffet during the deployment of spoilers and other high drag devices is permitted to the extent allowed under § 25.251(b) and (c), as described in paragraph (2) above.

(4) For airplanes with M_D greater than 0.6 or with a maximum operating altitude greater than 25,000 feet, the buffet onset envelope must be established for the ranges of airspeed and/or Mach number, weight, altitude, and load factor for which the airplane is to be certificated. This envelope must be provided in the AFM in accordance with § 25.1585(d). These AFM data should be valid criteria for forward c.g. conditions or correctable to forward c.g. by the use of AFM procedures. This boundary should be established by pilot qualitative evaluation or by correlation with pilot qualitative evaluation, as there is no predetermined criterion for buffet level at the pilot station. A normal acceleration of $\pm$0.05 g has been used in some cases; however, the appropriate acceleration level will vary from airplane to airplane and may also be affected by the dynamic response of the accelerometer. If a measured normal acceleration is to be used, the acceleration level and specific accelerometer should first be correlated against a pilot's assessment of the onset of buffet.

(5) Modifications to airplanes, particularly modifications that may affect airflow about the wing, should be evaluated for their effect on vibration and buffeting characteristics, changes in the speeds for onset of buffet, and maneuvering characteristics beyond buffet onset. This change may not only impact the buffet boundary envelope, but may change the acceptability of the V_{MO}/M_{MO} or V_{DF}/M_{DF} speeds established on the unmodified airplane. If this occurs, the maximum operating speed and demonstrated flight diving speed may need to be reduced. However, the regulations concerning the speed spread margin between $V_{MO}M_{MO}$ and V_{DF}/M_{DF} remain in effect. Systems and flight characteristics affected by the reduced maximum speeds should also be reevaluated. Indicator markings, overspeed horns, etc. must be reset, as necessary, to remain in compliance with the applicable regulations.

(6) On swept-wing airplanes, undesirable pitch-up maneuvering characteristics can occur as the center of lift moves inboard and forward with increasing g, due to shock-wave induced separation and/or as wing load alleviation systems unload the wingtips. Straight-wing airplanes can also exhibit similar characteristics; therefore, new airplanes and those modified in a manner that may affect the spanwise lift distribution or produce undesirable pitching moment as a function of g, or increase the exposure to high altitude buffet encounters, should be evaluated as described herein.

(7) Section 25.251(e) requires that "probable inadvertent excursions beyond the boundaries of buffet" may not result in "unsafe conditions." In order to assure that no unsafe conditions are encountered in maneuvering flight, maneuvering flight evaluations to demonstrate satisfactory maneuvering stability are described below. A determination of the longitudinal maneuvering characteristics should be made to assure the airplane is safely controllable and maneuverable in the cruise configuration to assure there is no danger of exceeding the airplane limit load factor, and that the airplane's pitch response to the primary longitudinal control is predictable to the pilot.

(8) If a high speed protection function (HSPF) is installed and that function prevents the aircraft from readily achieving the selected VDF/MDF, the HSPF may be adjusted or disabled to permit demonstrations showing compliance to § 25.251(b) provided the aerodynamic configuration of the airplane during the demonstration is the same as would be present if the HSPF were functioning normally.

b. Procedures.

(1) Section 25.251(a). The test procedures outlined below will provide the necessary flight demonstrations for compliance with § 25.251(a).

(2) Section 25.251(b). The airplane should be flown at V_{DF}/M_{DF} at several altitudes from the highest practicable cruise altitude to the lowest practicable altitude. The test should be flown starting from trimmed flight at V_{MO}/M_{MO} at a power or thrust setting not exceeding maximum continuous power or thrust. The airplane gross weight should be as high as practicable for the cruise condition, with the c.g. at or near the forward limit. In addition, compliance with § 25.251(b) should be demonstrated with high drag devices (i.e., speed brakes) deployed at V_{DF}/M_{DF}. Thrust reversers, if designed for inflight deployment, should be deployed at their limit speed conditions. A high-speed protection function, if installed, may be adjusted or disabled as discussed in paragraph 31.a.(8) if necessary to permit demonstrations at V_{DF}/M_{DF}.

(3) Section 25.251(c). The weight of the airplane should be as heavy as practical, commensurate with achieving the maximum certificated altitude.

(4) Section 25.251(d). It should be demonstrated in flight tests that perceptible buffeting does not occur in straight flight in the cruise configuration, at any speed up to V_{MO}/M_{MO}, to show compliance with § 25.251(d). This should be met from initial combinations of critical weight and altitude, if achievable, where the airplane has a 0.3 g margin to the buffet onset boundary developed under § 25.251(e). These initial conditions should be established using a nominal cruise Mach number (typically long-range cruise Mach, M_{LRC}) with the c.g. at the forward limit. This flight condition is representative of practical operating criteria imposed by most operators. From these initial conditions, the airplane should be accelerated in 1 g flight to V_{MO}/M_{MO} using maximum continuous power or thrust. Descending flight is acceptable if needed to achieve V_{MO}/M_{MO}.

(5) Section 25.251(e). Section 25.251(e) requires the determination of the buffet onset envelope, in the cruise configuration, for airplanes with M_D greater than 0.6 or maximum operating altitudes greater than 25,000 feet. This requirement also provides criteria for evaluation of maneuvering stability in cruise flight under load factor conditions up to and beyond the onset of buffet.

(a) The determination of compliance with § 25.251(e), using flight test data from maneuvers conducted well into buffet, is extremely difficult due to the dynamics of this type of maneuver and the establishment of the F_S/g relationship from such data. The pilot flying the airplane needs to evaluate the airplane characteristics under such conditions. Figure 31-1 provides guidance on stick force per g (F_S/g) characteristics that would be considered acceptable or unacceptable.

(b) For determination of the buffet onset envelope, the flight tests should be conducted at forward c.g. For maneuvering characteristics, airplanes should be evaluated at the most aft c.g. in accordance with the following criteria:

1 For all weight/altitude combinations where buffet onset occurs at various load factors between approximately +1 g and +2 g, the longitudinal control force (F_S) characteristics of § 25.255(b)(1) and (2) apply prior to encountering that buffet onset (see figure 31-1).

2 Under the airplane weight/altitude combinations of 1, above, but at load factors beyond buffet onset, the following F_S characteristics apply (see figure 31-1):

(aa) The evaluation should proceed to a g level that will allow recovery to be accomplished near +2.5 g, unless sufficient buffet or other phenomena (natural, artificial, or a combination) of such intensity exists that is a strong and effective deterrent to further pilot application of nose-up longitudinal control force (as in § 25.201(d)(2)) so that there is no danger of exceeding the airplane limit load factor (Ref. § 25.143(b)).

NOTE: A strong and effective deterrent is analogous to that required for stall identification; stick shaker or stall warning buffet are not considered to be an adequate end point for these tests.

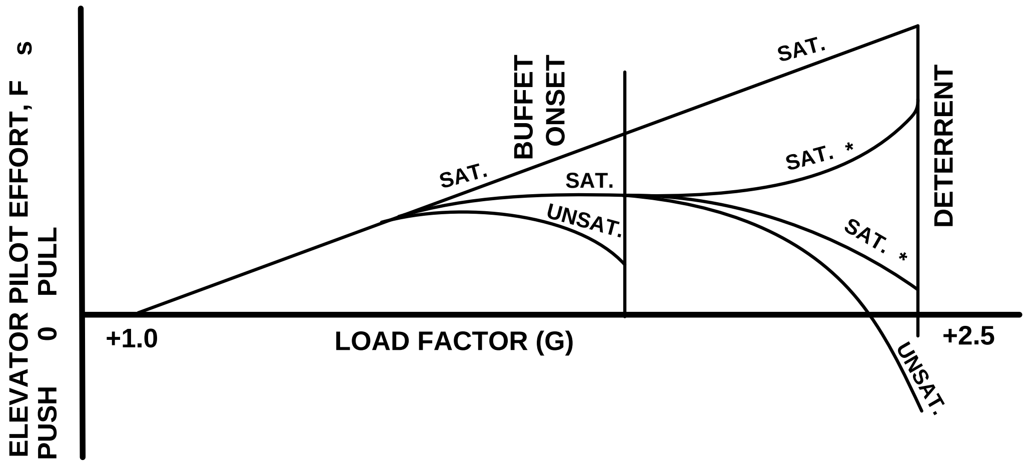
(bb) Any pitching tendency (uncommanded changes in load factor) should be mild and readily controllable.

(cc) Sufficient control should be available to the pilot, through unreversed use of only the primary longitudinal control, to affect a prompt recovery to +1 g flight from the load factors described herein.

(dd) The airplane's pitch response to primary longitudinal control should be predictable to the pilot.

3 Experience has shown that maneuvering evaluations conducted at the highest Mach and the highest weight and altitude (W/δ) combination may not necessarily produce the most critical results. Equally important is the character of the buffet buildup (e.g., slowly increasing or rapid rise, and the g at which it starts). Conditions associated with buffet onset near 2 g at Mach numbers below M_{MO} have sometimes yielded the most critical characteristics. Therefore, a sufficient spread of conditions should be evaluated.

Figure 31-1. Maneuvering Characteristics at Speeds up to V_{MO}/M_{MO}



.
* These characteristics are satisfactory only in accordance with paragraphs 31b(5)(b)1 and 2.

32. High Speed Characteristics - § 25.253.

a. Explanation.

(1) The maximum flight demonstrated dive speed, V_{DF}/M_{DF}, selected by the applicant, is used along with V_D/M_D when establishing V_{MO}/M_{MO} in accordance with the associated speed margins under the provisions of § 25.1505. Both V_{MO}/M_{MO} and V_{DF}/M_{DF} are then evaluated during flight tests for showing compliance with § 25.253.

(2) The pitch upset defined in § 25.335(b), as amended by Amendment 25-23, or defined in § 25.1505, prior to Amendment 25-23, provides a means for determining the required speed margin between V_{MO}/M_{MO} and both V_D/M_D and V_{DF}/M_{DF}. The operational upsets expected to occur in service for pitch, roll, yaw, and combined axis upsets are evaluated when showing compliance to § 25.253 and must not result in exceeding V_D/M_D or V_{DF}/M_{DF}.

(3) In general, the same maneuvers should be accomplished in both the dynamic pressure and Mach critical ranges. All maneuvers in either range should be accomplished at power/thrust and trim points appropriate for the specific range. Some maneuvers in the Mach range may be more critical for some airplanes due to drag rise characteristics, and at high altitudes a lower gross weight may be required to achieve the maximum approved operating altitude and Mach/airspeed conditions.

(4) The airplane's handling characteristics in the high speed range should be investigated in terms of anticipated action on the part of the flightcrew during normal and emergency conditions.

(5) At least the following factors should be considered in determining the necessary flight tests:

(a) Effectiveness of longitudinal control at V_{MO}/M_{MO} and up to V_{DF}/M_{DF}.

(b) Effect of any reasonably probable mistrim on upset and recovery.

(c) Dynamic and static stability.

(d) The speed increase resulting from likely passenger movement when trimmed at any cruise speed to V_{MO}/M_{MO}.

(e) Trim changes resulting from compressibility effects.

(f) Characteristics exhibited during recovery from inadvertent speed increase.

(g) Upsets due to vertical and horizontal gusts (turbulence).

(h) Speed increases due to horizontal gusts and temperature inversions.

(i) Effective and unmistakable aural speed warning at V_{MO} plus 6 knots, or M_{MO} plus 0.01 M.

(j) Speed and flight path control during application of deceleration devices.

(k) Control forces resulting from the application of deceleration devices.

(6) Section 25.1505 states that the speed margin between V_{MO}/M_{MO}, and V_D/M_D or V_{DF}/M_{DF}, as applicable, "may not be less than that determined under § 25.335(b) or found necessary during the flight tests conducted under § 25.253." Note that **one** speed margin must be established that complies with both § 25.335(b) and § 25.253. Therefore, if the applicant chooses a V_{DF}/M_{DF} that is less than V_D/M_D, then V_{MO}/M_{MO} must be reduced by the same amount (i.e., compared to what it could be if V_{DF}/M_{DF} were equal to V_D/M_D) in order to provide the required speed margin to V_{DF}/M_{DF}. In determining the speed margin between V_{MO}/M_{MO} and V_{DF}/M_{DF} during type certification programs, the factors outlined in paragraph (5), above, should also be considered in addition to the items listed below:

(a) Increment for production tolerances in airspeed systems (0.005 M), unless larger differences are found to exist.

(b) Increment for production tolerances of overspeed warning error (0.0l M).

(c) Increment ΔM due to speed overshoot from M_{MO}, established during flight tests in accordance with § 25.253, should be added to the values for production differences and equipment tolerances. The value of M_{MO} may not be greater than the lowest value obtained from each of the following equations, which reflect the requirements of §§ 25.253 and 25.1505:

$$M_{MO} \leq M_{DF} - \Delta M - 0.005\ M - 0.0l\ M$$

or

$M_{MO} \leq M_{DF} - 0.07\ M$

NOTE: The combined minimum increment may be reduced from 0.07 M to as small as 0.05 M if justified by the rational analysis used to show compliance with § 25.335(b)(2).

(d) At altitudes where V_{MO} is limiting, the increment for production differences of airspeed systems and production tolerances of overspeed warning errors are 3 and 6 knots, respectively, unless larger differences or errors are found to exist.

(e) Increment ΔV due to speed overshoot from V_{MO}, established during flight tests in accordance with § 25.253, should be added to the values for production differences and equipment tolerances. The value of V_{MO} should not be greater than the lowest obtained from the following equation, and from § 25.1505:

$$V_{MO} \leq V_{DF} - \Delta V - \underset{\text{(production differences)}}{3\text{ knots}} - \underset{\text{(equipment tolerances)}}{6\text{ knots}}$$

(f) For an airplane with digital interface between the airspeed system and the overspeed warning system, the production tolerance for the warning system may be deleted when adequately substantiated.

(7) Considerations for Aircraft Employing a High Speed Protection Function

(a) Some aircraft may utilize a High Speed Protection Function (HSPF) which acts to reduce speed excursions beyond the normal operating envelope. An HSPF is likely to become active during maneuvers described in paragraph 32.c. If an HSPF of suitable availability is installed, the upset maneuvers specified in paragraphs 32.c.(1) through (5) below can be limited to that which is achievable with the HSPF functioning normally and the pilot's pitch control full forward, and a load factor in excess of 1.5 g may be used during recovery if applied automatically by the HSPF with the pilots pitch control at the neutral (zero force) position. For the purposes of compliance with § 25.253, suitable availability of an HSPF means that the probability of loss of the function should be improbable (no greater than 10^{-5} per flight hour).

(b) An HSPF when functioning normally may, by design, limit the airspeed the airplane can achieve even with full forward pitch control; however, an applicant may choose to demonstrate high-speed flight characteristics at a selected V_{DF}/M_{DF} speed higher than can be achieved with full forward pitch control. This might be done in order to meet requirements for margin from V_{MO}/M_{MO} to V_{DF}/M_{DF}. If an HSPF is installed and an applicant chooses to demonstrate high speed characteristics at a selected V_{DF}/M_{DF} that can not readily be achieved with the nominal HSPF settings, the HSPF may be adjusted or disabled to permit achievement of that higher speed for demonstrations of control characteristics and speedbrake extension at V_{DF}/M_{DF} showing compliance to § 25.253(a)(3) – (5). The aerodynamic configuration during the demonstration at V_{DF}/M_{DF} should be the same as would be present if the HSPF were functioning normally. In this way the underlying aerodynamic control capability and buffet characteristics are demonstrated to V_{DF}/M_{DF}. Demonstrations showing compliance to § 25.253(a)(1) and (2) (handling qualities, speed excursion and load factor control and buffeting during recovery from specified maneuvers) should be performed with the HSPF functioning normally.

b. Regulations Affected. These criteria refer to certain provisions of part 25. They may also be used in showing compliance with the corresponding provisions of the former Civil Air Regulations (CAR) in the case of airplanes for which these regulations apply. Other affected CFR are as follows:

Section 25.175(b)	Demonstration of static longitudinal stability.
Section 25.251	Vibration and buffeting.
Section 25.253	High-speed characteristics.
Section 25.335(b)	Design dive speed, V_D.
Section 25.1303(b)(1) and (c)	Flight and navigation instruments.
Section 25.1505	Maximum operating limit speed.

c. Procedures. Using the speeds V_{MO}/M_{MO} and V_{DF}/M_{DF} determined in accordance with §§ 25.1505 and 25.251, respectively, and the associated speed margins, the airplane should be shown to comply with the high-speed characteristics of § 25.253. Unless otherwise stated, the airplane characteristics should be investigated beginning at the most critical speed up to and including V_{MO}/M_{MO}, and the recovery procedures used should be those selected by the applicant, except that the normal acceleration during recovery should be no more than l.5 g (total). The force limits of § 25.143(d) for short term application apply during the recovery. If a high speed protection function as described in paragraph 32.a.(7)(a) is installed, a load factor in excess of 1.5 g may be used during recovery if applied by the automatic function with the pilots pitch control at the neutral (zero force) position. Testing should be conducted with the c.g. at the critical position and generally perpendicular to local wind aloft.

(1) C.g. Shift. The airplane should be upset by the c.g. shift corresponding to the forward movement of a representative number of passengers (and/or serving carts) depending upon the airplane interior configuration. The airplane should be permitted to accelerate until 3 seconds after V_{MO}/M_{MO}.

(2) Inadvertent Speed Increase. Simulate an evasive control application when trimmed at V_{MO}/M_{MO}, by applying sufficient forward force to the pitch control to produce 0.5 g (total) for a period of 5 seconds, after which recovery should be initiated ~~at not more than 1.5 g (total).~~. If an HSPF as described in paragraph 32.a.(7)(a) is installed, the aircraft may not be able to maintain 0.5 g for 5 seconds; load factor may be limited to that achieved at full forward control.

(3) Gust Upset. In the following three upset tests, the values of displacement should be appropriate to the airplane type and should depend upon airplane stability and inertia characteristics. The lower and upper limits should be used for airplanes with low and high maneuverability, respectively.

(a) With the airplane trimmed in wings-level flight, simulate a transient gust by rapidly rolling to the maximum bank angle appropriate for the airplane, but not less than 45 degrees nor more than 60 degrees. The rudder and longitudinal control should be held fixed during the time that the required bank is being attained. The rolling velocity should be arrested at this bank angle. Following this, the controls should be abandoned for a minimum of 3 seconds after V_{MO}/M_{MO} or 10 seconds, whichever occurs first.

(b) Perform a longitudinal upset from normal cruise. Airplane trim is determined at V_{MO}/M_{MO} using power/thrust required for level flight but with not more than maximum continuous power/thrust. (If V_{MO}/M_{MO} cannot be reached in level flight with maximum continuous power or thrust, then the airplane should be trimmed at V_{MO}/M_{MO} in as shallow a descent as practicable that allows V_{MO}/M_{MO} to be reached.) This is followed by a decrease in speed, after which a pitch attitude of 6-12 degrees nose down, as appropriate for the airplane type, is attained using the same power/thrust and trim. The airplane is permitted to accelerate until 3 seconds after V_{MO}/M_{MO}. ~~The force limits of § 25.143(d) for short term application apply~~ For airplanes equipped with a high speed protection function as described in paragraph 32.a.(7)(a), the nose down pitch attitude is permitted to diminish if it cannot be sustained with the pilot's pitch control full forward.

(c) Perform a two-axis upset, consisting of combined longitudinal and lateral upsets. Perform the longitudinal upset, as in paragraph (b) above, and when the pitch attitude is set, but before reaching V_{MO}/M_{MO}, roll the airplane 15-25 degrees. The established attitude should be maintained until 3 seconds after V_{MO}/M_{MO}.

(4) Leveling Off from Climb. Perform transition from climb to level flight without reducing power or thrust below the maximum value permitted for climb until 3 seconds after V_{MO}/M_{MO}. ~~Recovery should be accomplished by applying not more than 1.5 g (total).~~

(5) Descent from Mach Airspeed Limit Altitude. A descent should be performed at the airspeed schedule defined by M_{MO} and continued until 3 seconds after V_{MO}/M_{MO} occurs~~, at which time recovery should be accomplished without exceeding 1.5 g (total)~~.

(6) Roll Capability, § 25.253(a)(4).

(a) Configuration:

1 Wing flaps retracted.

2 Speedbrakes retracted and extended.

3 Landing gear retracted.

4 Trim. The airplane trimmed for straight flight at V_{MO}/M_{MO}. The trimming controls should not be moved during the maneuver.

5 Power:

(aa) All engines operating at the power required to maintain level flight at V_{MO}/M_{MO}, except that maximum continuous power need not be exceeded; and

(bb) If the effect of power is significant, with the throttles closed.

(b) Test Procedure. An acceptable method of demonstrating that roll capability is adequate to assure prompt recovery from a lateral upset condition is as follows:

1 Establish a steady 20-degree banked turn at a speed close to V_{DF}/M_{DF} limited to the extent necessary to accomplish the following maneuver and recovery without exceeding V_{DF}/M_{DF}. Using lateral control alone, it should be demonstrated that the airplane can be rolled to a 20-degree bank angle in the opposite direction in not more than 8 seconds. The demonstration should be made in the most adverse direction. The maneuver may be unchecked.

2 For airplanes that exhibit an adverse effect on roll rate when rudder is used, it should also be demonstrated that use of rudder to pick up the low wing in combination with the lateral control will not result in a roll capability significantly below that specified above.

(7) Extension of Speedbrakes. The following guidance is provided to clarify the meaning of the words "the available range of movements of the pilot's control" in § 25.253(a)(5) and to provide guidance for demonstrating compliance with this requirement. Normally, the available range of movements of the pilot's control includes the full physical range of movements of the speedbrake control (i.e., from stop to stop). Under some circumstances, however, the available range of the pilot's control may be restricted to a lesser range associated with in-flight use of the speedbrakes. A means to limit the available range of movement to an in-flight range may be acceptable if it provides an unmistakable tactile cue to the pilot when the control reaches the maximum allowable in-flight position and compliance with § 25.697(b) is shown for positions beyond the in-flight range. Additionally, the applicant's recommended procedures and training must be consistent with the intent to limit the in-flight range of movements of the speedbrake control.

(a) Section 25.697(b) requires that lift and drag devices intended for ground operation only must have means to prevent the inadvertent operation of their controls in flight if that operation could be hazardous. If speedbrake operation is limited to an in-flight range, operation beyond the in-flight range of available movement of the speedbrake control must be shown to be not hazardous. Two examples of acceptable, unmistakable tactile cues for limiting the in-flight range are designs incorporating either a gate or both a detent and a substantial increase in force to move the control beyond the detent. It is not an acceptable means of compliance to restrict the use of or available range of the pilot's control solely by means of an Airplane Flight Manual limitation or procedural means.

(b) The effect of extension of speedbrakes may be evaluated during other high speed testing (for example, paragraphs 31b(2) and 32c(1) through (5) of this AC) and during the development of emergency descent procedures. It may be possible to infer compliance with

§ 25.253(a)(5) by means of this testing. To aid in determining compliance with the qualitative requirements of this rule, the following quantitative values may be used as a generally acceptable means of compliance. A positive load factor should be regarded as excessive if it exceeds 2 g. A nose-down pitching moment may be regarded as small if it necessitates an incremental force of less than 20 pounds for a conventional control wheel or 15 pounds for a side stick controller to maintain 1 g flight. These values may not be appropriate for all airplanes, and will depend on the characteristics of the particular airplane design in high speed flight. Other means of compliance may be acceptable, provided that compliance has been shown to the qualitative requirements specified in § 25.253(a)(5).

33. Out-Of-Trim Characteristics - § 25.255.

a. Explanation. Certain early, trimmable stabilizer equipped jet transports experienced "jet upsets" that resulted in high speed dives. When the airplane was mistrimmed in the nose-down direction and allowed to accelerate to a high airspeed, it was found that there was insufficient elevator power to recover. Also, the stabilizer could not be trimmed in the nose-up direction, because the stabilizer motor stalled due to excessive airloads imposed on the horizontal stabilizer. As a result, a special condition was developed and applied to most part 25 airplanes with trimmable stabilizers. With certain substantive changes, it was adopted as § 25.255, effective with Amendment 25-2. While these earlier problems seem to be generally associated with airplanes having trimmable stabilizers, it is clear from the preamble discussions to Amendment 25-42 that § 25.255 applies "regardless of the type of trim system used in the airplane." Section 25.255 is structured to give protection against the following unsatisfactory characteristics during mistrimmed flight in the higher speed regimes:

(1) Changes in maneuvering stability leading to overcontrolling in pitch.

(2) Inability to achieve at least l.5 g for recovery from upset due to excessive control forces.

(3) Inability of the flightcrew to apply the control forces necessary to achieve recovery.

(4) Inability of the pitch-trim system to provide necessary control force relief when high control force inputs are present.

With the advent of Electronic Flight Control Systems ("Fly-By-Wire"), some airplanes have included automatic longitudinal trim systems whereby the trim surface position is automatically adjusted without direct command from the pilot. Such systems have the ability to minimize or eliminate the potential mistrim of the trimming surface under normal operation. However, depending on the design of the automatic trim system, some level of mistrim may exist at high speed cruise conditions under normal maneuvering conditions or atmospheric disturbances, including those leading to the "jet upsets" described above. It is the intent of this regulation to demonstrate the required maneuvering characteristics in any achievable high speed condition up to V_{DF}/M_{DF} and minimum controllability at V_{DF}/M_{DF} with the level of mistrim that can be expected in service, including any automatic movement, in response to normal maneuvering and atmospheric disturbances expected in the cruise phase of flight.

The maximum achievable speed for maneuvering characteristics demonstration, referred to in sec. 25.255(b)(2), is the maximum speed reached during maneuvers specified for compliance with 25.253(a)(1) in paragraph 32.c. of this AC, conducted with the flight control system and envelope protections operating normally. This speed may be lower than or equal to V_{DF}/M_{DF} at some or all altitudes in the envelope to be approved depending on the criteria used to establish V_{DF}/M_{DF}.

b. Reference Regulation. Section 25.255.

c. Discussion of the Regulation.

(1) Section 25.255(a) is the general statement of purpose. Maneuvering stability may be shown by a plot of applied control force versus normal acceleration at the airplane c.g.. Characteristics need only be shown for critical out of trim positions, including in trim, where applicable. Mistrim must be set within the design and operational constraints of the longitudinal trim system~~Mistrim must be set~~ to the greater of the following:

(a) Section 25.255(a)(l). For airplanes with longitudinal trim systems where the pilot directly adjusts the trim surface position, a~~A~~ 3-second movement of the longitudinal trim system at its normal rate for the particular flight condition with no aerodynamic load, unless otherwise limited by system stops or other design features that restrict trim movement under certain conditions.~~.~~ Since many modern trim systems are variable rate systems, this subsection requires that the maneuver condition be defined and that the no-load trim rate for that condition be used to set the degree of mistrim required. For airplanes that do not have power-operated trim systems, experience has shown a suitable amount of longitudinal mistrim to be applied is that necessary to produce a 30 pound control force for a conventional control wheel or 20 pounds for a side stick controller, or reach the trim limit, whichever occurs first.

(b) Section 25.255(a)(2). The maximum mistrim that can be sustained by the autopilot while maintaining level flight in the high speed cruising condition. The high speed cruising condition corresponds to the speed resulting from maximum continuous power or thrust, or V_{MO}/M_{MO}, whichever occurs first. Maximum autopilot mistrim may be a function of several variables, and the degree of mistrim should therefore correspond to the conditions of test. In establishing the maximum mistrim that can be sustained by the autopilot, the normal operation of the autopilot and associated systems should be taken into consideration. If the autopilot is equipped with an auto-trim function, then the amount of mistrim that can be sustained, if any, will generally be small. If there is no auto-trim function, consideration should be given to the maximum amount of out-of-trim that can be sustained by the elevator servo without causing autopilot disconnect.

(c) Section 25.255(a)(3). For airplanes with a longitudinal trim function where the pilot does not directly adjust the longitudinal trim surface position and the trim surface is controlled by an automatic function, the amount of mistrim should be determined by analysis, accounting for system design, thresholds for automatic trimming, capability of the trim system to move the trim surfaces during the demonstrations and system tolerances. It must also account for any mistrim that may result from normal maneuvering or atmospheric disturbances expected in cruise flight. Maneuvering to normal load factors ranging from 0.8g to 1.3g are considered acceptable in this assessment (Reference: Figure 5 of Appendix 5 of this AC). The gusts and shears of § 25.335(b) and AC 25.335-1A are considered acceptable levels of atmospheric disturbances to assess the maximum out-of-trim condition. If the amount of possible mistrim from paragraphs (a)(2) and (a)(3) is considered negligible and paragraph (a)(1) is not applicable, the testing required by paragraphs (b) through (f) can be conducted with no specific level of mistrim (see paragraph d.(1)(a) below for details).

(2) Section 25.255(b) establishes the basic requirement to show positive maneuvering stability throughout a specified normal acceleration envelope at all speeds to V_{FC}/M_{FC}, and the absence of longitudinal control force reversals throughout that normal acceleration envelope at speeds between V_{FC}/M_{FC} and any achievable speed up to V_{DF}/M_{DF} with the flight control system (including envelope protections) operating normally.. (Later subsections (d) and (e) recognize that buffet boundary, envelope protections or other limiting features, and control force limits will limit the normal acceleration actually reached; this does not account for Mach trim gain, etc.)

(a) The out-of-trim condition for which compliance must be shown with § 25.255(b) is specified in § 25.255(a). For the initial trimmed condition before applying the mistrim criteria, the airplane should be trimmed at:

1 For speeds up to V_{MO}/M_{MO}, the particular speed at which the demonstration is being made; and

2 For speeds higher than V_{MO}/M_{MO}, V_{MO}/M_{MO}.

(b) Section 25.255(b)(2) appears to indicate that unstable airplane characteristics would be satisfactory, regardless of the character of the primary longitudinal control force as load factor is increased, as long as the force did not reverse (e.g., from a pull to a push). While such criteria may have merit for evaluating airplanes when starting the maneuver from a trimmed condition, it can be shown that this provides a poor specification for evaluating an airplane's maneuvering characteristics when starting the test from the specified mistrimmed condition. For example, an airplane would be deemed to have unacceptable characteristics with a nose-up mistrim, if while relaxing the large initial elevator push force to increase the load factor to the specified value, the elevator force just happened to cross through zero to a slight pull force at one load factor, and then back through zero to a push force at a higher load factor. Such an airplane's characteristics are clearly superior to one that has a severe elevator force slope reversal, during the same maneuver, but never reaches a zero elevator force condition as the load factor is increased. A literal interpretation of § 25.255(b)(2) would find this airplane to be compliant, while finding the preceding airplane non-compliant because it had a slight reversal of the primary longitudinal control force.

(c) Section 25.255(b)(2) should be interpreted to mean that the primary longitudinal control force, for load factors greater than 1.0, may not be less than that used to obtain the initial 1g flight condition. This is illustrated in Figure 33-1. Slight control force reversals, as discussed in paragraph (a), above, will be permitted for speeds above~~between~~ V_{FC}/M_{FC} ~~and V_{DF}/M_{DF}~~ only if:

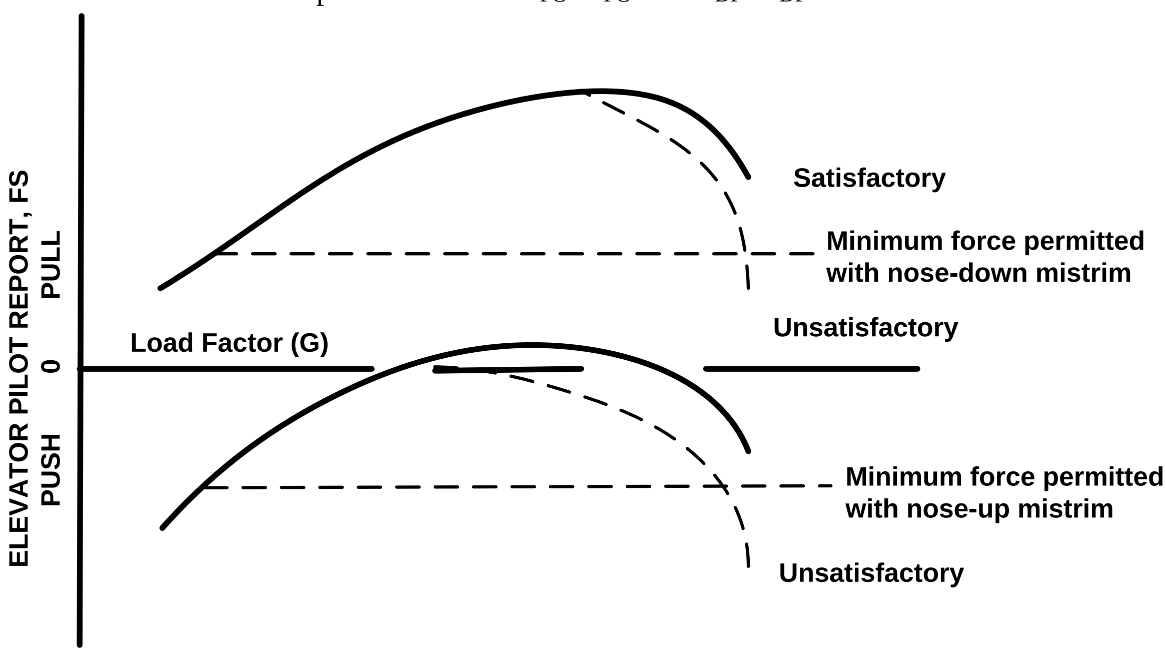
1 No severe longitudinal control force slope reversals exist;

2 Any pitching tendency (uncommanded changes in load factor) should be mild and readily controllable; and

3 The airplane's pitch response to primary longitudinal control should be predictable to the pilot.

Figure 33-1. Mistrimmed Maneuvering Characteristics

Speeds Between V_{FC}/M_{FC} and V_{DF}/M_{DF}



(3) Section 25.255(c) requires that the investigation of maneuvering stability (§ 25.255(b)) include all attainable normal acceleration values between –l g and +2.5 g. Sections 25.333(b) and 25.337, to which it refers, limit the negative g maximum to 0 g at V_D. Section 25.251 further limits the g to that occurring in probable inadvertent excursions beyond the buffet onset boundary at those altitudes where buffet is a factor.

(4) Section 25.255(c)(2) allows for extrapolation of flight test data by an acceptable method. For example, if the stick force gradient between 0 and +2 g agrees with predicted data, extrapolation to -1 g and 2.5 g should be allowed. As described in § 25.255(e), the maneuvering tests may be restricted by flight control system characteristics or features. Likewise, the extrapolation need not extend beyond the limits established by such features.

(5) Section 25.255(d) requires flight tests to be accomplished from the normal acceleration at which any marginal stick force reversal conditions are found to exist to the applicable limits of § 25.255(c~~b~~)(1). This requirement takes precedence over the extrapolation allowance described in paragraph (4), above. However, the exceptions described in § 25.255(e) may still restrict the maneuvering tests.

(6) Section 25.255(e), limits the investigation to the required structural strength limits of the airplane and maneuvering load factors associated with probable inadvertent excursions beyond the boundary of the buffet onset envelope. Additionally, it allows the maneuvering demonstrations to be restricted to the limits permitted by flight control system characteristics or features (for example, Nz limiting, high speed protection systems or AOA limiting), if failure of those features is shown to be at least improbable (not more probable than remote). It also accounts for the fact that speed may increase substantially during test conditions in the -1 g to +1 g range. It limits the entry speed to avoid exceeding V_{DF}/M_{DF}.

(7) Section 25.255(f) requires that in the out-of-trim condition specified in § 25.255(a), it must be possible to produce at least 1.5 g during recovery from the overspeed condition of V_{DF}/M_{DF} by applying not more than 125 pounds of longitudinal control force for a conventional control wheel or 50 pounds for a side stick controller. For this demonstration, flight envelope protections may be disabled or modified to allow reaching V_{DF}/M_{DF}. The objective of this test is to demonstrate that the airplane and its flight system are capable of producing 1.5 g during recovery from an overspeed condition, even if a protection system would normally act to deter or prevent such an overspeed encountered due to upsets similar to those used compliance with Section 25.253(a). This could include more extreme upsets or large horizontal wind shear or gusts that result in momentary exceedences of the normally achievable airspeed with the protections operating normally. If adverse flight characteristics preclude the attainment of this load factor at the highest altitude reasonably expected for recovery to be initiated at VDF/MDF following an upset at high altitude, the flight envelope (e.g., V_{DF}/M_{DF}, altitude, etc.) of the airplane should be restricted to a value where 1.5 g is attainable. Inability to attain 1.5g due to encountering deterrent buffet or envelope protection is not considered an adverse flight characteristic. Although a pilot commanded trim input may be used to assist in producing the required normal acceleration of 1.5 g, it is not acceptable for recovery to be completely dependent upon the pilot commanded trim input. It should be possible to produce at least 1.2 g by applying not more than 125 pounds of longitudinal control force for a conventional control wheel or 50 pounds for a side stick using the primary longitudinal control alone. If trim surface movement must be used for the purpose of obtaining 1.5 g, whether commanded by manual pilot trim inputs or by the automatic trim system ~~If trim must be used for the purpose of obtaining 1.5 g~~, it must be shown to operate with the primary control surface loaded to the least of three specified values.

(a) The control input~~force~~ resulting from application of the pilot limit loads of § 25.397. ~~(300 lbs.).~~

(b) The control inputforce required to produce 1.5 g with elevator deflection alone, or as limited by elevator control system characteristics, including elevator command limits or actuator hinge moment capability.. (between 125 and 300 lbs.).

(c) The control inputforce corresponding to buffeting or other phenomena of such intensity that it is a strong deterrent to further application of primary longitudinal control force.

d. Procedures.

(1) Compliance is determined by the characteristics of F_S/g (normally a plot). Any standard flight test procedure that yields an accurate evaluation of F_S/g data in the specified range of speeds and acceleration should be considered for acceptance. Bounds of investigation and acceptability are set forth in the rule and in discussion material above, and broad pilot discretion is allowed in the selection of maneuvers.

(a) For airplanes that include a design that provides automatic trimming under all cruise flight conditions (including auto-flight), the amount of mistrim should be determined by analysis, accounting for system design, thresholds for automatic trimming, and system tolerances. It must also account for any mistrim that may result from normal maneuvering or atmospheric disturbance expected in cruise flight. If the possible mistrim is considered negligible (and paragraph (a)(1) is not applicable) the testing required by paragraphs (b) through (f) can be conducted with no specific level of mistrim. Alternatively, if the amount of mistrim is not negligible, it would be considered acceptable to conduct the flight testing with no specific mistrim if it can be shown by analysis that, (1) the level of mistrim does not affect the maneuvering characteristics (Fs vs g) of the airplane (e.g., a maneuver demand control system) and (2) the maneuvering capability of 1.5g demonstrated during flight tests for §25.255(f) would still be possible if the mistrim was present at the start of the recovery (this could be shown by demonstrating controllability beyond 1.5g during flight test and adjusting the peak Nz achieved by the effect of the mistrim on pitching moment, or by showing sufficient margin in elevator authority during the flight tested recovery at 1.5g to offset the possible level of mistrim and still generate 1.5g).

(b) The flight testing for § 25.255(b) is required at achievable airspeeds up to V_{DF}/M_{DF} (established in accordance with §25.253(a)), with the flight control system (including envelope protections) operating normally. While conducting these tests, the airplane should be accelerated from a level flight condition at V_{MO}/M_{MO} (or any lower initial airspeed with the level of mistrim established with paragraph (a) above) using up to Maximum Continuous Thrust to the target airspeed. Testing should be conducted with the flight control system operating normally to accurately present the airplane's maneuvering characteristics. Upset maneuvers similar to those used to establish the achievable overspeed conditions during certification tests for § 25.253(a) may be necessary to achieve the airspeed for the maneuvering characteristics demonstration. If full forward pitch control input is required to maintain the target airspeed after it is achieved, no pushover maneuver is possible. A wings-level pull-up or constant speed/Mach wind-up turn maneuver to the extent required for the maneuver should be accomplished from this condition with the control system operating normally, including any automatic trim surface movement.

(c) The flight testing for § 25.255(f) is required at V_{DF}/M_{DF} with the flight control system operating normally, except that flight envelope protections may be disabled or modified if necessary to allow reaching V_{DF}/M_{DF}. While conducting these tests, the airplane should be accelerated from a level flight condition at V_{MO}/M_{MO} (or any lower initial airspeed with the level of mistrim established with paragraph (a) above) using up to Maximum Continuous Thrust until V_{DF}/M_{DF} is achieved. A wings-level pull-up maneuver to at least 1.5g should be accomplished from this condition with the control system operating normally, including any automatic trim surface movement. Recovery capability is generally critical at altitudes where airspeed (V_{DF}) is limiting. If at the highest altitude reasonably expected for recovery to be initiated at VDF/MDF following an upset the maneuver capability is limited by buffeting of such an intensity that it is a strong deterrent to further increase in normal acceleration or an AOA Limit imposed by a High Angle of Attack Limiting Function is reached, some reduction of maneuver capability will be acceptable, provided that it does not reduce to below 1.3 g and that 1.5 g is possible at lower altitudes. The entry speed for flight test demonstrations of compliance with this requirement should be limited to the extent necessary to accomplish a recovery without exceeding V_{DF}/M_{DF}, and the normal acceleration should be measured as near to V_{DF}/M_{DF} as is practical.

(d) In accordance with § 25.255(e), the maneuvering characteristics tests for § 25.255(b) and any extrapolation of Nz in accordance with § 25.255(c)(2) need only extend to the lesser of

(i) The levels defined in § 25.255(c);
(ii) The positive load factors associated with probable inadvertent excursions beyond the boundaries of the buffet onset envelopes determined under § 25.251(e); and
(iii) The +/- load factors achievable at the test airspeed with the flight control system operating normally, including high speed protections, AOA limiting, Nz limiting, or other control system limitations.

(2) Investigation Range. Out-of-trim testing should be done at the most adverse loading for both high and low control forces, and the most adverse for the controllability test for §25.255(f).~~.~~ Testing should be accomplished both at the dynamic pressure (q) and Mach limits.

(3) The ability to move the primary controls (including trim), when loaded, should be considered prior to the tests.

Chapter 6 - Equipment

Section 1. General

174. Equipment, Systems, and Installations - § 25.1309.

a. Explanation. The following procedures outline and paraphrase the appropriate provisions of § 25.1309. Further definition and explanation, if required, may be found in part 25 and in AC 25.1309-1A, "System Design and Analysis," dated June 21, 1988.

Specific guidance is also provided to establish an acceptable method of assessing the hazard classifications of airplane system failure conditions leading to runway excursions during takeoff or landing for compliance with §25.1309(b). These same criteria can also be used to show that the airplane is capable of continued safe flight and landing for failure conditions for compliance with §§25.671(c), 25.672(c) and 25.901(c). The severity of runway excursions depends on many factors, such as airplane kinetic energy and configuration, and environmental conditions. Other threats, like airport environment, are treated separately in aerodrome designs in ICAO Annex 14.

b. Procedures.

(1) Evaluate functioning of required installed equipment to verify that performance is as intended under any foreseeable operating and environmental conditions.

(2) Evaluate failure conditions, as appropriate, to determine their impact on the capability of the airplane or the ability of the crew to operate it.

(3) Review, as appropriate, any design analyses, proposals, studies, or tests that correlate probabilities of failure condition occurrence with the effects of those failure conditions, to determine that they are properly categorized for the appropriate criticality level.

(4) Verify that adequate warnings are provided of unsafe conditions, and that these warnings enable the flightcrew to take appropriate corrective action with a minimum of error.

(5) In accordance with § 25.1310, for probable operating combinations of required electrical installations, verify that the following power loads are provided for probable durations:

(a) Loads connected to the system with the system functioning normally;

(b) Essential loads after failure of any one prime mover, power, converter, or energy storage device;

(c) Essential loads after failure of one engine on a two-engine airplane;

(d) Essential loads after failure of two engines on airplanes with three or more engines;

(e) Essential loads for which an alternate source of power is required, after any failure or malfunction in any one power supply system, distribution system, or other utilization system.

(6) For probable operating combinations of required electrical installations that must be provided with an alternate source of power in accordance with § 25.1331(a), verify that power is provided for probable durations after failure of any one power system.

c. Procedures - Runway Excursion Hazard Assessment.

(1) Background:

a. The service history of transport category airplanes indicates that high speed runway excursions can be catastrophic. However, that service history also indicates that excursions at low speed and low thrust conditions usually result in no injuries or damage to the airplane. A catastrophic event (in terms of multiple fatalities, usually with the loss of the airplane) is less probable at low speed because of lower airplane kinetic energy, a higher survivability margin for the airplane, and a higher controllability margin to avert the excursion or to lessen its severity.

b. Failure in certain systems, including flight controls, nose or main landing gear, brakes, and propulsion, could cause a runway excursion (either off the side or the end of the runway) and the effects should be included in the functional hazard assessment for these systems.

c. In assessing the criticality of a failure condition, the safety analyst typically considers intensifying factors in accordance with the guidance in AC 25.1309-1A 'System Design and Analysis' dated June 21, 1988 or AC 25.1309-Arsenal, System Design and Analysis, dated June 10, 2002 (if applicant request an equivalent level of Safety finding to §25.1309). These factors include, but are not limited to, atmospheric conditions expected to be encountered in service, such as temperature, crosswind and runway width and length.

(2) Hazard Assessment :

a. As with other functional hazard assessments, a combination of analysis, simulation and flight testing can be used to determine the effects of the failure and assess the associated hazard to the airplane and occupants. The deceleration capability of the airplane following failures affecting wheel braking or other deceleration devices should be determined in a manner consistent with that used to determine compliance with §§25.109, 25.113 and 25.125 and associated guidance provided in this AC.

b. The hazard for each functional failure that results in loss of deceleration capability during landing or during a rejected takeoff should be assessed individually and in combination with other failures. A rejected takeoff initiated due to external events or ATC instruction need not to be considered when assessing the runway hazard for system failures that are un-annunciated and un-detectable by the pilot (i.e. the pilot can be assumed to continue the Take off rather than reject the Take off under certain failure conditions).

c. The hazard for each functional failure that results in a lateral deviation from runway centerline during takeoff or landing where there is potential for departing the runway should also be assessed individually and in combination with other failures.

d. The pilot recognition and reaction time appropriate for each failure condition should be established commensurate with the flight deck annunciations, airplane response to the failure condition and pilot workload expected at the time of the failure. The recognition time for the failure condition is defined as the time from the failure condition to the point at which a pilot in service operation may be expected to recognize the need to take action. The pilot reaction time is defined as the time following recognition of the failure condition until initial action by the crew to counteract or otherwise respond to address the failure condition. Total delay = Recognition time + Reaction time.

e. Recognition of the malfunction may be through the behavior of the airplane or an appropriate alerting system. Pilot control movements alone should not be used for recognition. The recognition time should not normally be less than 1 second unless justification is provided for the specific failure condition based upon piloted simulation or flight test that reflect the cues available to the pilot. The pilot reaction time should not normally be less than 1 second for failures requiring the pilot to initiate a new action (such as initiating a rejected takeoff, activation of an alternate braking mechanism, alternate ground spoiler selection, selection of thrust reversers, differential braking, etc.), unless piloted simulation or flight testing can justify a lower reaction time. For directional control on the runway following failures that generate lateral deviations from centerline, it can be assumed that the pilot will apply recovery inputs to controllers normally used during takeoff or landing (e.g., rudder pedals, control wheel/lateral stick, nose wheel steering tiller, etc.) at the recognition point without delay.

f. All deceleration devices, including thrust reversers, and ground directional control devices, including nose wheel steering and differential braking, can be used for hazard assessment if they would be available during the failure condition under assessment, consistent with applicable procedures (normal procedures up to the point of the failure recognition and abnormal procedures following the failure recognition).

g. Example methodology to identify the design conditions and classify hazard level for longitudinal runway landing excursions.

1. Define intensified airport conditions to a level that represent an appropriate level of aggravated risk:
    - Field elevation should be intensified per criteria in Table 1
    - Ambient temperature should be intensified per criteria in Table 1
    - Engineering judgment may be necessary when considering further intensifying factors
2. Determine design mission weight:
    - A typical mission weight should be used to determine a design mission takeoff weight. Typical assumptions need to be made for the payload and reserves, similar to fatigue design conditions.

3. Determine takeoff limited field length:

- From the design mission takeoff weight and intensified airport conditions above, determine the best (shortest) takeoff field length.

4. Determine the baseline landing weight from the takeoff limited field length for the minimum design mission weight defined above:

- Using the takeoff limited field length as the baseline (no failures) landing distance; determine the landing weight limit for the baseline case using the aggravated condition assumptions. This weight should not exceed maximum landing weight.
- It may be assumed that the baseline landing distance represents un-factored 14 CFR 25.125 landing distance. This assumption is conservative, but is not considered representative of the actual operations of many fleets.
- An alternate method is to assume the baseline represents the AFM dispatch landing distance for the aggravated risk conditions. This distance may include an operational landing distance factor as appropriate for the particular certification basis (e.g. 14 CFR 121.195: factor is 1.67 for dry runway) and fleet operations.
- Another acceptable method is to assume the baseline represents an operational landing distance including an operational factor (e.g. TALPA: factor is 1.15).

5. Analyze landing case with un-annunciated failure(s) or failures occurring during the landing phase.

- Using the same landing weight and aggravated risk condition as the baseline case, determine the speed at the point of overrun (baseline distance).

6. Classify hazard level based on speed of overrun

Another method may be the comparison of the aggravated risk landing failure condition to a minimum field length established from fleet operational data. In this comparison, it would be appropriate to include maximum landing weight as an intensifying factor for the failure condition.

The following is a numerical example of the methodology above used to design a hypothetical airplane.

1. Define intensified airport conditions to a level that represent an appropriate level of aggravated risk:
    - Using data from a fleet similar to the airplane being designed, a 2,500 ft elevation was identified to represent 90% of the expected operations.
    - Using world meteorological data, and knowledge of the operational latitudes of the fleet, a conservative estimate of ISA+20 was identified to represent 90% of the expected operations.
    - A forward center of gravity is conservatively assumed for takeoff and landing performance.
2. Determine design mission weight:

- A typical 3 hour mission with an 85% load factor was selected for a design mission, similar to flutter design analysis. Assuming the intensified temperature and elevation conditions, this mission requires a 140,000 lb design takeoff weight.

3. Determine takeoff limited field length:
   - The 140,000 lb design takeoff weight requires a 5,000 ft field length.
4. Determine the baseline landing weight from the takeoff limited field length:
   - Using 5,000 ft as the baseline landing distance, and assuming the intensified conditions above, a design landing weight of 120,000 lb. It is known that this fleet operates in a Part 121 operational environment that requires a 1.67 factor on landing dispatch.
   - Note that it is known from similar fleet data that 99% of operations are anticipated on runways over 6,000 ft long, and most considerably longer. This may be a consideration when using maximum landing weight as an intensifying factor.
5. Analyze landing case with un-annunciated failure(s):
   - Using 120,000 lb landing weight, and the same intensified conditions, each of the identified un-annunciated failure cases (at landing touchdown) are analyzed and compared to the baseline landing field length to determine the potential excursion speeds.
6. Classify hazard level based on speed of overrun:
   - The speed of the overrun for each failure case will determine its hazard classification.

h. Rationale statement for coverage of specific risk versus average risk. The excursion speed criteria proposed by the FTHWG was developed based on industry experience and hundreds of millions of cycles of service history representing multiple aircraft manufacturers. This historic data naturally takes into account all of the possible variables (intensifying factors) as well as the frequency of operations into specific airports, with specific airlines, with various quality crews, etc. Per AC/AMJ 25.1309, classification of Failure Conditions should always be accomplished with consideration of all relevant factors, including intensifying and alleviating factors.

The FTHWG considered relevant intensifying and alleviating factors and defined a set of factors by which to assess or simulate failures to define relevant combinations of failures for a probability assessment. These factors do not just consider the average operational and environmental conditions, but define a combination of conditions that envelope the vast majority of departures and landings. Therefore the FTHWG proposed factors and approach is much more conservative than the literal interpretation of ‘average risk’. This approach should not be confused with specific risk, which is not considered appropriate for runway excursions as explained below.

Specific risk is ‘the risk on a given flight due to a particular condition’. As one could imagine, there is the potential that a particular condition or combination of conditions could be such that a runway departure (even at low speed) is catastrophic (e.g. an off-runway obstacle). Likewise, a particular condition or combination of factors could be such that the combination of failures and operational and environmental factors resulting in the failure condition were inadvertently excluded. There are no regulatory criteria for specific risk, that is, there is no regulatory basis that says for a specific combination of airport, environmental conditions, and operational considerations that the aircraft must meet. Rather, the aircraft must be able to perform (without failures) to the specifications in the FAR/CS; this, and the applicable criteria for airport design, have proven to be robust in all but the most extreme specific risk conditions as evident in the historical data. It should be noted that when an ARAC ASAWG committee addressed specific risk, their recommendations refined how average risk was performed with respect to operational and environmental conditions, but did not set criteria for operational and environmental specific risk conditions.

The factors associated with runway excursion criticality: field length, runway width, weight and CG, runway surface condition, crosswind, elevation, temperature, reaction time, off-runway obstacles, etc., are not all independent, and it is impossible to conclude what the likelihood of being in a particular condition (a combination of these variables) will be. Engineering judgment, and fleet history was used in selecting a set of factors that when combined would envelope the extremes of any one condition where it was practical to do so.

When defining the design conditions to prevent runway excursions due to system failures, it is assumed that the construction of the runway and surrounding terrain are compliant with ICAO Annex 14 standards. While any specific runway may have some manner of deviation from the ICAO standards, it would be impractical to design systems generally to account for every known deviation in airport construction. Furthermore, existing airplane crashworthiness requirements are complementary to the prevention of runway excursions, by reducing the consequence when excursions occur. The crashworthiness standards focus on protecting airplane occupants from a crash, minimizing the development and severity of a potential crash fire, and ensuring the rapid evacuation of airplane occupants.

i. Table 1 below provides specific criteria that have been found acceptable for longitudinal and lateral runway excursion hazard assessments and are relevant for ICAO Annex 14 compliant aerodromes: these are acceptable design assumptions and not intended to require mandatory AFM limitations.

TABLE 1: Runway Excursion Hazard Criteria

Parameter	**Criteria**
Longitudinal runway excursion speed	0-30 kt MAJ >30-60 kt HAZ > 60 kt CAT
Lateral runway excursion speed	0-30 kt MAJ (if all MLG exit runway) 30-60 kt HAZ (if all MLG exit runway) > 60 kt CAT (if all MLG exit runway) *Next lower classification to be used if any Main Landing Gear (MLG) remains on the runway

Take off Field Length	AFM Take Off Field Length limited weight for the design case (Outside Air Temperature & Field elevation & weight/cg specified below). Without credit of stop way or clearway for obstacle clearance
Speed for Failure consideration (during Take off)	Longitudinal: At decision speed V1. Lower than V1 may be accepted if supported by rationale(e.g. control surface failure message before V1) Lateral: Between brake release and V1 for Rejected Take off and between V1 and V_{LOF} for a Continued Take off.
Landing Field Length (Longitudinal analyses)	At the choice of the applicant (ref §g. for methodology explanation): 1) Consistent with a reasonable take off distance for the type of operation, OR 2) Runway length based on 90% statistics of historical operations for airplane of their type, size and gross weight Combined with 90% statistics of field elevation and Outside Air Temperature. Should not be greater than the 1.67 field length at MLW.
Runway Width	Use ICAO airport design level letter code or narrower. Operational guidance or other mitigations should be provided for operations (unlimited or frequent) on runway narrower than that used for the Type Certification safety analysis, if the hazard failure classification would be increased.
Weight and CG	Longitudinal and Lateral: - for Take off: critical weight & CG between minimum TOW (1 hour mission and 25% passenger) to MTOW - for Landing : critical weight & CG between minimum Landing Weight (25% passenger + reserve fuel) up to a Landing Weight consistent with the criteria for the design runway field length (refer to §g.)
Runway Surface Condition (Longitudinal analyses)	Dry

Runway Surface Condition (Lateral analyses)	Dry
Crosswind (Lateral analyses)	At the choice of the applicant Method 1) OR Method 2): Method 1) 10kt (wind prob. 1): FC from 10-9 to 10-7 20kt(wind prob. 10-2):FC from 10-7 to10-6 25kt(wind prob. 10-3):FC from 10-6 and above (Failure Case prob. may include exposure time) OR Method 2) 10kt basic scenario (prob. 1) 25kt aggravating factor (prob. 10-3) * but need not to be more stringent than AC 25-7X Appendix 5 Fig 8 (HQRM) **Failure Case probability including exposure time
Field Elevation	Up to an altitude sufficient to cover at least 90% of the intended operation at Type Certificate. If data on the intended operation is missing use a default value of 5,000 ft. (ref §g. and §h. for further details)
Outside Air Temperature	Up to a temperature sufficient to cover at least 90% of the intended operation at TC. If data on the intended operation is missing use a default value of ISA deg C (ref §g. and §h. for further details)

Section 2. Instruments: Installation

177. Airspeed Indicating System - § 25.1323.

a. Explanation.

(1) Methods. Unless a calibrated reference system is provided, the airspeed system should be calibrated throughout as wide a range as necessary to cover the intended flight tests. The procedures of this section are for the purpose of showing compliance with § 25.1323(b) and are not intended to cover the speed range of the flight tests. If an alternate airspeed indicating

system is provided, it should be calibrated. The airspeed indicating system should be calibrated in accordance with the following methods:

(a) The tests should be conducted in stabilized flight at airspeeds throughout the speed range for the airplane configurations to be tested. The airplane's airspeed system should be calibrated against a reference airspeed system.

(b) A reference airspeed system should consist of either of the following:

1 An airspeed impact pressure and static pressure measurement device (or devices) that are free from error due to airplane angular changes relative to the direction of the free stream or due to slipstream variation resulting from changes in airplane configuration or power/thrust. In addition, the device or devices should have a known calibration error when located in the free stream; or

2 Any other acceptable airspeed calibration method (e.g., the altimeter method of airspeed calibration).

(c) If an alternate system is provided, it may be calibrated against either the reference system or the airplane's system.

(d) An acceptable means of compliance when demonstrating a perceptible speed change between 1.23 V_{SR} to stall warning speed or the airspeed achieved at full aft control input if compliance is shown with §§ 25.202 and 25.204 (§ 25.1323~~(§ 23.1223~~(d)) is for the rate of change of IAS with CAS to be not less than 0.75.

(e) An acceptable means of compliance when demonstrating a perceptible speed change between V_{MO} to V_{MO} + 2/3 (V_{DF} - V_{MO}) (§ 25~~23~~.1323(e)) is for the rate of change of IAS with CAS to be not less than 0.50.

Chapter 8 - Airworthiness: Miscellaneous Items

228. Design and Function Of Artificial Stall Warning and Identification Systems.

a. Applicable Regulations. Sections 25.103, 25.201, 25.203, and 25.207.

f. System Functional Requirements.

(1) Operation of the stall identification system should reduce the airplane's angle-of-attack far enough below the point for its activation that inadvertent return to the stall angle-of-attack is unlikely.

(2) The characteristics of stall identification systems, which by design are intended to apply an abrupt nose-down control input (e.g., a stick pusher), should make it unlikely that a flightcrew member will prevent or delay its operation. The required stick force, rate of application, and stick travel will depend on the airplane's stall and stick force characteristics, but a force of 50 to 80 pounds for a conventional control wheel applied virtually instantaneously has previously been accepted as providing this characteristic. Stick pusher force levels for a side stick controller should be evaluated on a case-by-case basis, but should not be less than 35 pounds.

(3) Normal operation of the stall identification system should not result in the total normal acceleration of the airplane becoming negative.

(4) The longitudinal maneuvering capability of an airplane equipped with stall identification systems, at all speeds likely to be encountered in normal operations, should be substantially the same as would be expected for an airplane with acceptable aerodynamic stall characteristics.

231. Criteria For Approval Of Steep Approach To Landing.

a. Applicable Regulations. Sections 25.119, 25.121, 25.125, and 25.143.

b. Explanation.

(1) Airworthiness Approval. The standard approach angle assumed as part of the type certification of transport category airplanes is 3 degrees, which coincides with the nominal ILS approach angle. Those evaluations are considered adequate to address approach angles of less than 4.5 degrees. The criteria listed below represent FAA policy for airworthiness approval of steep approach landing capability using an approach angle of 4.5 degrees or more. Additions or deletions to these criteria may be needed to address specific design features. It should be noted in the AFM that the presentation of the steep approach limitations, procedures, and performance information reflects the capability of the airplane to perform steep approaches, but does not constitute operational approval.

(2) Operational Approval. Operational approval to conduct steep approaches in the United States is the exclusive responsibility of FAA Flight Standards Service, and cannot be delegated to FAA Aircraft Certification Service employees, designees, or to foreign civil aviation authorities. FAA Flight Standards Service has assigned this responsibility to the Flight Standardization Board (FSB) with oversight for the airplane type in question. Operational approval will, in part, be based on the results of the airworthiness testing described in this section. Additional testing, for operational concerns, may be combined with the airworthiness testing. Ideally, the testing for operational approval would be conducted by the Flight Standardization Board during the test program for airworthiness certification of steep approach capability.

c. General Criteria.

(1) If approval is sought to conduct steep approaches in icing conditions, compliance with the part 25 requirements applicable to steep approach operations identified below should also be shown for icing conditions.

(2) The following criteria apply when showing compliance with § 25.125 for steep approaches:

(a) The airplane should be in the landing configuration used for steep approaches.

(b) Compliance with the requirement that a stable approach be conducted to a height of 50 feet with a speed not less than V_{REF} (§ 25.125(b)(2)) should be shown with an approach path angle not exceeding the maximum for which approval is sought. The V_{REF} used for steep approaches may be different than the V_{REF} used for normal approaches.

(c) If the parametric method of determining the landing distance is used (see paragraph 19b(3) of this AC), approach angles should be appropriate to the steep approach path angle desired, and the touchdown sink rate for data expansion should be limited to 6 feet per second.

(3) The landing distance established under § 25.125(a) begins at a point 50 feet above the landing surface. If an applicant proposes to use a different height for the beginning of the steep approach landing distance, this must be done through an equivalent level of safety finding, in accordance with § 21.21(b)(1), or an exemption, in accordance with part 11. This has been done in

some steep approach certifications to take advantage of precision approach guidance at an airport that guides the airplane to a height over the runway threshold of less than 50 feet.

(4) Compliance with §§ 25.119 and 25.121(d) should be shown using the configurations and speeds established for steep approach operations.

d. Test Conditions For Reasonably Expected Variations In Approach Speed and Path Angle.

(1) The following additional criteria should be applied to show that the airplane is safely controllable and maneuverable during landing (§ 25.143(a)(5)).

(a) Under calm air conditions, demonstrate that it is possible to complete an approach, touchdown, and stop without displaying any hazardous characteristics in the following conditions:

1 An approach path angle 2 degrees steeper than the steepest approach path angle for which approval is sought at the V_{REF} established for a steep approach; and

2 The steepest approach path angle for which approval is sought at a speed 5 knots lower than the V_{REF} established for a steep approach; and.

3 An approach path angle 1 degree steeper than the steepest approach path angle for which approval is sought at the V_{REF} established for a steep approach. A value less than 1° may be used if appropriate substantiation is provided by the applicant (examples that can be used for substantiation: the maximum FPA deviations at screen height from a large number of approaches conducted by a variety of different pilots, environmental factors considerations or system design considerations).

(b) For theboth conditions above:

1 The airplane should be loaded to the most critical weight and c.g. combination;
2 The airplane should be in the steep approach configuration;

3 The rate of descent should be reduced to no more than: 3 feet per second at touchdown;

3 feet per second at touchdown for conditions 1 and 2 of above §231d (1)(a);
6 feet per second at touchdown for condition 3 of above §231d (1)(a), provided sufficient control margin is demonstrated and no exceptional pilot skill is required;

4 Below a height of 200 feet, no action should be taken by the pilot to increase power or thrust, apart from those small changes needed to maintain an accurate approach;

5 After initiating the flare, the longitudinal control should not be used to depress the nose apart from those small changes necessary to maintain a continuous and consistent flare flight path;

6 The flare, touchdown, and landing should not require exceptional piloting skill, alertness, or strength; and

7 To ensure adequate capability for a go-around or down path adjustment, the engines should remain above flight idle power or thrust when stabilized on the approach path. When

conducting the 2 degrees steeper approach path angle test condition of paragraph 231d(1)(a)1, the engines can be periodically at flight idle power or thrust provided the target airspeed and approach path are maintained.

NOTE: The 2 degrees steeper approach path angle demonstration is to account for tailwinds on the approach and to take into account necessary corrections back to the desired approach path after inadvertent excursions. The purpose of the test at V_{REF} minus 5 knots is to account for an unnoticed speed decrease during the approach, hence the requirement in paragraph 231d(1)(b)4 for no power or thrust increase to account for the slower speed. The 1 degree steeper approach path angle demonstration is to account for flight path deviations at screen height (for any reason including piloting, guidance instrument accuracy, and environmental conditions).

(c) WhenFor flight test safety reasons, when conducting the 2 degrees steeper approach path angle test condition of paragraph 231d(1)(a)1, the pilot may begin to flare the airplane (or reduce the approach angle) at a reasonable height somewhat higher than the normal steep approach flarescreen height, but not exceeding 150% of.. If this is done, it should be shown by analysis that there is sufficient pitch control to arrest the descent rate if the flare were to be initiated at the normal steep approach flarescreen height. When conducting the test conditions of paragraph, keeping in mind the criteria in paragraphs 231d(1)(a)2b)3 and 231d(1)(a)3, the pilot must not begin to flare the airplane above the normal steep approach screen height6.

(2) Compliance with § 25.143(b)(1) should be assessed as follows: Demonstrate that the airplane can both safely land and safely transition to a go-around following a failure of the critical engine at any point in the approach under the following conditions:

(a) The steepest approach angle for which approval is sought;

(b) The V_{REF} established for a steep approach; and

(c) The most critical combination of weight and c.g.; and

(d) For propeller powered airplanes, the propeller of the inoperative engine should be in the position it would normally assume without any action taken by the pilot following an engine failure.

(3) The height loss experienced during the maneuver described in paragraph 231d(2) should be determined.

NOTE:

At least one demonstration should be done to establish height loss. Additional go-arounds are not required if a proper design review is done to assess the impact of transition to go-around and confirm that system would not prohibit the airplane to initiate a go-around from any height.

e. One-Engine-Inoperative Steep Approach.

(1) If approval is sought for one-engine inoperative steep approach capability, the following criteria should be met at the most critical weight and c.g. position, using the configuration and speed established for a one-engine-inoperative steep approach:

(a) The demonstrations identified in paragraph 231d(1) above; and

(b) Demonstrate that the airplane can safely transition to a go-around during a one-engine inoperative steep approach.

f. Airplane Flight Manual.

(1) In accordance with §§ 25.1581, 25.1583, 25.1585, and 25.1587, the following information must be provided in the AFM:

(a) Limitations, operating procedures, and performance information necessary for steep approach operations, including the configuration(s), speeds and flight path angle(s) approved for conducting a steep approach; and

(b) Operating limitations prohibiting initiation of a steep approach:

1 With one engine inoperative, unless the airplane is approved for one-engine inoperative steep approaches; and

2 In forecast or known icing conditions unless the airplane is approved for conducting steep approaches in icing conditions.

(c) A statement in the limitations section that the steep approach limitations, procedures, and performance information reflect the capability of the airplane to perform a steep approach, but do not constitute operational approval to conduct steep approach operations.

(d) The height loss determined in accordance with paragraph 231d(3).

(e) A statement of headwind and crosswind limitations if they are different from those for non-steep approaches. The tailwind limitation is 10 knots or less unless test evidence shows that more than 10 knots is acceptable. Results of the non-steep approach wind component testing may be used to establish the safe headwind and crosswind limitation components. If flight test data and/or analysis show that the sideslip angle capability demonstrated is similar to that shown with the non-steep approach airplane, and the flight characteristics (control forces and deflections, for example) are similar, then the non-steep approach airplane crosswind component test result is considered valid for steep approach.

Colors for AC 25-25A changes
Topic 2 Adaptation for Flight in Icing
Topic 6 Stability
Topic 7 Side Sticks

U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Performance and Handling Characteristics in Icing Conditions

Date: 10/27/14

Initiated By: ANM-110

AC No: 25-25A

This advisory circular describes an acceptable means of showing compliance with the airplane performance and handling characteristics certification requirements for flight in the icing conditions defined in Appendices C and O of Title 14, Code of Federal Regulations part 25.

If you have suggestions for improving this AC, you may use the feedback form at the end of this AC.

Michael Kaszycki
Acting Manager, Transport Airplane Directorate
Aircraft Certification Service

Note: At the option of the applicant V_{SR} in non icing may be used when showing compliance for conditions specified as a factor of VSR for the following paragraphs : 25.145(b)(c), 25.147(a)(b)(c)(e), 25.161(b)(c)(d), 25.175(a)(b)(c)(d), 25.177(a)(b), 25.181(a)(b), and 25.231(a)(2).

CHAPTER 2. REQUIREMENTS AND GUIDANCE

2.1 Overview

2.1.12 SLD icing conditions, or runback ice in any icing condition, can cause a ridge of ice to form aft of the protected area on the upper surface of the wing. This can lead to separated airflow over the aileron. Ice-induced airflow separation upstream of the aileron can have a significant effect on aileron hinge moment. Depending on the extent of the separated flow and the design of the flight control system, ice accretion upstream of the aileron may lead to aileron hinge moment reversal, reduced aileron effectiveness, and aileron control reversal. Although airplanes with deicing boots and unpowered aileron controls are most susceptible to this problem, all airplanes should be evaluated for roll control capability in icing conditions. Acceptable flight test procedures for checking roll control capability are presented in paragraphs 4.9.3, 4.15, and 4.17.2.5 (or 4.18.2.5 for airplanes where compliance is shown to §§25.202 and 25.204) of this AC and consist of bank-to-bank roll maneuvers, steady heading sideslips, and rolling maneuvers at stall warning speed or AOA limit, as applicable.

2.2 Proof of Compliance, §25.21(g)

2.2.3 If different stall warning system or stall identification system activation settings, or different High Angle-of-Attack Limiting Function AOA limits, if so equipped, are used for flight in icing conditions (for example, if the stall warning or stall identification system activation settings or AOA limits are changed when the ice protection system is activated), it is acceptable to return to the non-icing settings/AOA limits when the critical wing surfaces are free of ice. The applicant should validate that the means for determining when the critical wing surfaces are free of ice accretions is reliable under all expected operating conditions.

2.5 Reference Stall Speed, § 25.103.

Certification experience in meeting this requirement has shown that, for airplanes of conventional design, the effects of Mach number on stall speeds is unaffected by the presence of ice accretions.

For airplanes equipped with a High Angle-of-Attack Limiting Function (HALF) that meets the requirements of §§ 25.202 and 25.204, determination of reference stall speeds in icing conditions is at the option of the applicant and would only be necessary if V_{SR} in icing conditions is used as a factor to determine compliance with a required performance standard, as allowed by § 25.103(b)(3) and the performance standards of sections 25.105(a)(2), 25.107(c)(g), 25.121(b)(2)(ii), 25.121(c)(2)(ii), 25.121(d)(2)(ii), 25.123(a), 25.123(b)(2), 25.125(b)(2)(ii).

§25.103(e) for High Angle-of-Attack Limiting Function (HALF) equipped airplanes requires that the 1g minimum steady flight speed, V_{MIN1g}, be determined in icing conditions if it is used to determine compliance with a required performance standard or other requirement in icing conditions.

If V_{SR} or V_{MIN1g} is to be established, it must be determined for all aerodynamic configurations for which it is to be used to show compliance (e.g., takeoff, en route, approach, and landing configurations) with the appropriate ice accretion for that flight phase specified in Part II of Appendix C.

2.6 Takeoff, §25.105 and Climb: One-engine-inoperative, §25.121:

2.6.1 Performance - Takeoff Path Determination

Inclusion of the effects of ice during the determination of the takeoff path and takeoff performance parameters must be in accordance with §§ 25.105(a) and 25.121(b) and (c) which include ice accountability thresholds based on a relative increase in the reference stall speed or degradation in climb gradient due to ice. If any of the applicable ice accountability thresholds are exceeded, the airplane performance for the entire takeoff path, including takeoff speeds and distances, must be determined with ice accretions on the airplane.

2.6.2 The gradient degradation threshold contained in these sections only refers to the degradation due to aerodynamic effects of ice accretion. Propulsive effects are accounted for separately when computing of the takeoff thrust with anti-ice operating.

2.~~6~~ 7 **Failure Conditions, § 25.1309.**

2.~~6~~ 7.1 The applicant should analyze failure modes of the ice protection………..

2.~~6~~ 7.2 The guidance in this AC for a normal (that is, non-failure)……….

2.~~6~~ 7.3 For probable ice protection failure conditions annunciated ………..

2.~~6~~ 7.4 For failure conditions that are improbable……….

2.~~7~~ 8 Flight Related Systems.

2.~~7~~ 8.1 Ice protection systems …

2.~~7~~ 8.2 Ice may block control surface gaps …

2.~~7~~ 8.3 Ice may block unprotected inlets …

2.~~7~~ 8.4 Airspeed, altitude, or angle-of-attack sensing errors …

2.~~7~~ 8.5 There may be an effect on operation of stall warning, stall identification and/or a High Angle-of-Attack Limiting Function ~~reset features~~ for flight in icing conditions, including effects of failure to operate.

2.~~7~~ 8.6 Operation of icing condition …

2.~~7~~ 8.7 Flight guidance …

2.~~7~~ 8.8 There may be an effect on installed thrust …

2.~~8~~ 9 Airplane Flight Manual, § 25.1581 through § 25.1587.

2.~~8~~ 9.1 Section 25.1581 states …

2.~~8~~ 9.1.1 The limitations required …

2.~~8~~ 9.1.2 Performance limitations …

2.~~8~~ 9.1.3 All airspeed limitations …

2.~~8~~ 9.1.4 As applicable …

2.~~8~~ 9.1.5 For turbojet airplanes …

2.~~8~~ 9.2 To comply with § 25.1583(e)…

2.~~8~~ 9.3 For airplanes not certified …

2.~~8~~ 9.4 To comply with § 25.1585…

2.~~8~~ 9.4.1 Flight in icing conditions …

2.~~8~~ 9.4.2 Normal operating procedures …

2.~~8~~ 9.4.3 For turbojet airplanes without …

2.~~8~~ 9.4.4 Non-normal operating procedures …

2.~~8~~ 9.5 Performance information …

2.~~8~~ 9.6 Examples of AFM limitations …

4.2 Reference Stall Speed and V_{MIN1g} Determination, § 25.103.

4.2.1 The reference stall speed, V_{SR}, or the minimum steady flight speed, V_{MIN1g}, for intermediate high lift configurations (for takeoff configurations, for example) can normally be obtained by interpolation. However, additional tests may be necessary if—

4.2.1.1 A stall identification system (for example, a stick pusher) activation point or High Angle-of-Attack Limiting Function (HALF) AOA limit is set as a function of the high lift configuration,

4.2.1.2 The activation point or HALF AOA limit ~~is reset~~ adjusted for icing conditions, or

4.2.1.3 Significant configuration changes occur with extension of trailing edge flaps (such as extension of wing leading edge high lift devices).

4.2.2 Acceptable Test Program.

The following specifications represent an example of an acceptable test program subject to the provisions outlined paragraph 4.2.1 of this AC.

Maneuvers

4.2.2.1 Load the airplane to a forward center-of-gravity position appropriate to the airplane configuration.

4.2.2.2 Conduct the test at the reference stall speed test altitude used in non-icing tests.

4.2.2.3 Trim in level flight at an initial speed of 1.13 to 1.30 V_{SR} or 1.13 to 1.3 V_{MIN1g}, as applicable. If determining V_{SR}, decrease~~Decrease~~ speed at a rate not to exceed 1 knot per second until an acceptable stall identification as defined in § 25.201(d) or the angle of attack corresponding to V_{SR} is obtained; or until activation of a stall identification device (e.g., stick pusher), if installed. If determining V_{MIN1g}, decrease speed at a rate not to exceed 1 knot per second until the longitudinal control reaches the aft stop and the airplane has reached a stabilized flight condition from which V_{MIN1g} can be determined. Perform this maneuver with the following ice accretions:

4.2.2.3.1 In high lift devices retracted configuration—final takeoff ice.

4.2.2.3.2 In high lift devices retracted configuration—en route ice.

4.2.2.3.3 In holding configuration—holding ice.

4.2.2.3.4 In lowest lift takeoff configuration—holding ice.

4.2.2.3.5 In highest lift takeoff configuration—takeoff ice.

4.2.2.3.6 In highest lift landing configuration—holding ice.

4.4 **Takeoff Path, § 25.111.**

In accordance with § 25.105(a), the applicant should conduct takeoff evaluations to substantiate the speed schedule and distances for takeoff in icing conditions if the following applies:

4.4.1 VSR in the configuration defined by § 25.121(b) with the takeoff ice accretion exceeding VSR for the same configuration without ice accretions by more than the greater of 3 knots or 3 percent, if compliance is not shown to §25.202 and § 25.204

4.4.2 Any need for a takeoff speed increase, and any effects of thrust loss or drag increase on the takeoff path, may be determined by a suitable analysis.

4.9 Controllability and Maneuverability -- General, § 25.143.

4.9.3 Evaluation of Lateral Control Characteristics.

Aileron hinge moment reversal and other lateral control anomalies have been identified as causal factors in icing accidents and incidents. The following maneuvers, along with the following two evaluations, are intended to determine susceptibility of the airplane to aileron hinge moment reversals or other adverse effects on lateral control characteristics due to ice accretion.

Evaluations

4.9.3.1 Evaluate lateral controllability during deceleration to the stall warning speed (covered in paragraph 4.17.2.5 of this AC) or to the AOA Limit if a High Angle-of-Attack Limiting Function is included and compliance is shown with §§25.202 and 25.204 (covered in paragraph 4.18.2.5 of this AC), and

4.9.3.2 Evaluate static lateral-directional stability (covered in paragraph 4.15 of this AC).

4.9.4 Low g Maneuvers and Sideslips.

The maneuvers in paragraph 4.9.4.3 of this AC represent an example of an acceptable test program for showing compliance with controllability requirements in low g maneuvers and in sideslips to evaluate susceptibility to ice-contaminated tailplane stall.

4.9.4.1 Section 25.143(i)(2).

4.9.4.1.1 The regulation states: "It must be shown that a push force is required throughout a pushover maneuver down to a zero g load factor, or to 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 **for a conventional control wheel or 35 pounds for a side stick**…."

4.9.4.1.1 [No Change]

4.9.4.2 [No Change]

4.9.4.3 [No Change]

4.9.5 Controllability Prior to Activation and Operation of the Ice Protection System.
The following is an example of an acceptable test program for showing compliance with § 25.143(j).

During the pull-up maneuvers, controllability must be acceptable throughout the maneuver. At no time should airplane exhibit hazardous characteristics, and the airplane must maintain good lateral and directional control and it must always be possible to reduce AOA by conventional use of the controls. During the push-over maneuvers, the longitudinal control forces must not reverse and there should be no uncommanded pitch response. If necessary, the pull-up maneuvers may be limited to the point at which stall warning occurs (if compliance is shown with §25.207) or to activation of another suitable warning alert in accordance with §25.1322, to the point where control inceptor constraints are encountered or as limited by a High Angle-of-Attack Limiting Function, if installed.

Maneuvers

4.9.5.1 For the configurations, speeds, and power settings listed below, with the ice accretion specified in the requirement, trim the airplane at the specified speed, conduct a pull-up maneuver to 1.5 g and pushover maneuver to 0.5 g, and show that longitudinal control forces do not reverse.

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

4.9.5.1.2 Landing configuration, V_{REF} for non-icing conditions, power or thrust for landing approach. If necessary, limit the pull-up maneuver to the point at which stall warning occurs.

4.9.6 Maneuver Margin in Icing Conditions.

The following is an example of an acceptable test program for showing compliance with § 25.143(h).

Maneuvers

4.9.6.1 Load the airplane to a forward center-of-gravity position appropriate to the airplane configuration.

4.9.6.2 Trim the airplane at the specified test speed to be used for operation in icing conditions at the gross weight and thrust as specified, accounting for drag due to the applicable ice accretion and any thrust effects due to ice protection operation, as appropriate.

4.9.6.3 Achieve the specified bank angle in a coordinated turn and confirm that stall warning or any other characteristic (including the envelope protection features of fly-by-wire flight control systems or automatic power or thrust increases) that might interfere with normal maneuvering are not encountered. Perform the maneuvers specified by § 25.143(h) with the following configurations and ice accretions at the scheduled operating speeds for operating in icing conditions:

4.9.6.3.1 30º deg banked turn at V_2 for each approved takeoff configuration — takeoff ice.

4.9.6.3.2 40º banked turn at V_{2+XX} for each approved takeoff configuration — takeoff ice.

4.9.6.3.3 40º banked turn at V_{FTO} in the en route configuration — final takeoff ice.

4.9.6.3.4 40º banked turn at V_{ER} in the en route configuration — en route ice.

4.9.6.3.5 40º banked turn at V_{REF} for each approved landing configuration — holding ice.

4.10 Longitudinal Control, § 25.145.

4.10.1 No specific quantitative evaluations are required for demonstrating compliance with § 25.145(b) and (c). Qualitative evaluations should be combined with the other testing. Review results of tests on the uncontaminated airplane for any cases of marginal compliance. All tests showing marginal compliance should be repeated with ice accretions on the airplane.

4.10.2 Acceptable Test Program.

The following specifications represent an example of an acceptable test program for compliance with § 25.145(a).

Maneuvers

4.10.2.1 The holding ice accretion should be used.

4.10.2.2 The airplane is at a medium to light weight, aft center-of-gravity position, with symmetric fuel loading.

4.10.2.3 In the configurations listed below, trim the airplane at 1.3 V_{SR}. Reduce speed approximately 1 knot per second using elevator control to 1 second past stall warning with airplanes for which compliance is shown to § 25.207 or one second after achieving full aft control input with airplanes for which compliance is shown with §§ 25.202 & 25.204, and demonstrate prompt recovery to the trim speed using elevator control.

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

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

4.14 **Demonstration of Static Longitudinal Stability, § 25.175 and § 25.176.**

4.14.1 To show compliance with § 25.175, … [unchanged]

4.14.2 Acceptable Test Program, § 25.175. [remainder unchanged].

4.14.3 Static Longitudinal Stability- Alternate, § 25.176

To show compliance with this requirement, the applicant should combine qualitative evaluations with the other testing. Each change in airplane or control system behavior due to icing that has a significant effect on the characteristics relative to the requirement of 25.176 should be specifically investigated.

4.17 Stall Demonstration, § 25.201/Stall Characteristics, § 25.203.

4.17.1 For an airplane where compliance is shown to §§ 25.201 & 25.203, tThe applicant should conduct sufficient stall testing to demonstrate that the stall characteristics comply with the requirements of §§ 25.201 and 25.203…..

4.18 Handling demonstrations for high angle-of-attack limiting functions, § 25.202/Flight Characteristics for High angle-of-Attack Limiting Functions, § 25.204.

4.18.1 For an airplane where compliance is shown to §§ 25.202 & 25.204, the applicant should conduct sufficient testing with simulated ice accretions to demonstrate that the flight characteristics up to the AOA limit comply with the applicable requirements of §§ 25.202 and 25.204 in icing conditions.

In addition, § 25.202(e) requires that flight characteristics up to the angle-of-attack corresponding to V_{SR} (if determined) or the maximum angle-of-attack achieved during the dynamic maneuver of § 25.202(d)(1)-(4) be conducted in icing conditions per the procedures described below in sections 4.18.2.1-4.18.2.4 and the resulting characteristics shown to comply with the requirements of § 25.204(f). At the option of the applicant, this testing may be conducted with the High Angle-of-Attack Limiting Function deactivated (disabled) or adjusted to a higher AOA-limit.

In general, it is not necessary to conduct a test program that encompasses all weights, center-of-gravity positions, altitudes, high lift configurations, deceleration device configurations, straight and turning flight attitudes, and thrust or power settings. The applicant can establish a reduced test matrix based on a review of the high AOA characteristics of the uncontaminated airplane. However, additional tests may be necessary if --

4.18.1.1 The high AOA characteristics with ice accretion show a significant difference from those on the uncontaminated airplane,

4.18.1.2 The testing indicates borderline compliance, or

4.18.1.3 The AOA limit of the HALF is adjusted for icing conditions.

4.18.2 Acceptable Test Program.

The requirements of 25.202(d)(4) specify maneuvers with increased entry rates to the AOA limit in icing conditions up to 3 kts/sec. If dynamic application of go-around thrust at any time following initiation of the deceleration to the time at which the longitudinal control reaches the aft stop would result in higher peak angle-of-attack during this increased entry rate test, these tests for landing configuration must also be conducted with the most critical dynamic thrust application.

Note that slower decelerations (much slower than 1 knot per second) may be critical on airplanes with anticipation logic in their HALF design or on airplanes with low directional stability, where large sideslip angles could develop. The following specifications represent an example of an acceptable test program subject to the provisions outlined above.

Maneuvers

4.18.2.1 The holding ice accretion should be used.

4.18.2.2 The airplane should be loaded to a medium to light weight, aft center-of-gravity position, with symmetric fuel loading.

4.18.2.3 The tests should be conducted at the normal high AOA handling test altitude.

4.18.2.4 In the configurations listed in paragraphs 4.18.2.4.1 through 4.18.2.4.4 below, and each other configuration if deemed more critical, trim the airplane at the same initial airspeed ratio as was used for stall reference speed or V_{MIN1g} determination in icing. For power on maneuvers, use the power setting as defined in § 25.202(b)(2)(ii), but with ice accretions on the airplane. Decrease speed at entry rates of 1 and 3 knots per second to the AOA limit and recover using the same recovery maneuver as for the uncontaminated airplane.

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

4.18.2.4.2 Lowest lift takeoff configuration: Straight/Power On, Turning/Power Off.

4.18.2.4.3 Highest lift takeoff configuration: Straight/Power Off, Turning/Power On.

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

4.18.2.5 For the configurations listed in paragraphs 4.18.2.4.1 and 4.18.2.4.4 above, and each other configuration if deemed more critical, at a stabilized condition at the AOA limit with wings level and power off, roll the airplane left and right up to 10° of bank using the lateral control using approximately 5°/sec roll rate.

4.18.2.6 If considered more critical, the increased entry rate (3 knots per second) tests of 4.18.2.4 should be repeated for the highest lift landing configuration with rapid application of go-around power or thrust at any time following initiation of the maneuver to the time at which the longitudinal control reaches the aft stop.

4.18.2.7 For compliance with §§ 25.202(e) and 25.204(f), flight characteristics testing to the applicable maximum AOA should be conducted for the configurations listed in paragraphs 4.18.2.4.1 and 4.18.2.4.4 above. This is to be done in wings-level flight with a deceleration from the trim speed of not more than 1 kt/sec.

4.18.3 Flight in Icing Conditions Prior to Activation and Operation of the Ice Protection System

Provided that the time from entry into icing conditions until the ice protection system is activated and performing its intended function is sufficiently brief, as described in Appendix A paragraph A.2.3 of this AC, the following represents an acceptable means for showing compliance with §25.202(d)(5). The deceleration maneuvers below are to extend until encountering the first of the following, representing the lowest operational airspeed under normal operation:

a) A suitable warning alert, in accordance with §25.1322, followed by normal recovery input delayed by 1 second;
b) A suitable caution alert, in accordance with §25.1322, combined with engagement of an automatic protection function that operates to deter further reduction in airspeed, followed by normal recovery input delayed by 3 seconds; or
c) The aft control stop, followed by normal recovery input delayed by 3 seconds.

§25.1322(c)(2) specifies that warning and caution alerts must provide cues through at least two different senses with a combination of aural, visual or tactile indications. A stick shaker, used in combination with a High Angle-of-Attack Limiting Function, that includes clearly distinguishable aural component, or that is combined with warning level display cues, is considered an example of a suitable warning alert consistent with (a) above. When combined with a caution level alert, an automatic low speed or low energy protection system that engages to deter further airspeed reduction, either through automatic thrust/power advance or control system characteristics that deter further deceleration, are considered examples of designs consistent with (b) above.

Depending on the included automatic systems or if the maneuver is to be continued until achieving the aft control stop, it is not expected that the specified deceleration can be continued for the 1 or 3 seconds beyond engagement of the automatic protection or limit. During the 1 or 3 seconds prior to normal pilot recovery inputs, the pilot force inputs should be continued in the sense and rate as that applied approaching the engagement point.

Maneuvers

4.18.3.1 In the configurations listed in paragraphs 4.18.3.1.1 and 4.18.3.1.2 below, with the ice accretion specified in the requirement, trim the airplane at 1.3 V_{SR} or 1.3 V_{MIN1g} for non-icing conditions, as applicable.

4.18.3.1.1 High lift devices retracted configuration: Straight Flight/Power Off or Power On, if more critical.

4.18.3.1.2 Landing configuration: Straight Flight/Power Off or Power On, if more critical.

4.18.3.2 At deceleration rates of up to 1 knot per second, reduce the speed until encountering the first of the following and demonstrate that stalling can be prevented using a normal recovery technique without encountering any adverse characteristics (for example, rapid wing roll-off).

a) A suitable warning alert, followed by normal recovery input delayed by 1 second;

b) A suitable caution alert, combined with engagement of an automatic protection function that operates to avoid further reduction in airspeed, followed by normal recovery input delayed by 3 seconds; or

c) The aft control stop, followed by normal recovery input delayed by 3 seconds.

4.~~18~~ 19 Stall Warning, § 25.207.

4. ~~18~~ 19.1 To show compliance with § 25.207(a)-(i), the applicant should assess stall warning in conjunction with stall speed testing and stall demonstration/characteristics testing (§§ 25.103, 25.201, and 25.203, and paragraphs 4.2 and 4.17 of this AC, respectively), and in tests with faster entry rates, as defined in Section 4.19.2 below.

For airplanes equipped with a High Angle-of-Attack Limiting Function that meets the requirements of §§ 25.202 and 25.204, the stall warning requirements of §25.207 (j) must be met following failure of the function. In icing conditions, the stall warning must be shown to provide sufficient margin to prevent encountering unacceptable characteristics and encountering stall. An example of an acceptable test program for showing compliance with §25.207(j)(2) is provided in Section 4.19.4 below.

4. ~~18~~ 19.2 Normal Ice Protection System Operation

The following specifications represent an example of an acceptable test program for stall warning in slow-down turns of at least 1.5 g and at entry rates of at least 2 knots per second: ……..

4. ~~18~~ 19.3 Stall Warning Prior to Activation and Operation of the Ice Protection System

The following represents an acceptable means for showing compliance with § 25.207(h)………..

4.19.4 Stall Warning Following Failure of a High Angle-of-Attack Limiting Function

The following represents an acceptable means for showing compliance with § 25.207(j).

Maneuvers

4.19.4.1 The holding ice accretion should be used.

4.19.4.2 The airplane should be loaded to a medium to light weight, aft center-of-gravity position, with symmetric fuel loading.

4.19.4.3 The test should be conducted at the normal high AOA handling test altitude.

4.19.4.4 In the configurations listed in paragraphs 4.19.4.4.1 through 4.19.4.4.3 below, and each other configuration if deemed more critical, trim the airplane in straight flight at the minimum recommended airspeed following failure of the HALF, with idle power/thrust. In both straight and 30º banked turning flight, decrease speed at a rate not exceeding 1 kt/sec until 3 second after stall warning and recover using the same recovery maneuver as for the uncontaminated airplane.

4.19.4.4.1 High lift devices retracted configuration.

4.19.4.4.2 Approach configuration appropriate to the highest lift landing configuration.

4.19.4.4.3 Highest lift landing configuration.

4.~~21~~ 22 Natural Icing Conditions, § 25.1419(b).

To show compliance with this requirement, the applicant should perform additional flight testing…..

4. ~~21~~ 22.3 Acceptable Test Program.

During each of the maneuvers specified in paragraph 4.21.4 below, the behavior of the airplane should be consistent with that obtained with simulated ice accretions. 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.

Maneuvers

4.~~21~~ 22.4 Ice Accretion Maneuvers.

4.~~21~~ 22.4.1 Holding scenario.

4.~~21~~ 22.4.1.1 The maneuvers specified in table 4-4 below should be carried out with ice accretions defined in paragraphs 4.21.4.1.2 and 4.21.4.1.3 below, which is representative of normal operation of the ice protection system:

4.~~21~~ 22.4.1.2 Ice on unprotected parts. A target accretion thickness equivalent to the 45-minute dry air ice accretions on an unprotected part of the wing should be the objective. (A thickness of 2 inches is normally a minimum value, unless a lesser value is agreed to with the responsible ACO).

4.~~21~~ 22.4.1.3 Ice on protected parts. The ice accretion thickness should be that resulting from normal operation of the ice protection system.

4.~~21~~ 22.4.1.4 For airplanes with control surfaces that may be susceptible to jamming due to ice accretion (for example, elevator horns exposed to the air flow), the holding speed that is critical with respect to this ice accretion should be used.

Table 4-4. Holding Scenario—Maneuvers

Airplane Configuration	Center-of- Gravity Position	Trim Speed**	Maneuver
Flaps up, Gear up	Any position in the aft range	Holding, except 1.3 V_{SR} or 1.3 V_{MIN1g} for the stall maneuver	Level, 40° banked turn; Bank-to-bank rapid roll, 30° - 30°; Speedbrake extension, retraction; ~~Full straight stall~~ Wings level deceleration at 1 knot per second to stall ID or HALF AOA limit (~~1 knot per second deceleration rate, wings level,~~power off)
Flaps in Intermediate positions, gear up	Any position in the aft range	1.3 V_{SR} or 1.3 V_{MIN1g}	~~Deceleration~~ Wings level deceleration at 1 knot per second to the speed reached 3 seconds after activation of stall warning ~~in a 1knot per second deceleration~~, or to full aft control input for 3 second if no §25.207 compliant stall warning is provided
Landing flaps, gear down	Any position in the aft range	V_{REF}	Level, 40° banked turn; Bank-to-bank rapid roll, 30° - 30°; Speedbrake extension, retraction (if approved); ~~Full straight stall~~ Wings level deceleration at 1 knot per second to stall ID or HALF AOA limit (~~1 knot per second deceleration rate, wings level,~~power off)

4. .~~21~~ 22.4.2 Approach/Landing Scenario.

4. .~~21~~ 22.4.2.1 The maneuvers specified in table 4-5 of this AC should be carried out with successive accretions in different configurations on unprotected surfaces.

4. .~~21~~ 22.4.2.2 Each test condition should be accomplished with the ice accretion that exists at that point.

4. .~~21~~ 22.4.2.3 The final ice accretion (Test Condition 3) represents the sum of the amounts that would accrete during a normal descent from holding to landing in icing conditions.

Table 4-5. Approach/Landing Scenario—Maneuvers

Test Condition	Ice Accretion Thickness*	Airplane Configuration	Center-of-Gravity Position	Trim Speed**	Maneuver
—	First 0.5 inch	Flaps up, gear up	Any position in the aft range	Holding	No specific test
1	Additional 0.25 inch (0.75 inch total)	First intermediate flaps, gear up	Any position in the aft range	Holding, except 1.3 V_{SR} or 1.3 V_{MIN1g} for the deceleration maneuver	Level 40° banked turn; Bank-to-bank rapid roll, 30°- 30°; Speed brake extension and retraction (if approved); Wings level deceleration at 1 knot per second Deceleration to the speed reached 3 seconds after activation of stall warning in a 1 knot per second deceleration, or to full aft control input for 3 second if no §25.207 compliant stall warning is provided.
2	Additional 0.25 inch (1.00 inch total)	Further intermediate flaps, gear up (as applicable)	Any position in the aft range	1.3 V_{SR} or 1.3 V_{MIN1g}	Bank-to-bank rapid roll, 30° - 30°; Speed brake extension and retraction (if approved); DecelerationWings level deceleration at 1 knot per second to the speed reached 3 seconds after activation of stall warning in a 1 knot per second deceleration, or to full aft control input for 3 second if no §25.207 compliant stall warning is provided.
3	Additional 0.25 inch (1.25 inch total)	Landing flaps, gear down	Any position in the aft range	V_{REF}	Bank-to-bank rapid roll, 30° - 30°; Speed brake extension and retraction (if approved), Bank to 40°; Full straight stall Wings level deceleration at 1 knot per second to stall ID or HALF AOA limit (1 knot per second deceleration rate, wings level, power off).

* The indicated thickness is that accumulated on the parts of the unprotected airfoil most likely to accumulate ice.

**In Tables 4-4 and 4-5 above, the applicant may use non icing VSR for scheduling the trim speed conditions

4.~~22~~ 23 Failure Conditions, § 25.1309.
To show compliance with this requirement:

4.~~22~~ 23.1 For failure conditions that are annunciated to the flightcrew, the applicant may take credit for flightcrew action to follow the established operating procedures provided in the AFM.

4.~~22~~ 23.2 Acceptable Test Program.
In addition to a general qualitative evaluation, the applicant should carry out the following test program for the most critical, probable failure condition for which the associated procedure requires the airplane to exit the icing condition. The test program should be modified as necessary to reflect the specific operating procedures.

Maneuvers

4.~~22~~ 23.2.1 The ice accretion is defined as a combination of the following:

4.~~22~~ 23.2.1.1 Ice on unprotected surfaces. The holding ice accretion described in paragraph A.2.1.3 of appendix A of this AC.

4.~~22~~ 23.2.1.2 Ice on normally protected surfaces that are no longer protected. The failure ice accretion described in paragraph A.3.2 of appendix A of this AC.

4.~~22~~ 23.2.1.3 Ice on normally protected surfaces that are still protected following segmental failure of a cyclical deice system. The ice accretion that will form during the rest time of the deice system following the critical failure condition.

4.~~22~~ 23.2.2 The airplane should be loaded to a medium to light weight, at aft center-of-gravity position, with symmetric fuel loading.

4.~~22~~ 23.2.3 In the configurations listed in paragraphs 4.~~22~~ 23.2.3.1 through 4.~~22~~ 23.2.3.3 below, trim the airplane at the specified speed. Conduct 30° banked turns left and right with normal reversals. Conduct a pull-up maneuver to 1.5 g and a pushover maneuver to 0.5 g.

4. ~~22~~ 23.2.3.1 High lift devices retracted configuration (or holding configuration if different): Holding speed, power or thrust for level flight. In addition, deploy and retract the deceleration devices.

4.~~22~~ 23.2.3.2 Approach configuration: Approach speed, power or thrust for level flight.

4.~~22~~ 23.2.3.3 Landing configuration: Landing speed, power or thrust for landing approach (limit pull-up to 1.3 g). In addition, conduct steady heading sideslips to the angle of sideslip appropriate to the airplane type and the AFM landing procedure.

4.~~22~~ 23.2.4 In the configurations listed in paragraphs 4.~~22~~ 23.2.4.1 and 4.~~22~~ 23.2.4.2 below, trim the airplane at the estimated 1.3 V_{SR} (the applicant may use non icing Vsr) or 1.3 V_{MIN1g}. Decrease speed at approximately 1 knot per second until 1 second after stall warning or until the High Angle-of-Attack Limiting Function AOA limit is reached if so equipped and no §25.207 compliant stall warning is provided, and demonstrate prompt recovery using the same recovery maneuver as for the uncontaminated airplane. It is acceptable for stall warning to be provided by a different means (for example, by the behavior of the airplane rather than by stick shaker) for failure cases not considered probable.

4. ~~22~~ 23.2.4.1 High lift devices retracted configuration: Straight Flight/Power Off.

4. ~~22~~ 23.2.4.2 Landing configuration: Straight Flight/Power Off.

4. ~~22~~ 23.2.5 Conduct an approach and go-around with all engines operating using the AFM approach and go-around procedure.

4. ~~22~~ 23.2.6 Conduct an approach and landing with all engines operating (unless the one-engine-inoperative condition results in a more critical probable failure condition) using the appropriate AFM approach and landing procedure.

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4. ~~22~~ 23.3 For improbable failure conditions, flight testing may be required to demonstrate that the effect on safety of flight (as measured by degradation in flight characteristics) supports the system safety analysis, or to verify results of analyses or wind tunnel tests. The extent of each required flight testing should be similar to that described in paragraph 4.22.3 above, or as agreed to by the responsible ACO for the specific failure condition.

APPENDIX A. AIRFRAME ICE ACCRETIONS

A.2.3 Ice Accretions Before Activation and Effective System Operation

A.2.3.1 When considering the ice accretion before the ice protection system has been activated and is performing its intended function, you should take into account the means of activating the ice protection system and the system response time. However, if artificial stall warning or a High Angle-of-Attack Limiting Function is provided and the point at which stall warning is initiated or the AOA limit changes when the ice protection system is activated, then the pre-activation ice accretion used to evaluate the "clean" stall warning or AOA Limit schedule does not need to include consideration of the ice protection system response time. System response time is defined as the time interval between activation of the system and its effective operation (for example, for a thermal ice protection system used for deicing, the time to heat the surface and perform its deicing function). If activation of the ice protection system depends on flightcrew recognition of icing conditions or response to a cockpit annunciation, appropriate delays in identifying the icing conditions and activating the ice protection system should be taken into account. For the icing conditions of Appendix C, the airplane should be assumed to be in continuous maximum icing conditions during the time between entering the icing conditions and effective operation of the ice protection system.

It is intended that the time from entry into icing conditions until activation and normal operation of the ice protection system is brief, such that exposure to the reduced standards for stall prevention permitted with this ice accretion is minimal. For compliance with §25.202(d)(5), if this time is not sufficiently brief and consistent with the intent, it is required that compliance with the requirements of §25.202(d)(1)-(4) in icing conditions be met in lieu of §25.202(d)(5). For the purposes of §25.202(d)(5) compliance, the "brief" exposure time should not be more than approximately 5 minutes while operating in any icing condition within the Appendix C Continuous Maximum envelope.

A.4.2 Ice Accretions for Encounters with Appendix O Conditions Beyond those in Which theAirplane is Certified to Operate

A.4.2.1 Use the ice accretions in table A-1 below, to evaluate compliance with the applicable subpart B requirements for operating safely after encountering Appendix O atmospheric icing conditions for which the airplane is not approved, and then safely exiting all icing conditions.

A.4.2.2 These ice accretions apply when the airplane is not certified for flight in any portion of Appendix O atmospheric icing conditions, when the airplane is certified for flight in only a portion of Appendix O conditions, and for any flight phase for which the airplane is not certified for flight throughout the Appendix O icing envelope.

A.4.2.3 Table A-1 shows the scenarios to be used for determining ice accretions for certification testing of encounters with Appendix O conditions beyond those in which the airplane is certified to operate (for detecting and exiting those conditions).

Table A-1. Appendix O Detect-and-Exit Ice Accretions per Flight Phase

Flight Phase/ Condition	**Appendix O Detect-and-Exit Ice Accretion**
Ice Accretion Before the Ice Protection System Has Been Activated and is Performing its Intended Function	Ice accreted on protected and unprotected surfaces during the time it takes for icing conditions (either Appendix C or Appendix O) to be detected, the ice protection system to be activated, and the ice protection system to become fully effective in performing its intended function. (Note: If artificial stall warning or a High Angle-of-Attack Limiting Function is provided and the initiation point of that warning or the AOA limit changes when the ice protection system is activated, this ice accretion does not need to include consideration of the time it takes for the ice protection system to be effective in performing its intended function.)

Appendix 1 Topic 1 Envelope Limiting Final Report

FAA Aviation Rulemaking Advisory Committee
FTHWG Topic 1
Envelope Protection

Recommendation Report – Rev A
March, 2017

Table of Contents

Executive Summary

Many new airplanes incorporate advanced Electronic Flight Control Systems (EFCS). These systems have architectures and features which allow limiting of the flight envelope in ways not previously available. Because the existing regulations were not written to address such airplanes, Special Conditions have been needed to address these features. The Flight Test Harmonization Working Group (FTHWG) was tasked to recommend standards for accommodating airplanes which embody modern EFCS and which exhibit envelope limiting features.

The FTHWG has considered the relevant standards and guidance material, the relevant Special Conditions and Certification Review Items (CRI's), and engaged in discussion regarding the nature of the special features provided by these modern systems. The working group devised a structured method of evaluating what standards would be required of airplanes using these EFCS features to ensure safe operation. Further, the group found a way to incorporate those standards into the current 14CFR25 regulatory structure.

The group has drafted both regulations and guidance material as appropriate to ensure a safe certification path. This includes the creation of a new regulation (14CFR25.144) specifically covering the general requirements for airplanes employing various envelope protection and limiting features, plus two new regulations (14CFR25.202 and 14CFR25.204) specifically covering requirements for airplanes that use a High Angle of Attack limiting function to prevent stall. Because of the performance considerations, changes to many other regulations are necessary to ensure that envelope-limited airplanes make appropriate use of these limiting features. This package forms a coherent standard against which new configurations can be evaluated.

There were no dissenting opinions regarding the need for new and modified regulations, the structure of the regulations proposed and the certification paths thus created. Nevertheless, there was no complete consensus for some of the details. These are known items of contention, and this situation is not unexpected.

Notwithstanding these successes, not all of the guidance material was able to be covered in the time allotted to release the initial report in January 2017. The FTHWG continued work during January and February in order to complete the guidance material for inclusion in the final report in March 2017. There were also three topics identified where additional work related to envelope protection is recommended.

This report contains recommendations that the FAA enact these new regulations (and associated guidance), and that they also be adopted by EASA and other national authorities.

Background

As a result of the 20 March, 2014 ARAC meeting, FAA has assigned and ARAC has accepted a tasking which would use the existing Flight Test Harmonization Working Group (FTHWG). The part of the tasking described in this Appendix is:

The working group should develop recommended standards in the following topic areas. If there are disagreements within the working group, these should be documented, including the reasons for the disagreement and rationale from each party. The following subject areas should be worked upon within this task:

1. Fly-by-wire Flight Controls.

Regulatory requirements and associated guidance material for airworthiness certification of airplane designs using fly-by-wire technology to remove the need for longstanding, repetitively-used fly-by-wire special conditions. Specific areas include:

a. …
b. …
c. …
d. …
e. Flight envelope protection.

Details of the task has been defined at the working level in the work plan (Topic 1, Envelope Protection) resulting from Phase 1. The approved work plan is included as Attachment 1A.

The working title of this topic “Envelope Protection” was the subject of some discussion. In the end, the Working Group used the term "Envelope Protection" as a general description of functions that affect the pilot's ability to access parts of the flight envelope, while the term “envelope limiting” is used for specific functions where it is clear that the intent of the function is to prevent exceedence of some boundary and that limit can't be overridden by pilot control action. This is consistent with industry colloquial uses of the terms “protection” and “limiting”.

While transport airplanes incorporating fly-by-wire systems and flight envelope protection features have been certified and in service since the late 1980’s, the basis on which the airworthiness was determined has always been Special Conditions (CRI’s in Europe). These have evolved over the years, were each written against specific system architectures and feature sets and were not necessarily intended to provide broad airworthiness coverage, as this task is asking the FTHWG to do.

A. What is the underlying safety issue addressed by the JAR/FAR?

While the stated task is to remove the need for repetitively used Special Conditions (SC), the result will be a single, harmonized set of standards which will have the effect of ensuring a consistent safety standard. The established standard of safety is taken to be the current airworthiness requirements applied to conventional (not-flight-envelope-protected) configurations as well as the current industry practice achieved via SC’s and CRI’s for those aircraft with modern EFCS architectures.

B. What is the task?

The task assigned by ARAC in the above cited Federal Register tasking statement has been further refined in the Work Plan, as developed in Phase 1 of this tasking. The task in the work plan is:

"Recommend revisions to regulations and guidance material to include criteria to be used in the assessment of airplanes incorporating electronic flight control systems which include flight envelope protection features or functions which are harmonized across FAA/EASA/TCCA/ANAC."

C. Why is this task needed?

Many new transport category aircraft include control system designs which incorporate flight envelope protection (limiting) on a full-time basis that will prevent the pilot from inadvertently or intentionally exceeding any of a number of flight envelope parameters. These limiting features may or may not be active in all normal and alternate flight control modes and may or may not be capable of being overridden by the pilot. There is no requirement in the regulations for these limiting features, nor do current requirements address these features. Features which have been incorporated in the past and which have received attention via Special conditions or Issue Papers (CRI's) include:

- Normal load factor (Nz) limiting
- Angle of attack limiting
- Speed limiting
- Pitch and Roll Attitude limiting

In addition, the mode switching involved when these features become active has been addressed.

EASA has included provisions for this feature in Nz limiting in their recently published CS25, Amendment 13, while the FAA has not included any provisions to date. Harmonization of FAA, EASA, TCCA, and ANAC requirements should be addressed.

FAA has expressed interest in considering a broad range of envelope parameter limiting schemes in the development of harmonized rulemaking.

D. Who has worked the task?

This task has been worked by the Flight Test Harmonization Working Group (FTHWG) representing the following organisations:

- Authorities : FAA, EASA, TCCA, JCAB*, CAAI*
- Manufacturers : Airbus, Boeing, Bombardier, Dassault, Embraer, Gulfstream, Textron
- Airlines : American Airlines, Delta Airlines*
- Labour Union: ALPA

(*) non-voting members

ANAC of Brazil began participating with the group, but stepped away fairly early in the harmonization process.

While the work plan (Attachment 1A) allows consideration for consultation with subject matter experts from other Harmonization Working Groups, such consultation was not found necessary for this topic. One reason for this is the fact that the Flight Controls HWG is currently inactive. More important, though, is that individual members of the FTHWG were in consultation on matters associated with this topic with their colleagues, many of whom were associated with the FCHWG.

E. Any relation with other topics?

This topic, Envelope Protection is tightly intertwined with:

Topic 2 Adaptation of Flight in Icing (in fact, inseparable)
Topic 6 Stability
Topic 7 Sidesticks
Topic 13 Out of Trim (less-closely related)

In addition to these relationships, because of the performance impact of angle of attack protection and the economic impact of performance to OEM's and operators, this topic touches many parts of Subpart B, as will be seen.

Because of the fact that the protection (limiting) is provided via systems features, discussion frequently turned to the relation with systems requirements, 14CFR25.671, 672 and 1309. These discussions will be taken up again in the topics of HQRM and Failure Assessment Methodology, to be addressed in Phase 3.

Historical Information

The FTHWG met to discuss this topic during 5 face-to-face meetings comprising 9 (13 if the closely-tied Topic 2 is included) days of detailed discussion. In addition 31 teleconferences were dedicated to this topic. This task was identified early as perhaps the most challenging of the tasks assigned, and it was given appropriate attention because of this.

Very early discussions centered around fundamental constructs. These were identified early as the most difficult issues, and have proven to be.

- Availability: when systems are used in place of aerodynamic characteristics, what requirement should be applied for system availability (or, conversely, failure rate) in order to use that system for compliance to Flight Characteristics requirements? While it was generally agreed that such systems need to be highly reliable, the details and means of expressing this intent in the regulatory material has been a fundamental point of contention, and is still not fully resolved, as captured in Dissenting Opinions.
- Pilot overridability of limiting functions: if the protection (limiting) system is there to protect the airplane from exceeding flight envelope limits, should the pilot be given the ability to override the system inputs, and if so, how and when? Final decision was to allocate overridability on a function-by-function basis; it did not seem practical to legislate one hard rule on this topic.
- Whether it is appropriate for regulations or means of compliance to demand a greater level of maneuverability or control for an airplane that employs envelope protection functions than would otherwise be required by current regulations. The consensus was that airplanes with protection functions should not be held to a higher standard than current regulation unless it is necessary for intended function of the protection function, but at the same time such functions should not be used to unduly reduce airplane capability.

- How to distinguish between "envelope protection" functions and other flight control functions that may be used to comply with existing regulations or for other purposes such as reducing structural loads. The conclusion was that functions that are adequately covered by existing regulations and are not designed primarily to restrict some flight parameter are in general not considered envelope protection functions.
- Fundamental definitions of terms were necessary: e.g. function vs system. In this example, the Working Group settled on the term Function as being more generic, not specific to a particular flight control architecture, and more amenable to regulatory consideration under Subpart B.
- Even the name was debated: Notwithstanding the tasking statement which referred to "Envelope Protection", there was considerable variation in the industry colloquial usage of that term versus "Envelope Limiting". In the end, the term Protection was used as a general term to describe functions that affect the pilot's access to regimes beyond normal operational boundaries, while Limiting was used for discussion of certain non-overrideable functions such as High Angle of Attack Limiting Function.

The FTHWG received briefings from various OEM's regarding the specific systems architectures employed on their products (in conjunction with their appropriate SC's and CRI's).

The Working group felt it necessary to limit the scope of the discussion, so specific consideration was given to just which envelope parameters limiting might be applied, and which deserved regulatory attention. The list of parameters considered and selected is given in Table 1. In general, the parameters that were not selected were judged to be adequately addressed by existing regulations and guidance, or were out of scope for this task. Once the selected parameters were identified, the Working Group considered just how they should be "regulated". The harmonized proposal herein is the result of that work.

Parameters Considered	Parameters Selected
Airspeed (low and high) Load Factor (load factor rate) Angle of Attack Low Energy (awareness / protection) Pitch Attitude (in-air / on-ground) Roll Attitude Roll Rate Sideslip Sideslip Rate Local Structural Loads Flight Path	Angle of Attack Pitch Attitude Roll Attitude Load Factor High Speed

Table 1. Limiting Parameters Considered and Selected for Detailed Discussion

A detailed analysis of the structure of 14CFR25 followed which allowed the Working Group to consider and debate how best to structure globally effective regulations (as contrasted with Special Conditions against particular systems implementations). It was concluded that the best approach would be a "branching" structure, in which regulatory paths would be built which could accommodate conventional or modern EFCS architectures equally. This approach was found particularly valuable in the case of stall demonstrations and stall characteristics. The branching structure is illustrated in Figure 1. Very careful attention was paid to ensuring equivalent safety in either branch. Equally, careful attention was paid to the resulting reference speeds, which spread through the rest of Subpart B.

The structure of the 14CFR25.202/204 branching was chosen specifically to mirror both the structure of 14CFR25.201/203/207 AND to mirror the "equivalent safety" embodied by the characteristics chosen. This was guided by both knowledge of the current 14CFR and by the decades of industry experience with angle of attack limited airplanes certified under Special Conditions. Besides the branching structure embodied in the stall/high angle-of-attack regulations, the FTHWG discovered the need for a more "generic" set of regulations, and decided that the best place for them would be a new regulation, 14CFR25.144, detailed below.

As the proposed regulatory structure began to emerge, the detailed task of crafting some regulations within that structure was first tackled by a small task team. This team's initial drafts were reviewed, and a second, somewhat larger task team was formed. Finally the details were debated with the entire FTHWG.

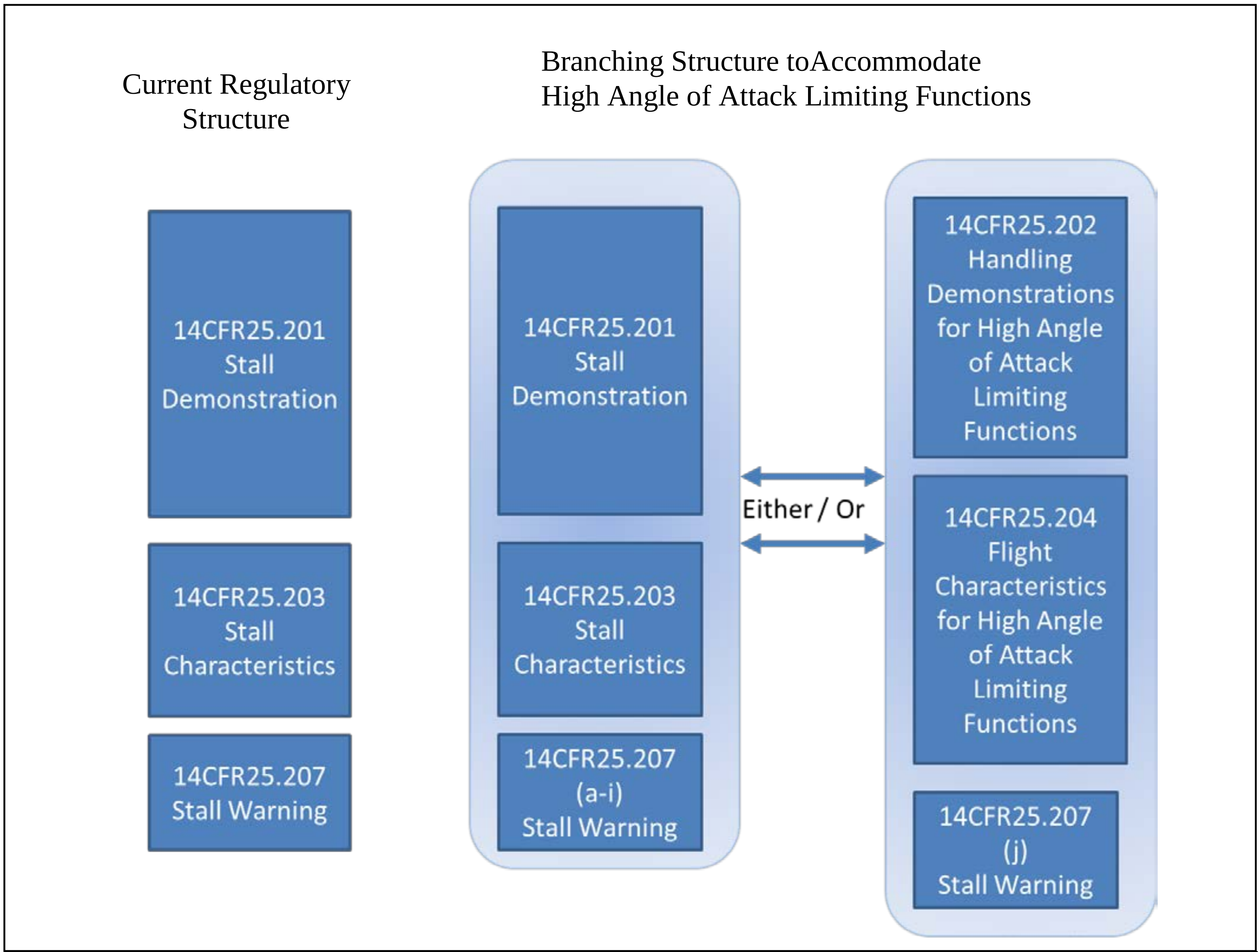


Figure 1. Branching Structure to Accommodate High Angle of Attack Limiting Functions

A. What are the current regulatory and guidance material CS 25 and FAR 25?

Current regulatory constructs are built on a combination of demonstration of safe (benign) behaviour at a place beyond the normal operational flight envelope (e.g. V_{FC}/M_{FC}) and the margin between where that behaviour is demonstrated and where the normal operational flight envelope is constructed. This margin is complimented by characteristics regulated to help enforce the margin. Examples include the fact that static stability (stick force vs speed) combined with a speed margin to potentially dangerous characteristics makes it difficult for a pilot to inadvertently stray too far. Similar examples can be found in the stick force vs load factor requirement in 14CFR25.143.

Fundamentally, both 14CFR25 and CS25 are built on the same principles (exception in the next section).

What makes this significant is the fact that effective envelope limiting can obviate the need for these margins (or at least the magnitude of the margins), and performance can be affected. As a result of the structure of the regulations being based on the philosophy of margins, many things in the structure are touched.

B. What, if any, are the differences in the existing regulatory and guidance material CS 25 and FAR 25?

14CFR25 Subpart B does not contain any regulations on the behaviour of airplanes equipped with architectures specifically designed to limit the airplane's excursions from any flight envelope.

EASA CS25, at Amendment 13 did introduce some requirements on load factor limiting in CS25.143(l), and it is noted that some structural relief is given in Mach (25.335) and load factor (25.337), the same for both sets of regulations.

The FTHWG notes that the Subpart B regulations are not harmonized, and could benefit from becoming so.

C. What are the existing CRIs/IPs (SC and MoC)?

The FAA and EASA have applied Special Conditions/CRIs to numerous airplanes that employ envelope protection functions. ANAC and TCCA have issued similar Special Conditions for aircraft under their purview. In general the Special Conditions and CRIs have been harmonized. These airplanes include various Airbus products, Dassault Falcon, Bombardier C-series, Embraer EMB-550, Gulfstream GVI and GVII, and Sukhoi Superjet. Selected references are provided below for representative aircraft, focusing on the FAA version of the Special Conditions.

Airbus aircraft starting with A320 models have had Special Conditions/CRIs addressing the various protection functions employed on those aircraft. The most recent versions apply to the A380 and A350-900; FAA Special Condition references for these aircraft are provided here. Similar documents exist for EASA CRIs.

Special Conditions No. 25-316-SC "Airbus A380 Final Special Condition [Sections addressing Flight Envelope Protection-General Limiting Requirements, Flight Envelope Protection-Normal Load Factor (G) Limiting, Flight Envelope Protection-High Speed Limiting, Flight Envelope Protection-Pitch and Roll Limiting, Flight Envelope Protection-High Incidence Protection and Alpha-Floor Systems]", April 11, 2006

Special Conditions No. 25–517–SC "Special Conditions: Airbus, A350-900 Series Airplane; Flight Envelope Protection (Icing and Non-Icing Conditions); High Incidence Protection and Alpha-Floor Systems", Nov. 5, 2014

Special Conditions No. 25–540–SC "Special Conditions: Airbus Model A350-900 airplane; General Limiting Requirements", Sept. 22, 2014

Special Conditions No. 25–521–SC "Special Conditions: Airbus Model A350-900 Series Airplane; Electronic Flight-Control System to Limit Pitch and Roll", Aug. 1, 2014

Special Conditions No. 25–531–SC "Special Conditions: Airbus Model A350-900 Airplane; Flight-Envelope Protection, Normal Load-Factor (G) Limiting", Sept. 8, 2014

FAA Special Conditions relating to Envelope Protection functions were also applied to the Embraer EMB-550. Similar conditions were applied by ANAC which is the original certificating authority.

Special Conditions No. 25–564–SC, "Special Conditions: Embraer S.A. Model EMB-550 Airplane; Flight Envelope Protection: High Incidence Protection System", Sept. 3, 2014

Special Conditions No. 25–492–SC "Special Conditions: Embraer S.A., Model EMB-550 Airplanes; Flight Envelope Protection: General Limiting Requirements", June 27, 2013

Special Conditions No. 25-520-SC "Special Conditions: Embraer S.A., Model EMB-550 Airplanes; Flight Envelope Protection, Normal Load Factor (g) Limiting", April 14, 2014

Special Conditions No. 25-486-SC "Special Conditions: Embraer S.A., Model EMB-550 Airplanes; Flight Envelope Protection: Pitch and Roll Limiting Functions", April 3, 2013

D. What, if any, are the differences in the Special Conditions (CRIs/IPs) (SC and MoC) and what do these differences result in?

For a given aircraft the Special Conditions and CRIs are generally similar among the affected regulatory agencies. There are some differences in recommended testing. The Topic 2 Report, Attachment 2D contains a chart comparing details of the differences in regulations/guidance affected by High Angle of Attack Limiting Functions.

Since the Special Conditions and CRIs are specific to a particular aircraft design, there are differences related to the designs; for instance the guidance related to the Alpha Floor/thrust advance function present on the Airbus aircraft is not relevant to aircraft that do not have that function.

The FTHWG believes that with the increased use of systems which might limit the flight envelope in various ways, the industry would benefit from having a single safety standard to design to.

Consensus

The FTHWG has agreed in principle on the need for new and modified regulations and guidance. Further, the FTHWG has achieved unanimous consensus on the proposed structure of the new regulations (new 14CFR25.144, and branching with 14CFR25.202, 204, and 207). There are no objections or dissenting opinions on those elements.

The dissenting opinions identified are largely centered around a few contentious issues identified very early in the deliberations including whether to regulate to a particular numerical availability for envelope protection functions. Note that there is no controversy over the importance of ensuring an appropriately high availability for envelope protection function; the differences of opinion relate to whether an availability requirement should appear in the regulation or in guidance, whether that requirement should be a quantitative value or qualitative description, and whether current guidance in 25.671 and 25.1309 is sufficient.

The proposed Rule and Material Guidance updates respectively in Attachments 1B and 1C of this report represent the majority position of the FTHWG members. Nevertheless there are four dissenting opinions to specific parts of the proposed regulations and ten dissenting opinions to the associated guidance material. It should be noted that eight of the dissenting opinions address the same issue, namely how an availability requirement should be expressed for envelope protection functions. This issue appears in several places in the regulations and guidance. There are actually only eight unique dissenting opinions. Each of those has been considered, and the majority disposition has been offered.

To summarize, the FTHWG majority position believes that a common harmonized standard for airplanes utilizing various Envelope Protection Functions can be adopted by implementing new paragraphs 14CFR25.144 (General Regulations for Envelope Protection Functions), as well as offering compliance to 14CFR25.202 (Handling demonstrations for High Angle of Attack Limiting Functions) and 14CFR25.204 (Flight characteristics for High Angle of Attack limiting functions) and 14CFR25.207(j) (Stall Warning for HALF failures) in lieu of 14CFR25.201, 14CFR25.203 and 14CFR25.207(a)-(i) (for non HALF aircraft). Changes to several other requirements are also proposed, as a result of the important connections between these and other parts of Subpart B, outlined in Paragraph A.2.

Dissenting opinions relative to the proposed regulations are presented below. They are also shown in the 'Comments / Rationale' column of Attachment 1B, highlighted in yellow.

Dissenting Opinions on Regulations

14CFR25.143(g)	Majority Disposition
(1) Airbus and Dassault do not concur with the inclusion of a failure rate requirement for a load-factor limiting function in order to apply proposed changes to 14CFR25.143. Instead, Airbus and Dassault propose that showing compliance to CS25.302 and 14CFR25.1309 for normal load factor limiting function	The FTHWG majority position considers that a function availability requirement for a load factor limiting function is justified in order to apply proposed changes to 14CFR25.143. The majority considers that loss of a load factor limiting function should be "improbable" (FAA terminology), or "not more

failures is sufficient.	probable than remote" (EASA terminology).
(2) TCCA agrees that a failure rate requirement should be included for normal load factor limiting functions used to show compliance with 14CFR25.143, but does not concur with use of the term "improbable" or "not more probable than remote". Instead, the numerical failure rate of 1E-5/flt-hr should be included in the regulation. The limiting system is being used to substitute for basic aerodynamic characteristics and 1E-5/flt-hr is considered a rock bottom minimum reliability requirement.	The FTHWG majority position considers that including a specific probability availability/reliability regulation in Subpart B is overly prescriptive and that use of the term "improbable" (FAA) or "not more probable than remote" (EASA) is appropriate and consistent with prior regulatory practice.

Proposed Regulation 14CFR25.202 and 204	Majority Disposition
(3) (similar to (1)) Airbus does not concur with inclusion of a failure rate requirement for High Angle of Attack Limiting Function (HALF) in order to apply proposed 14CFR25.202 and 204. Instead Airbus proposes that showing compliance to 14CFR25.1309 for HALF failures is sufficient.	The FTHWG majority position considers that a function availability requirement for HALF is justified in order to apply proposed 14CFR25.202 and 204. The majority feels that the incorporation of HALF and application of proposed 14CFR25.202 and 204 results in a significant change in flight characteristics requirements and means of compliance, such that it is appropriate to include a function availability requirement independent of the equipment requirements imposed by 14CFR25.1309 or 14CFR25.671. The FTHWG majority considers that loss of HALF should be "improbable" (FAA), or "not more than remote" (EASA terminology).
(4) (similar to (2)) TCCA agrees that a failure rate requirement should be included for HALF function used to show compliance with 14CFR25.202 and 204, but does not concur with use of the word "Improbable" or "not more probable than remote". Instead, the numerical failure rate of 1E-5/flt-hr should be included in the regulation. The HALF system is being used to substitute for basic aerodynamic characteristics and 1E-5/flt-hr is considered a rock bottom minimum reliability requirement.	The FTHWG majority position considers that including a specific availability/reliability regulation in Subpart B is overly prescriptive and that use of the term "improbable" or "not more probable than remote" (EASA) is appropriate and consistent with prior regulatory practice.

Dissenting opinions relative to the proposed guidance material are presented below. They are also shown in abbreviated form in the relevant section of Attachment 1C, highlighted in yellow.

<u>Dissenting Opinions on Guidance Material</u>

Proposed Guidance AC25-7C Paragraph 20.e(2)(a)	Majority Response
(5) (similar to (1)) Airbus and Dassault: CS25.302 and 25.1309 adequately cover failure conditions and it's not necessary to include a maximum failure rate	This is related to similar dissenting opinions in the regulation text. FTHWG majority position considers that it is appropriate to specify a minimum availability

here.	for a load factor limiting function used to show compliance to 14CFR25.143(g).

Proposed Guidance AC25-7C Paragraph 29.d.(5)	Majority Response
(6) (similar to (1)) Airbus does not concur with inclusion of a failure rate requirement for HALF credit in the regulation. Instead 25.1309 compliance should be sufficient and this guidance should be modified to only refer to 25.1309 compliance for failures of the HALF.	This is related to similar dissenting opinions in the regulation text. FTHWG majority position considers that it is appropriate to specify a minimum availability for a load factor limiting function used to show compliance to proposed 14CFR25.202 and 204
(7) (similar to (2)) TCCA agrees that a failure rate requirement should be included, but does not concur with use of the word “Improbable” or “not more probable than remote”. Instead, the numerical failure rate of 1E-5/flt-hr should be included in the regulation. The HALF system is being used to substitute for basic aerodynamic characteristics and 1E-5/flt-hr is considered a rock bottom minimum reliability requirement. The 25.1309 reference for interpretation of “Improbable” and “on the order of” should be removed from the guidance	This is related to similar dissenting opinions in the regulation text. The FTHWG majority position considers that including a specific availability/reliability regulation in Subpart B is overly prescriptive and that use of the term “improbable” or “not more probable than remote” (EASA) is appropriate and consistent with prior regulatory practice.

Proposed Guidance AC25-7C paragraph 29h(2)g	Majority Response
(8) Airbus does not support the testing outlined in changes to proposed AC25-7C Paragraph 29h(2)(g), which require that characteristics to the AOA limit be demonstrated up to the maximum approved operating altitude in a near-1-g deceleration. Airbus state that such testing has not been required in past certification of airplanes utilizing HALF systems. Instead, Airbus feel that it is sufficient to conduct maneuvers at high altitude to the AoA limit in wind up turns to cover the range of Mach numbers, but not necessarily performing 1-g decelerations at the max approved altitude.	The FTHWG majority position considers that it is the intent of §25.21(c) to ensure that stall is prevented during slow decelerations at the maximum approved operating altitude and that the testing suggested in AC25-7C Paragraph 29h(2)(g) is an appropriate means of compliance. Conventional airplanes are required to show acceptable stall characteristics to the maximum approved operating altitude, including those with artificial stall ID devices (e.g., stick pusher), as described in current guidance of AC25-7C paragraph 29e(2)(g). Since existing Issue Paper and CRI special conditions do not modify §25.21(c) and do not otherwise specify the altitude range for testing, some other manufacturers with HALF installed have demonstrated stall prevention up to the maximum approved operating altitude.

Proposed Guidance AC25-7C paragraph 29h(3)(e)(iii)	Majority Response

(9) TCCA disagrees with allowing "maximum practical rate" tests to the AOA limit for any type of sidestick to be conducted using less than an abrupt input to full aft control, regardless of stick force characteristics. TCCA feels that there is not currently sufficient flight test experience with different categories of sidesticks and sidestick forces or with the minimum force values proposed for compliance with 25.143(g) to provide this alleviation.	The FHWG majority position considers that the wording of that section is acceptable because it places the burden on the applicant "to substantiate a different maximum practical rate ... through pilot-in-the-loop simulation, by similarity to a previous project, or by flight tests."
(10) Dassault considers that it is not homogeneous to require a maximum entry rate of 3kt/s for aircraft fitted with a conventional column while "an abrupt step" is required for classical sidesticks. In the first case (conventional column) the guidance defines a maximum reasonable manoeuver whereas in the other case (sidestick) it defines a maximum achievable stick movement. For a 3kt/s deceleration it may take several seconds to reach full stick whereas an abrupt step is achieved in much less than a second, which is significantly different. Obviously a conventional column can be moved less quickly than a sidestick but it would be more homogeneous to also require a quick movement of the column for a conventional column. This could be more precisely described as a quick application of force on the column/sidestick to take into account the dynamic characteristics (damping …) of the inceptor.	The FTHWG majority position recognizes that the form of the pilot input is specified differently for a conventional wheel/column than for a sidestick, and considers the difference to be appropriate due to the differences in controller types.

Proposed Guidance AC25-7C, paragraph 29n	Majority Response
(11) Boeing and Dassault disagree with proposed guidance that states that in order to certify a HALF system under §25.202 and § 25.204 and 25.207(j), not only must stall warning be provided for failures of HALF that are not extremely improbable, but the regulation "also requires that combined loss of HALF and stall warning be extremely improbable." This interpretation is significantly more stringent than current guidance for stall warning and stall ID functions on conventional aircraft. Boeing understands this guidance to be intended for airplanes that have not demonstrated stall characteristics so that these systems are viewed as replacing aerodynamic characteristics. Boeing feels this interpretation is overly prescriptive and only gives credit for a warning system although good aerodynamic characteristics might be preferable.	The FTHWG majority position considers that the wording of that section is appropriate as written. The statement in the regulation that stall warning **must** be provided for failures of HALF that are not extremely improbable is effectively a requirement that the combined failure must be extremely improbable. It is not appropriate to give relief from this requirement in the proposed guidance. This interpretation has been applied to a recent FAA certification program with the same requirement applied via Special Condition. The higher standard when compared to conventional airplanes is considered appropriate due to the pilot's expectation of stall prevention and docile characteristics during maneuvering at high AOA on an airplane normally equipped with HALF. The suggestion to use low-speed alerting in lieu of stall

Alternate means of compliance should be acceptable, such as a stall warning function having sufficient reliability that loss of both HALF and stall warning is "extremely remote" (<10-7/fh), combined with stall characteristics that are shown not to be hazardous (consistent with 25.204(f)(1)-(3)) in the airplane state corresponding to loss of HALF and stall warning; alternatively a low speed alerting function could be provided in event of loss of stall warning.	warning was not discussed in FTHWG.

Proposed Guidance AC25-7C Paragraph 32.a.(7)(a)	Majority Response
(12) FAA, EASA, TCCA, and Boeing disagree with the proposal to allow in excess of 1.5 g during recovery from §25.253 "Speed increase and recovery characteristics" maneuvers described in AC 25-7C paragraphs 32.c(1)-(5) if applied by a high speed protection function with pitch control at neutral. These members feel that load factor during recovery should be no greater than 1.5 g even with HSPF active because these recoveries are considered to be performed with the pilot in the loop (manual control) and 1.5 g represents a reasonable recovery technique even if the pilot has to push to maintain that g level. Also, there is no upper bound provided for the load factor that could be applied automatically. An excessive HSPF command could cause the pilot to intervene to reduce the load factor, leading to a higher final speed than if the recovery was completed with the controller at neutral.	The FTHWG majority position is that while for conventional aircraft it has been assumed that a pilot will not necessarily pull elevated load factors (greater than 1.5 g) during a recovery from a large gust or upset that puts the airplane close to Vd/Md, it is reasonable to assume that for an aircraft equipped with an HSPF the pilot will not intervene to reduce load factor by pushing on the controller if the airplane is recovering automatically and predictably with the controller at neutral. An HSPF ensures that the recovery is performed automatically at a predictable load factor. Recovery characteristics will be evaluated during the maneuvers described in AC 25-7C paragraphs 32.c(1)-(5) to ensure that the characteristics are acceptable and do not require exceptional piloting skill. Automatic recovery at greater than 1.5 g with the controller at neutral has been considered acceptable for showing compliance to CS-25 §25.335(b)(1)(ii) upset maneuvers used for defining minimum margin from Vc to Vd. since CS-25 Amdt. 13 and in applicable Special Conditions.
(13) Airbus disagrees with the proposed guidance that a high speed protection function (HSPF) should have a probability of failure no greater than "improbable". Failure conditions are adequately covered by §25.1309 and further guidance is unnecessary. Also, if, by implementing appropriate mitigation means, loss of HSPF is made MINOR, a "not greater than improbable" availability requirement is too stringent. If guidance for probability of loss of HSPF function no greater than improbable is included, it would be appropriate to also include a provision for meeting this guidance with a less stringent availability combined with annunciation of failures and appropriate mitigations such as a reduced Vmax/Mmax speed that provide a sufficient speed margin without HSPF to ensure consistency between HSPF failure rate and consequence of HSPF failure. Such provisions have	The FTHWG majority position considers that including availability guidance for this function is appropriate considering that an HSPF changes the airplane pitch response to controller inputs and affects the speed increase that results from the maneuvers described in paragraphs 32.c.(1) – (5). Requiring that loss of an HSPF be improbable is consistent with §25.671(c) regulation that probable malfunctions must only have minor effects on control system operation. This position is also consistent with other requirements and guidance proposed for this topic and others for acceptable probability of loss when a protection function is used to show compliance with Subpart B requirements, which is consistent with the guidance for 25.672 in AC25.672-1 where it states for Active Control Systems, " For systems having a probability of loss of function greater than 10^{-5} per flight hour, all of

been accepted for compliance to §25.335 in previous Special Conditions.	the applicable Part 25 requirements shall be met with the system inoperative."

Proposed Guidance AC25-7C Paragraph 32.a.(7)(b)	Majority Response
(14) Airbus and Dassault disagree with the proposal to allow an HSPF to be disabled as a means to demonstrate characteristics at a speed greater than can be achieved with full forward pitch control. This provision is unnecessary and not applicable to aircraft utilizing a high speed protection function (HSPF), because Vdf/Mdf for such aircraft is typically defined as the maximum speed achievable with full forward control. Allowing certain flight characteristics (controllability and buffet) to be determined with HSPF disabled at a speed greater than that which can be achieved with HSPF active calls into question the definition of Vdf/Mdf. This dissenting opinion also applies to the corresponding proposed change in paragraph 31.a.(8) which provides guidance for §25.251. It is Dassault opinion that it is important to demonstrate the HQ at high speed with the flight control system in its normal mode, so with the High Speed Protection Function active. In consequence the Handling Qualities of 25.253(a)(3)-(5) has only to be demonstrated up to the maximum speed reachable in manoeuvers up to full forward stick (VDF0/MDF0). With HSPF active, reaching speeds (especially Mach numbers) higher than VDF0/MDF0 could only be the result of very high front wind encounters (as the ones defined for 25.335(b)(2)). At speeds higher than VDF0/MDF0, up to VD/MD, it could only be required to demonstrate the capability to return safely to the normal flight domain. This demonstration might be considered as a by-product of the flight envelope expansion tests (e.g. flutter tests), done without high speed protection. This possibility could be discussed in the proposed further phase about VDF/MDF definition.	The FTHWG majority position recognizes that the definition of Vdf/Mdf needs further discussion and possibly interactions with the Structures Harmonization Working Group, in light of a passage of AC 25-7C paragraph 32a.(6) which presents an interpretation §25.1505 linking the §25.253 demonstrations to the §25.335(b) demonstrations in terms of margins to Vmo/Mmo. However, it should be noted that this proposal to disable or modify the HSPF *should it be necessary* to achieve Vdf/Mdf does not change the definitions of Vdf/Mdf per se. The same discussion, leading to the same conclusion, is also documented in the Topic 13 report, dealing with 25.255(f). .

Recommendation

The FAA should adopt the harmonized standard proposed. Further, the FAA should liaise with EASA, TCCA, and ANAC to ensure consistent implementation in their jurisdictions.

Even though a great deal of work has been expended to get this far, and a great many issues have been debated, harmonized and concluded, there are also a number of issues which have not yet been concluded. The FTHWG worked on a "triage" basis, addressing what were considered the most important issues first. Recognizing the dependence of Topic 2 (Adaptation for Icing) on resolving the regulations and guidance related to High Angle of Attack Limiting Functions (HALF), this aspect of the Envelope Protection topic was worked as first priority and has been concluded. A need for additional guidance related to use of angle of attack limiting systems in conventional stall certification was identified, but this topic was not addressed in sufficient depth to provide recommendations in the present report. FTHWG recommends future tasking include this item.

There are a few other specific areas that the FTHWG feel warrant additional attention. One is how to demonstrate compliance with the very simple directive of the SC's and CRI's to consider effects of atmospheric disturbances. This issue has not yet been fully developed for the Envelope Protection topic (nor in the Stability or Out of Trim topics). Therefore, the FTHWG recommends continuing this work to provide more complete guidance for showing compliance to the requirement for robustness in the presence of atmospheric disturbances.

Another topic which deserves more deliberation is the question of whether an airplane that employs a function that limits pitch attitude or angle of attack on takeoff should utilize the same Vmu factors as a geometry limited airplane (14CFR25.107(e)(1)(iv)), and what guidance should be provided. The FTHWG discussed the issue and drafted a proposal, but shelved the discussion in favor of concluding the other issues noted above. Therefore, it is requested that the FTHWG complete that deliberation in a future phase of this effort.

Finally, the FTHWG recommends a cross-discipline "harmonization" between FTHWG, FCHWG and Structures HWG to achieve consensus on consideration of high-speed protection functions and associated speed/Mach margins affecting 14CFR25.253, 335, and 1505, and use of load factor limiting systems affecting 14CFR143(g) and 337. This work is identified in paragraph A7 below.

A. Rulemaking

1. What is the proposed action?

The FTHWG recommends changes to 14CFR25 paragraphs 25.103, 143, 145, 175, 207, 1323 and Appendix C: Part II a, and the addition of paragraphs 144, 202 and 204 as presented in Attachment 1B. Further, the FTHWG recommends that the FAA liaise with EASA, TCCA, ANAC and other national authorities to ensure consistent implementation.

In addition FTHWG will recommend concomitant changes to the relevant guidance material and that identical changes be made to the guidance published by the counterpart authorities.

2. What should the harmonized standard be?

The FTHWG believes that a single standard of airworthiness can be achieved which produces a level of safety equivalent to that seen by conventional (not-envelope-protected) airplanes complying with the current airworthiness standards. The intent was to generate a standard which could be applied to as broad a range of envelope protection features, and combinations of those features, as possible.

The harmonized standard is given in Attachment 1B.

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

The FTHWG believes that as a result of the process taken - that of analyzing the implicit safety elements provided to conventional airplanes, collecting the best industry practices utilized in certifying EFCS airplanes via SC's and CRI's, and creating a branched structure within the 14CFR25.200 series regulations along with the new 14CFR25.144 - the current level of safety will be maintained under the proposed harmonized regulations. In addition, when the regulations are harmonized, both industry and authorities will realize cost benefits due to reduced administrative burden.

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

The FTHWG believes that the proposed standard maintains the same level of safety, compared to the conventional, mechanical aircraft for which the current FAR was written. The proposed standard accommodates the envelope limiting features made available by implementation of modern EFCS architectures.

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

Because the baseline discussion began with comparisons of the certification processes (SC's, CRI's) used on a large number of transport airplanes over a significant period of time, and strove to drive to a consensus regulatory framework based on those, the FTHWG believes that the proposed standard maintains the same level of safety as represented by current industry practice.

6. Who would be affected by the proposed change?

All OEM's certifying airplanes with EFCS architectures incorporating envelope limiting features will be affected by the fact that after adoption of these proposed regulations and associated guidance, there will be one standard across the regulatory field.

In addition, the certifying and validating authorities will be affected in that everyone should be certifying and validating to the same standard, eliminating the need to generate custom Special Conditions and CRI's and their associated Issue Papers.

7. Does the proposed standard affect other HWG's and what is the result of any consultation with other HWGs?

The FTHWG, by limiting as much as possible, the discussion to the Subpart B configuration of all-up, healthy airplanes, felt it was not necessary to consult with other HWG's at this time, although individual Subject Matter Experts (SMEs) from other disciplines both at OEM's and at the authorities were consulted in the course of development of this material.

In particular, the FTHWG believes that significant benefit can be achieved by future consultation with both the Flight Controls HWG and the Structures HWG, since Subparts D, F and C will be affected by the implementation of these modern architectures. Specific actions for future consultation with these groups would be to achieve consensus (between Subparts) on the guidance for compliance to 14CFR25.253, 335, 337, and 1505 in the context of 14CFR25.671, 672 and 1309.

B. Advisory Material

1. Is existing FAA advisory material adequate? If not, what advisory material should be adopted?

The FTHWG believes that the current FAA advisory material is not adequate. Proposed changed material is provided. See Attachment 1C.

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

The FTHWG believes that the regulatory changes proposed and the associated guidance material proposed will afford equal levels of safety to both conventional and EFCS limited airplanes. With these changes, nothing more need be included.

Economics

A. What is the cost impact of complying with the proposed standard (it may be necessary to get FAA Economist support to answer this one)?

Because the approach taken by the FTHWG on this topic was to marry the experiences of current SC's and CRI's to the current regulatory structure, the FTHWG does not believe the cost impact will be significant for the same level of safety. Further, the FTHWG believes there may be a modest cost savings in administrative burden to OEM's for collecting the harmonized requirements and means of compliance in one place.

In addition, the FTHWG believes similar administrative cost savings should be available to each of the participating authorities for the same reasons.

If FAA economists are employed to generate specific analyses, the FTHWG would like to be engaged in that activity as it happens.

B. Does the HWG want to review the draft NPRM prior to publication in the Federal Register?

Yes, please.

ICAO Standards
How does the proposed standard compare to the current ICAO standard?

Given that the ICAO Annex 8, Part IIIB standards were written without consideration for any kind of systems-related envelope protection or limiting, the proposed standard is quite different, structurally. Because of the approach taken by the FTHWG, however, it is thought that the intents are the same; only the means to achieving the safety goal embodied in the ICAO standard is open to a wider design space, and more explicitly in the proposed regulation.

One exception is the explicit discussion of stall warning in the first sentence of Annex 8, Part IIIB paragraph 2.4.2.1 (that a distinctive warning shall be apparent). The second sentence refers to this warning "and other characteristics". These other characteristics could refer to operational characteristics of a limiting function. It is the requirement for warning and the use of the word "and" in the second sentence which would make the proposed regulations not compatible with the ICAO standard.

The second exception is found in Paragraph 3.5.1, Design Airspeeds. In considering the case of an airplane with envelope limiting and various levels of stability (including zero), the "margin" referred to may be provided by system features and functions not envisioned by Annex 8. Nevertheless, the FTHWG recognizes the intent of the standard in 3.5.1 and have included the need for robustness of limiting functions against both pilot action and atmospheric disturbances. Therefore, FTHWG believes that the proposed regulations and guidance is compatible with this aspect of Annex 8, even if limiting functions, required by the proposed regulations are not explicitly called out.

FTHWG believes that all other aspects of the proposal are compatible with ICAO Annex 8, Part IIIB.

Attachment 1A Topic 1 Work Plan

Work Plan – Envelope Protection

1. What is the Task?
Recommend revisions to regulations and guidance material to include criteria to be used in the assessment of airplanes incorporating electronic flight control systems which include flight envelope protection features or functions which are harmonized across FAA/EASA/TCCA/ANAC.
2. Who will work the task?
The Flight Test Harmonization Working Group (FTHWG) will have primary responsibility for this task. Consideration will be given for consultation with SME's representing flight controls, propulsion, and loads/dynamics disciplines.
3. Why is this task needed? (Background information)
Many new transport category aircraft include control system designs which incorporate flight envelope protection (limiting) on a full time basis that will prevent the pilot from inadvertently or intentionally exceeding any of a number of flight envelope parameters. These limiting features may or may not be active in all normal and alternate flight control modes and may or may not be capable of being overridden by the pilot. Except for 14CFR 25.1329(h) there is no requirement in the regulations for these limiting features, nor do current requirements address these features. Features which have been incorporated in the past and which have received attention via Special Conditions or Issue Papers (CRI's) include: a) Normal load factor limiting b) Angle of attack limiting c) Speed limiting d) Pitch and roll attitude limiting In addition, the mode switching involved when these features become active has been addressed. EASA has included provisions for this feature in Nz limiting in their recently published CS25, Amendment 13. Harmonization of FAA, EASA, TCCA, and ANAC requirements should be addressed. FAA has expressed interest in considering a broad range of envelope parameter limiting schemes in the development of harmonized rulemaking.
4. References (existing regulatory and guidance material, including special conditions, CRIs, etc.)
FAA 14 CFR Part 25 Subpart B / EASA CS-25 A-13 a) 25.103 Stall Speed b) 25.107 Takeoff Speeds c) 25.121 Climb, One Engine Inoperative d) 25.125 Landing e) 25.143 General Controllability and Maneuverability f) 25.145 Longitudinal Control g) 25.147 Directional and Lateral Control h) 25.149 Minimum Control Speed i) 25.161 Trim j) 25.171 General [Stability] k) 25.173 Static Longitudinal Stability

l) 25.175 Demonstration of Static Longitudinal Stability
m) 25.177 Static Lateral-Directional Stability
n) 25.181 Dynamic Stability
o) 25.201 Stall Demonstration
p) 25.203 Stall Characteristics
q) 25.207 Stall Warning
r) 25.253 High Speed Characteristics
s) 25.255 [Out of Trim Characteristics]
t) 25.335(b) Design Dive Speed
u) 25.671 [Control Systems] General
v) 25.672 Stability Augmentation and Automatic and Power-operated Systems
w) 25.1309 Equipment, Systems and Installations
x) 25.1323 Airspeed Indicating System
y) 25.1329 Flight Guidance System

FAA Special Conditions

a) FAA Final SC No. 25-316-SC Airbus A380-800
b) FAA Final SC No. 25-12-19, Embraer S. A., Model EMB-550 Airplane, Flight Envelope Protection, General Limiting Requirements
c) FAA Final SC No. 25-482-SC Embraer S. A., Model EMB-550 Airplane, Flight Envelope Protection, High Speed Limiting
d) FAA Final SC No. 25.486-SC Embraer S. A., Model EMB-550 Airplane, Flight Envelope Protection, Pitch and Roll Limiting Functions

EASA CRI's

a) CRI B-XX_Initial Draft Normal Load Factor Limiting System
b) CRI B-XX_Issue_Initial Draft Flight Envelope Protection
c) CRI B-XX Initial Draft Stalling and Scheduled Operating Speeds

ANAC Equivalent Level of Safety

ANAC Equivalent Level of Safety ELOS EV-35-EMB-550s4, Electronic Flight Control System, Mistrim Maneuvering
ANAC Equivalent Level of Safety ELOS EV-03-EMB-550s4, Flight Envelope Protection: Pitch and Roll and High Speed Limiting Functions
ANAC Equivalent Level of Safety ELOS EV-07-EMB-550s4, Flight Envelope Protection: Normal Load Factor (g) Limiting
ANAC Equivalent Level of Safety ELOS EV-25-EMB-550s4, Flight Envelope Protection: High Incidence Protection
ANAC Equivalent Level of Safety ELOS EV-37-EMB-550s4, Flight Envelope Protection: General Limiting Requirements

AC 25-7C Flight Test Guide for Certification of Transport Category Airplanes

EASA CS25 Book 2 (Advisory Material)

5. Working method

It is envisioned that 8-10 face-to-face meeting days over a period of 20-24 months will be needed to facilitate the discussion needed to complete these tasks. Telecons and electronic correspondence will be used to the maximum extent possible, in particular, between face-to face meetings to ensure that progress is maintained.
The working group should first consider the envelope(s) (parameter(s)) for limiting which will be considered applicable for this tasking (this will likely define a limitation on the applicability of any new regulation). This is likely to take the form of a list: e.g. AOA limiting, airspeed

limiting, load factor limiting, sideslip limiting, etc. Each parameter (or combination of parameters) which might be artificially limited may affect more than a single regulation. The work group should then produce a mapping of affected regulations to the parameters considered for limiting. Following this mapping exercise, the work group will have a clear view of which regulations should be considered for modification based on the resulting mapping. The group should then consider appropriate requirement revisions to accommodate these or combinations of these envelope limiting features.
6. Preliminary schedule (How long?)
Provide recommendations to the ARAC Transport Airplanes and Engines Subcommittee within 24 months of the initiation of work on these tasks.
7. Regulations/guidance affected
Regulations noted in Section 4 above.
8. Additional Information
This is a very broad and far-reaching task. The currently available issue papers/special conditions have been written in response to very specific system implementations. In contrast, the stated intent of this task is to generate one single visionary requirement set which will ensure safety and at the same time accommodate all potential envelope parameter limiting which might be considered, and presumably a large number of combinations and permutations of those. Within that intent, the task team will likely face the large challenge of generating a rational and defensible strategy for limiting the potential size of the pool of parameters and combinations of parameters under consideration. Many referenced regulations are identified only because of the potential that reference speeds might need to be revised as a result of implementing envelope limiting.

Attachment 1B Proposed Regulatory Material

Topic 1 – Proposal for Changes to 14CFR 25 Regulations

Existing regulatory text in plain font
New text that has been accepted shown in **Bold**.
-- except if existing text is **Bold**, new text is **<u>Bold Underlined</u>** **(generally section headings)**
Removed text that has been accepted shown in ~~**Bold Stikethrough**~~
Revisions that have not had final review shown in ***bold italics and*** ~~***bold italics strikethrough***~~
Comments that correspond to Dissenting Opinions (abbreviated) are highlighted in yellow.

Proposed Regulatory Changes	**Comments / Rationale**
§25.103 <u>Reference</u> Stall 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: $$V_{SR} \geq \frac{V_{CL_{MAX}}}{\sqrt{n_{zw}}}$$ where: V_{CLMAX} = Calibrated airspeed obtained when the load factor-corrected lift coefficient $\left(\frac{n_{zw}W}{qS}\right)$ is first a maximum during the maneuver prescribed in paragraph (c) of this section. 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.	Proposal keeps this general and same as existing reg for conventional airplanes. Those who choose to define Vsr in icing would comply with this paragraph for icing conditions as well as non-icing. (b)(3) provides allowance for determining Vsr only in non-icing conditions. See draft AC25-25X guidance para 4.2.2. This leaves V_{CLmax} rather than changing to V_{CLmax_demo} or V_{CL_demo}, etc. It needs to remain general for all applicants and stall systems. Current stick pusher designs may limit AOA below aero stall, so it is already understood that V_{CLmax} used here doesn't necessarily mean C_L at aerodynamic stall. See para (c) below and draft AC25-7X guidance para 29.e.(5)(c).
(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 takeoff 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	"Ice accretion" is noted as an example of "other respects" and would be applicable only in the case where a "performance standard in which Vsr is being used". So, if Vref in icing is based upon 1.23 Vsr_ice, then the appropriate ice accretions must be included in determining V_{CLmax_ice}. See draft AC25-25X guidance para 4.2.2.

performance standard; (5) The center of gravity position that results in the highest value of reference stall speed; **(6)** The airplane trimmed for straight flight at a speed selected by the applicant, but not less than 1.13V_{SR} and not greater than 1.3V_{SR}; and **(7) If installed, the High Angle-of-Attack Limiting Function disabled or adjusted, at the option of the applicant, to allow reaching the angle of attack corresponding to V_{SR}.**	
(c) Starting from the stabilized trim condition, apply the longitudinal control to decelerate the airplane **in straight flight** so that the speed reduction does not exceed one knot per second, **until stall as defined in Section 25.201(d) or the angle of attack corresponding to V_{SR} is reached; or until activation of a stall identification device (e.g., stick pusher), if installed.**	This clarification is added to allow stall speed testing for a HALF airplane or conventional airplane with natural stall ID to end at the AOA for Vsr rather than continuing to stall ID. However, for an airplane that must comply with 25.103(d) because it includes a stick pusher or similar stall ID device, the test would be continued to activation of the stall ID device.
(d) In addition to the requirements of paragraph (a) of this section, when a device that abruptly pushes the nose down at a selected angle of attack (**~~e.g.,~~i.e.,** a stick pusher) is installed, the reference stall speed, V_{SR}, may not be less than 2 knots or 2 percent, whichever is greater, above the speed at which the device operates.	This requirement applies only to a pusher type stall ID device.
(e) In addition to the requirements of paragraph (a) of this section, when a High Angle-of-Attack Limiting Function is installed and compliance is shown with §§25.202 and 25.204, the one-g minimum steady flight speed, V_{MIN1g}, must be established if it is used to determine compliance with a required performance standard or other requirements demonstrations in non-icing or icing conditions.	This only requires Vmin1g be determined in icing or non-icing if it is used to show compliance elsewhere. It is likely that Vref in icing is based on a ratio of Vmin1g. Otherwise, there will be no requirement to determine Vmin1g.
(1) The one-g minimum steady flight speed, V_{MIN1g}, is the minimum calibrated airspeed at which the airplane can develop a lift force (normal to the flight path) equal to its weight, while stabilized at the limit angle of attack achieved with the High Angle-of-Attack Limiting Function operating normally. **(2) V_{MIN1g} is determined with:** **(i) Engines idling;** **(ii) Flaps and landing gear in any likely combination of positions approved for operation;** **(iii) The weight used when the reference stall speed, V_{SR}, is being used as a factor to**	Vmin1g is the speed corresponding to a theoretical steady CL at the AOA limit. The method for determining Vmin1g by test or analysis of other test data is addressed in guidance.

determine compliance with a required performance standard; **(iv) The center of gravity position that results in the highest value of V_{MIN1g};** **(v) The airplane trimmed for straight flight at a speed selected by the applicant, but not less than 1.13 V_{MIN1g} (or the minimum trim speed if higher than 1.13 V_{MIN1g}), and not greater than 1.3V_{MIN1g}, and** **(vi) The ice accretions appropriate for the condition existing in the performance standard for which V_{MIN1g} is being used.**	

§25.107 Takeoff speeds.	***Changes to 25.107 related to determining Vmu and factors on Vmu for aircraft employing an on-ground pitch attitude limiting function have been proposed but not reviewed in detail or accepted by Topic 1 team***

§25.143 General. (a)-(f) [No change] (g) When maneuvering at a constant airspeed or Mach number (up to V_{FC}/M_{FC}), the stick forces and the gradient of the stick force 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 **if a load factor limiting function is not included that prevents overstressing the airframe, the stick forces** must not be so low that the airplane can easily be overstressed inadvertently. **If a load factor limiting function is used to prevent inadvertent overstressing of the airframe, its failure must be improbable.** Changes of gradient that occur with changes of load factor must not cause undue difficulty in maintaining control of the airplane, and local gradients must not be so low as to result in a danger of overcontrolling.	Dissenting Opinion (1): Airbus and Dassault: CS 25.302 and 25.1309 adequately cover failure conditions and it's not necessary to include a maximum failure rate here. Dissenting Opinion (2): TCCA agrees that a failure rate requirement should be included, but does not concur with use of the word "Improbable" or "not more probable than remote". Instead, the numerical failure rate of 1E-5/flt-hr should be included in the regulation. The Nz limiting system is being used to substitute for basic airplane characteristics and 1E-5/flt-hr is considered a rock bottom minimum reliability requirement.

<u>§ 25.144 Envelope Protection Functions—General</u>. **For airplanes that employ envelope protection functions:** **(a) Envelope protection functions must not unduly limit the maneuvering capability of the airplane nor interfere with its ability to perform maneuvers required for normal and emergency operations.** **(b) Onset characteristics of each envelope protection function must be appropriate to the phase of flight and type of maneuver, and must not conflict with the ability of the pilot to satisfactorily control the airplane flight path, speed, or attitude.** **(c) Excursions of a limited flight parameter beyond its nominal design limit value due to dynamic maneuvering, airframe and system tolerances, and non-steady atmospheric conditions must not result in unsafe flight characteristics or conditions.** **(d) Operation of envelope protection functions must not adversely affect aircraft control during expected levels of atmospheric disturbances, nor impede the application of recovery procedures in case of wind-shear.** **(e) Simultaneous action of envelope protection functions must not result in adverse coupling or adverse priority.** **(f) In case of abnormal attitude or excursion of any flight parameters outside the protected boundaries, operation of envelope protection functions must not hinder airplane recovery.**	These regulations provide a foundation for evaluating the characteristic of envelope protection functions similar to that provided by § 25.143 for conventional control functions.

§25.145 Longitudinal Control. (a) It must be possible, at any point between the trim speed prescribed in §25.103(b)(6) and stall identification (as defined in §25.201(d)) **or the angle**	Aircraft utilizing high angle-of-attack limiting functions do not provide "stall identification"; full

of attack achieved at full aft control input if compliance is shown with §§ 25.202 and 25.204, to pitch the nose downward so that the acceleration to this selected trim speed is prompt with (1) The airplane trimmed at the trim speed prescribed in §25.103(b)(6); (2) The landing gear extended; (3) The wing flaps (i) retracted and (ii) extended; and (4) Power (i) off and (ii) at maximum continuous power on the engines. (b) With the landing gear extended, no change in trim control, or exertion of more than 50 pounds control force (representative of the maximum short term force that can be applied readily by one hand) may be required for the following maneuvers: (1) With power off, flaps retracted, and the airplane trimmed at 1.3 V_{SR1}, extend the flaps as rapidly as possible while maintaining the airspeed at approximately 30 percent above the reference stall speed existing at each instant throughout the maneuver. (2) Repeat paragraph (b)(1) except initially extend the flaps and then retract them as rapidly as possible. (3) Repeat paragraph (b)(2), except at the go-around power or thrust setting. (4) With power off, flaps retracted, and the airplane trimmed at 1.3 V_{SR1}, rapidly set go-around power or thrust while maintaining the same airspeed. (5) Repeat paragraph (b)(4) except with flaps extended. (6) With power off, flaps extended, and the airplane trimmed at 1.3 V_{SR1}, obtain and maintain airspeeds between V_{SW}**, or the greater of V_{REF} - 5 knots CAS and the activation of a low airspeed caution or warning alert in accordance with § 25.1322 if compliance is shown with §§ 25.202 and 25.204,** and either 1.6 V_{SR1} or V_{FE}, whichever is lower. (c)-(d) [No Change]	aft stick is an equivalent condition for this requirement. Aircraft certified under §§ 25.202 and 25.204 are not required to determine Vsw; the proposed text provides a minimum speed appropriate for a HALF equipped airplane for this requirement consistent with existing guidance that "…reasonable changes in speed may be made without encountering very high control forces. 25.175(d) covers maximum aft force for decel to Vmin.

§25.175 Demonstration of static longitudinal stability. Static longitudinal stability must be shown as follows: (a) [No Change] (b) [No Change] (c) Approach. The stick force curve must have a stable slope at speeds between V_{SW} **or the airspeed achieved at full aft control input if compliance is shown with §§ 25.202 and 25.204** and 1.7 V_{SR1}, with— (1) Wing flaps in the approach position; (2) Landing gear retracted; (3) Maximum landing weight; and (4) The airplane trimmed at 1.3 V_{SR1} with enough power to maintain level flight at this speed. (d) Landing. The stick force curve must have a stable slope, and the stick force may not exceed 80 pounds, at speeds between V_{SW} **or the airspeed achieved at full aft control input if compliance is shown with §§ 25.202 and 25.204** and 1.7 V_{SR0} with— (1) Wing flaps in the landing position; (2) Landing gear extended; (3) Maximum landing weight; (4) The airplane trimmed at 1.3 V_{SR0} with— (i) Power or thrust off, and (ii) Power or thrust for level flight. ~~**(5) The airplane trimmed at 1.3 V_{SR0} with power or thrust off.**~~	Defines a speed range appropriate for airplanes that are not required to provide stall warning. Apparent error made in Amdt 25-115. (5) should have been deleted when (4) was revised, as was done in CS25.

<u>§25.202 Handling demonstrations for high angle-of-attack limiting functions</u> **(a) Applicability: If a High Angle-of-Attack Limiting Function is installed that meets the capability and reliability requirements of paragraphs (a)(1) through (a)(5) of this section, compliance with the high angle-of-attack handling demonstrations defined by paragraphs (b) through (e) of this section and the high angle of attack characteristics requirements of Section 25.204 can be shown in lieu of compliance with Sections 25.201 and 25.203.**	§25.202 and §25.204 define an alternative compliance path for aircraft utilizing a high angle-of-attack limiting function in lieu of conventional stall demonstrations. §25.202 specifies the required demonstrations and §25.204 specifies the characteristics during those demonstrations, similar to §25.201 and §25.203 for conventional aircraft.
(1) The HALF must be provided for all configurations used for normal operation, in icing and non-icing conditions; **(2) It must not be possible to encounter a stall during the pilot induced maneuvers required by paragraphs (b)-(d) of this section in icing and non-icing conditions;** **(3) The airplane must be protected against stalling and the operation of the High Angle-of-Attack Limiting Function must not adversely affect airplane control during expected levels of atmospheric disturbances, nor may it impede the application of recovery procedures in case of wind-shear;** **(4) The High Angle-of-Attack Limiting Function must be provided in each abnormal configuration of the high lift devices following high lift system failures not shown to be improbable; and**	Guidance is included that makes it clear that 25.202 does not apply in maneuvering flight in the cruise regime (see para 29h(2)(g)).
(5) Failure of the High Angle-of-Attack Limiting Function must be improbable. **(b) Maneuvers to the limit of the longitudinal control, in the nose up sense, must be shown in straight flight and in 30° banked turns with:** **(1) The High Angle-of-Attack Limiting Function operating normally and the automatic power or thrust increase system inhibited, if applicable;** **(2) Initial power or thrust conditions of:** **(i) Engines idling; and** **(ii) Power or thrust necessary to maintain level flight at 1.5 V_{SR1} (where V_{SR1} corresponds to the reference stall speed at maximum landing weight with flaps in the approach position and the landing gear retracted in non-icing**	"Improbable" can be changed to "not more probable than remote" for EASA CS25 or if 'Arsenal 25.1309' is implemented. <u>Dissenting Opinion (3):</u> Airbus does not concur with inclusion of a failure rate requirement for HALF credit. 25.1309 compliance should be sufficient. <u>Dissenting Opinion (4):</u> TCCA agrees that a failure rate requirement should be included, but does not concur with use of the word "Improbable" or "not more probable than remote". Instead, the numerical failure rate of 1E-5/flt-hr should be included in the regulation. The HALF system is being used to substitute for basic aerodynamic characteristics and 1E-5/flt-hr is considered a rock bottom minimum reliability requirement.

conditions). **(c) In each condition required by paragraph (b) of this section, it must be possible to meet the applicable requirements of §25.204(b)-(e) with –** **(1) Flaps, landing gear and deceleration devices in any likely combination of positions approved for operation;** **(2) Representative weights within the range for which certification is requested;** **(3) The most adverse center of gravity; and** **(4) The airplane trimmed for straight flight at the all-engine minimum normal operating speed appropriate for the configuration.**	Guidance describing "minimum normal operating speed" is included in AC25-7X, Para 29h(3)(a).
(d) The following procedures must be used to show compliance with §25.204(b)-(e) in icing and non-icing conditions: **(1) Starting at a speed such that the angle of attack is sufficiently below the AOA-limit to ensure that a steady rate of speed reduction can be established, apply the longitudinal control so that the speed reduction does not exceed one knot per second until the control reaches the aft stop.** **(2) The longitudinal control must be maintained at the stop until the airplane has reached a stabilized flight condition. With the control at the aft stop it must be shown that the airplane presents a satisfactory level of lateral control.** **(3) The airplane must be recovered by normal recovery techniques.** **(4) The demonstrations of paragraphs (b) and (c) of this section must also be conducted with increased entry rates, up to the maximum practical entry rate in non-icing conditions, and up to 3 knots per second in icing conditions. For approach and landing configurations, rapid application of go-around power or thrust at any time following initiation of the maneuver to the time at which the longitudinal control reaches the aft stop must also be considered, if more critical.**	
(5) For flight in icing conditions before the ice	For the recovery delay times specified in (d)(5), guidance explains that the pilot force input trend is

protection system has been activated and is performing its intended function, the handling demonstration requirements identified in paragraphs (b) and (c) of this section, except with all automatic protection functions operating normally, at the more critical power (or thrust) setting of paragraph (b)(2) of this section, must be met with the ice accretion defined in Appendix C, part II(e) of this part in a steady deceleration up to 1 knot per second. The deceleration must be continued until the first of (i)-(iii) is reached: **(i) A suitable warning alert, in accordance with §25.1322, followed by normal recovery input delayed by 1 second;** **(ii) A suitable caution alert, in accordance with §25.1322, combined with engagement of an automatic protection function that operates to deter further reduction in airspeed, followed by normal recovery input delayed by 3 seconds; or** **(iii) The aft control stop, followed by normal recovery input delayed by 3 seconds.** **If the time from entry into icing conditions until the ice protection system is activated and performing its intended function is not sufficiently brief, the requirements of paragraph (d)(1)-(4) are applicable in lieu of this paragraph.** **(e) In addition to the requirements outlined by paragraphs (b) through (d) of this section, maneuvers with a deceleration of not more than 1 knot per second up to the greater of the angle of attack corresponding to V_{SR} obtained per § 25.103(a) (if determined) and that reached during maneuvers from § 25.202(d)(1)-(4) must be shown be shown to meet the characteristics requirements of § 25.204(f) in straight flight (non-icing and icing conditions) and in 30° banked turns (non-icing conditions only) with:** **(1) The High Angle-of-Attack Limiting Function deactivated or adjusted, at the option of the applicant, to allow the airplane to achieve the angle of attack specified above;** **(2) Automatic power or thrust increase system inhibited (if applicable);**	to be continued during the noted time prior to recovery input. This does not require that the airplane continue to decelerate at 1 kt/sec after activation of protection function.

(3) Engines idling; **(4) Flaps, landing gear and deceleration devices in any likely combination of positions approved for operation;** **(5) The most adverse center of gravity; and** **(6) The airplane trimmed for straight flight at the speed prescribed in § 25.202(c)(4).**	

<u>§25.204 Flight characteristics for high angle-of-attack limiting functions</u> **(a) Applicability: If a High Angle-of-Attack Limiting Function is installed and compliance is being shown to §25.202 in lieu of §25.201, the high angle-of-attack flight characteristics during the handling demonstrations required by §25.202 must meet the requirements of paragraphs (b) through (f) in lieu of §25.203.** **(b) Throughout maneuvers with a deceleration of not more than 1 knot per second, both in straight flight and in 30° banked turns, and with the High Angle-of-Attack Limiting Function operating normally, the airplane's characteristics must be as follows:** **(1) There must be no abnormal nose-up pitching;** **(2) There must be no uncommanded nose-down pitching indicative of stall. Reasonable attitude changes associated with stabilizing the angle-of-attack at the AOA-limit as the longitudinal control reaches the stop are acceptable;** **(3) There must be no uncommanded lateral or directional motion indicative of stall, and the airplane must exhibit good lateral and directional control by conventional use of the controls throughout the maneuver; and** **(4) The airplane must not exhibit buffeting of a magnitude and severity that would act as a deterrent from completing the maneuvers.** **(c) In maneuvers with increased rates of entry some degradation of characteristics is acceptable, associated with a transient excursion beyond the stabilized AOA-limit. However, the airplane must not exhibit hazardous characteristics or characteristics that would deter the pilot from holding the longitudinal control on the stop for a period of time appropriate to the maneuver.** **(d) It must always be possible to reduce angle-of-attack by conventional use of the controls.** **(e) The High Angle-of-Attack Limiting Function must not unduly damp airplane pitch rate capability preventing achievement of decelerations**	

deemed necessary for normal operation and for showing compliance with §25.202. **(f) Throughout the maneuvers with the High Angle-of-Attack Limiting Function deactivated or adjusted for demonstration of §25.103(a)-(c) and §25.202(e) the following characteristics must be shown:** **(1) The airplane must not exhibit hazardous characteristics;** **(2) It must always be possible to reduce angle of attack by conventional use of the controls; and** **(3) The airplane must exhibit good lateral and directional control by conventional use of the controls.**	

§25.207 Stall warning. ***[… no change (a) through (i) …]*** **(j) If a High Angle-of-Attack Limiting Function is installed and compliance is shown with §§25.202 and 25.204, the stall warning requirements of paragraphs (a) through (i) are not required when the High Angle-of-Attack Limiting Function is operating normally. Following failures affecting the High Angle-of-Attack Limiting Function not shown to be extremely improbable, such that the capability of the function no longer satisfies §§25.202 and 25.204, stall warning must be provided that meets the requirements of § 25.207(a) and (g), and the requirements of § 25.207(b) except that the speed margins of the required stall warning must be as prescribed in (1) and (2) below. In addition,** **(1) In non-icing conditions, stall warning must provide sufficient margin to prevent encountering unacceptable characteristics or encountering stall in the following conditions:** **(i) In engines idling straight deceleration not exceeding one knot per second to a speed 5 knots or 5 percent CAS, whichever is greater, below the warning onset; and** **(ii) In engines idling turning flight deceleration at entry rates up to 3 knots per second when recovery is initiated not less than one second after the warning onset.** **(2) In the icing conditions identified in paragraphs (e)(3)-(5) of this section, stall warning must provide sufficient margin to prevent encountering unacceptable characteristics and encountering stall, in engines idling straight and turning flight decelerations not exceeding one knot per second, when the pilot starts a recovery maneuver not less than three seconds after the onset of stall warning.** **(3) Once initiated, stall warning must continue until the angle of attack is reduced to approximately that at which stall warning began.** **(4) For paragraphs (1) and (2) above, indications of**	This new paragraph 25.207(j) sets requirements for stall warning function when the high angle-of-attack limiting function is failed.

a stall encounter include uncommanded nose-down pitching that cannot be readily arrested or buffeting of a magnitude and severity that would act as a deterrent to further speed reduction. An airplane exhibits unacceptable characteristics during straight or turning flight decelerations if it is not always possible to produce and to correct roll and yaw by conventional use of lateral and directional controls, or if abnormal nose-up pitching occurs.	

§25.1323 Airspeed indicating system. (d) From 1.23 V_{SR} to the speed at which stall warning begins **or the airspeed achieved at full aft control input if compliance is shown with §§ 25.202 and 25.204**, the IAS must change perceptibly with CAS and in the same sense, and at speeds below ~~**stall warning speed**~~ **this range** the IAS must not change in an incorrect sense.	Defines the lower bound of the speed range for aircraft which are not required to have a stall warning function.

Appendix C: Part II: (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), **25.202(d)(5),** ~~**and**~~ 25.207(h), and 25.207(i).	Adds reference to new regulation

Attachment 1C Proposed Guidance Material

<u>Proposed Guidance Changes: AC25-7X</u>

Existing text shown in plain font
New text shown in **Bold;**
New text where original text is already **Bold** is shown in **<u>Bold Underline</u>**
Removed text shown in **~~Bold Stikethrough~~**
Other notes shown in *Italics*
<u>[Dissenting Opinion (abbreviated)</u>: shown in italics with yellow highlight and square brackets]

Chapter 2 – Flight

Section 3. Controllability and Maneuverability.

20. General - § 25.143 <u>and § 25.144.</u>

a. <u>Explanation</u>. The purpose of § 25.143 is to verify that any operational maneuvers conducted within the operational envelope can be accomplished smoothly with average piloting skill and without encountering a stall warning or other characteristics that might interfere with normal maneuvering, or without exceeding any aircraft structural limits. Control forces should not be so high that the pilot cannot safely maneuver the aircraft. Also, the forces should not be so light that it would take exceptional skill to maneuver the aircraft without over-stressing it or losing control. The aircraft response to any control input should be predictable to the pilot**. Many modern aircraft employ Envelope Protection Functions to limit excursions of one or more measured flight parameters. § 25.144 provides general regulations for such functions. The purpose of § 25.144 is to ensure that Envelope Protection Functions support safe operation and do not interfere with required maneuvering in normal and emergency operations and in forseeable atmospheric conditions.**

b. <u>General Test Requirements</u>.

(1) Compliance with § 25.143 (a) through (g) is primarily a qualitative determination by the pilot during the course of the flight test program. The control forces required and airplane response should be evaluated during changes from one flight condition to another and during maneuvering flight. The forces required should be appropriate to the flight condition being evaluated. For example, during an approach for landing, the forces should be light and the airplane responsive in order that adjustments in the flight path can be accomplished with a minimum of workload. In cruise flight, **the combination of control forces, airplane response and any envelope protection functions that are included ~~forces and airplane response~~** should be such that inadvertent control input does not result in exceeding limits or in undesirable maneuvers. Longitudinal control forces should be evaluated during accelerated flight to ensure a positive stick force with increasing normal acceleration. **If a load factor limiting envelope protection function that prevents exceedance of design limits is <u>not</u> installed, pitch control forces** should be heavy enough at the limit load factor to prevent inadvertent excursions beyond the design limit. Sudden engine failures should be investigated during any flight condition or in any configuration considered critical, if not covered by another section of part 25. Control forces considered excessive should be measured to verify compliance with the maximum control force limits specified in § 25.143(d). Allowance should be made for delays in the initiation of recovery action appropriate to the situation.

(2)-(3) [No Change]

c. - d. [No Change]

e. Maneuvering Characteristics - § 25.143(g).

(1) General. An acceptable means of compliance with the requirement that stick forces may not be excessive when maneuvering the airplane **with the flight control systems operating normally** is to demonstrate that, in a turn for 0.5g incremental normal acceleration (0.3g above 20,000 feet) at speeds up to V_{FC}/M_{FC}, the average stick force gradient does not exceed 120 pounds per g.

(2) Interpretive Material.

(a) **An** ~~The~~ objective of § 25.143(g) is to ensure that the limit strength of any critical component on the airplane would not be exceeded in maneuvering flight **with the flight control systems operating normally; however, this requirement is satisfied if the maximum achievable load factor is limited to the design limits by a load factor envelope protection function that is shown to comply with § 25.144 and is shown to have an improbable failure rate (less than 10^{-5} per flight hour).** *[Dissenting Opinion (5)--Airbus and Dassault: CS25.302 and 25.1309 adequately cover failure conditions and it's not necessary to include a maximum failure rate here.]* In much of the structure, the load sustained in maneuvering flight can be assumed to be directly proportional to the load factor applied. However, this may not be the case for some parts of the structure (e.g., the tail and rear fuselage). Nevertheless, it is accepted that the airplane load factor will be a sufficient guide to the possibility of exceeding limit strength on any critical component if a structural investigation is undertaken whenever the design positive limit maneuvering load factor is closely approached. If flight testing indicates that the positive design limit maneuvering load factor could be exceeded in steady maneuvering flight with a 50 pound stick force, the airplane structure should be evaluated for the anticipated load at a 50 pound stick force. The airplane will be considered to have been overstressed if limit strength has been exceeded in any critical component. For the purposes of this evaluation, limit strength is defined as the lesser of either the limit design loads envelope increased by the available margins of safety, or the ultimate static test strength divided by 1.5.

(b) Minimum Stick Force to Reach Limit Strength. **Unless a load factor envelope protection function is installed, the following applies:**

1 [No Change]

2 [No Change].

(c), (d) [No Change]

f. [No change]

g. General Requirements for Envelope Protection Functions - § 25.144.

(1) Background - § 25.144.

(a) General. Many modern aircraft employ Envelope Protection Functions (EPFs) to limit the achievable range of one or more measured flight parameters. Such functions are typically implemented by control laws in an electronic flight control system. Envelope Protection Functions are intended to reduce the likelihood of excursions, either commanded or uncommanded, to unintended or potentially hazardous aircraft operating states. As a consequence of preventing excursions, these functions can also restrict aircraft maneuver capability and introduce non-traditional behavior. The purpose of § 25.144 is to ensure that EPFs support safe operation and do not interfere with required maneuvering in normal and emergency operations and forseeable

atmospheric conditions. The description above refers to "measured flight parameters" because EPFs typically rely on closed-loop control of one or more flight parameters that may be measured directly or inferred from other measurements. In general, any flight control function that limits one or more flight parameters to a smaller range than would be achieved by traditional usage of the control surfaces should be considered an Envelope Protection Function. For example, a maneuver-command control law such as a g-command law may act as an EPF if the maximum command is less than the aircraft capability in some conditions. However, control laws or devices that simply limit control authority as a function of flight condition (such as rudder ratio changers, elevator travel limits or hinge moment limiters) and depend on aerodynamic stability to limit parameter excursions are generally not considered EPFs even if they are implemented as an element of an electronic flight control system.

(b) <u>Overrideability of Envelope Protection Functions by Pilot Force Input.</u> EPFs may be non-overrideable (also called an envelope limiting function), meaning that the pilot cannot command the aircraft beyond the parameter limit regardless of how much force is applied to the primary controller for that axis; or overrideable, meaning that while the function is intended to deter the pilot from commanding the aircraft beyond the parameter limit, a pilot input of sufficiently large force on the primary controller for that axis can command the aircraft beyond the parameter limit. Whether a particular EPF should be non-overrideable depends on the flight parameter being protected, and how rapidly the aircraft could enter a potentially unsafe flight condition due to intuitive but possibly inappropriate pilot action. High-angle of attack limiting functions (HALF) that are used for compliance with § 25.202 must be non-overrideable to successfully demonstrate the maneuvers specified by that regulation. Maneuver protection functions (i.e. load factor limiting) must be non-overrideable if the protection function is used to show compliance to § 25.143(g) in lieu of sufficiently large controller force characteristics, or is used to establish a reduced structural design load factor per § 25.337(d). Overrideability considerations for some other protection functions are addressed on a case-by-case basis in Paragraph 20.g.(2) below.

(c) <u>Disconnect of Envelope Protection Functions</u>. If the capability is provided to disconnect any or all EPFs by means of a switch(es) or similar device, that means should not be associated with the primary controller(s) for the flight parameter in question, and should not be likely to be invoked intuitively by the pilot in event the envelope protection limit is encountered.

(d) <u>Use of Simulation for Evaluation</u> In some situations it is appropriate to use a suitable flight simulation to demonstrate the function of an EPF, particularly for situations that are difficult to demonstrate in flight, such as performance in large atmospheric disturbances, or when a flight test could be hazardous. The guidance in Paragraph 3.a.(1)(f) regarding characteristics of a suitable simulation should be followed for simulation evaluations used to show compliance to § 25.144.

(2) <u>Maneuverability in the Presence of Envelope Protection Functions - § 25.144(a).</u>

<u>(a) General</u> § 25.144(a) states that "Envelope protection functions must not unduly limit the maneuver capability of the aircraft nor interfere with its ability to perform maneuvers required for normal and emergency operations." Guidance is provided below for evaluating envelope protection functions (EPFs) for several flight parameters, namely normal load factor, roll and pitch attitude, and high airspeed. Additional regulations applicable to high angle of

attack limiting functions are provided in § 25.202 and § 25.204; associated guidance material is included in Paragraph 29. In addition to the guidelines presented in this section, a qualitative assessment of aircraft maneuverability and dynamic response in the presence of EPFs should be performed by pilot evaluation of handling qualities throughout flight test, including conditions showing compliance to the general requirements of § 25.143(a). EPFs should not interfere with maneuver capability required for safe operation during emergency and non-normal maneuvers such as emergency descent, aborted landings, collision avoidance, terrain avoidance, Means of showing compliance for emergency maneuvers is discussed in Section g.(2)(f) of this paragraph. Effect of EPFs on control during atmospheric disturbances and recovery from windshear is addressed by § 25.144(d), with guidance provided in Paragraph 20.g.(5) of this paragraph.

(b) <u>Normal Load Factor Protection</u>

1 <u>Explanation.</u>

(aa) General. This guidance applies to aircraft employing control laws and protection functions that command and regulate pitch maneuver capability. Control laws or devices that simply limit pitch control authority as a function of flight condition (such as elevator travel limits or hinge moment limiters) and depend on aerodynamic stability to limit load factor excursions are generally not considered normal load factor protection functions. There is no requirement that a pitch maneuver command function must limit the achievable load factor to less than structural limits; however, if a maneuver command limit (i.e., a normal load factor protection function) is used to provide compliance with § 25.143(g) in lieu of suitably high pitch controller forces, the load factor protection function must not be overrideable by pilot force, and the function should have suitable reliability as discussed in Paragraph 20.e(2)(a). Control laws that regulate normal load factor are likely to also affect achievable pitch rate and/or g rate. Pitch up and pitch down response must be satisfactory while initiating and recovering from aggressive pitch maneuvers

(bb) Positive Load Factors. Unless positive maneuver capability is limited by airframe characteristics (e.g. wing lift, deterrent buffet, or pitch control power), or by other protection functions that serve specific flight characteristics design purposes (e.g., high-angle-of-attack protection or pitch attitude protection), the positive load factor command limit with the flight controls operating normally and the airplane in its normal trim state for the flight condition should not be less than:

2.5 g with the high-lift devices retracted, and

2.0 g with the EFCS functioning in its normal mode and with the high-lift devices extended.

A reduced positive limiting load factor that decreases gradually from 2.5 g at Vmo/Mmo to 2.25 g at Vd/Md has been considered acceptable on aircraft with negative pitch attitude protection and high-speed protection, provided it does not hinder overspeed recovery (§ 25.335b(1)).

(cc) Negative Load Factor. Unless negative maneuver capability is limited by airframe characteristics (e.g. wing lift, deterrent buffet, or pitch control power), or by other protection functions that serve specific flight characteristics design purposes (e.g., high speed protection, low-angle-of-attack protection or pitch attitude protection), the negative limiting load factor command with the EFCS functioning in its normal mode should be equal to or more negative than:

-1.0 g with the high-lift devices retracted; or

0 g with the high-lift devices extended.

Maximum negative load factor command may be further limited by flight control system characteristics or flight envelope protections, provided that:

pitch down responsiveness is satisfactory, and

from trimmed level flight, 0 g can be commanded or a satisfactory trajectory change is readily achievable at operational speeds.

It has also been considered acceptable for the control law to initially restrict negative load factor to approximately 0 g with high-lift devices retracted to reduce the risk of inadvertent brief negative-g maneuvers, with the load factor limit increasing gradually to approximately -1.0 g within a reasonable time.

2 Procedures.

(aa) Positive Load Factors. Compliance for positive load factor command capability may be shown in a pullup or in turning flight, at a speed/weight/cg combination at which the specified load factor is achievable, supported by design review of the control law to show that it does not limit inappropriately at other conditions. A pullup may be initiated from a pushover or descent condition to avoid excessive positive pitch attitudes during the pullup. If a turning maneuver is used to demonstrate maneuver command capability, pitch response in a pullup should be shown to be acceptably prompt.

(bb) Negative Load Factors. Compliance for negative load factor limits may be shown in a pushover to 0 g at a weight/speed/cg combination at which the aircraft is capable of achieving that load factor, supported by design review of the control law to show that it does not limit inappropriately at other conditions. The pushover may be initiated from a pullup or climb condition to avoid excessive negative pitch attitude and potential overspeed.

(c) Pitch Attitude Protection

1 Explanation.

(aa) General. Pitch attitude limits may be employed to protect the aircraft from achieving attitude states that could lead to undesired changes in airspeed or energy or could contribute to pilot disorientation. Pitch attitude protection may also be used in concert with other protection functions such as high angle of attack protection or high speed protection to achieve a flight characteristics objective. There is no requirement that pitch attitude protection be provided, but if it is provided, it should not interfere with the airplane's ability to perform maneuvers required for normal and emergency operations. This guidance is provided in support of the requirement of 25.144(a) to "not unduly limit" airplane capability, and is not intended to evaluate how well a pitch attitude limiting function serves its intended function of protection against undesired changes in energy. Non-interference of pitch attitude protection can generally be evaluated in the course of showing compliance to other Subpart B requirements, although it may be necessary to consider conditions that result in extremes of pitch attitude in addition to the typical conditions that result in extremes of performance or other flight characteristics. Inservice experience with pitch limit values on similar aircraft may be considered in establishing acceptable limit values.

(bb) Positive Attitudes. A pitch attitude protection function should not impede

attaining positive (nose-up) pitch angles up to the maximum required for normal maneuvering, including a normal all-engines operating takeoff or go-around, plus a suitable margin to allow for satisfactory speed control. Pitch attitude protection should not prevent attaining the pitch attitude necessary for emergency maneuvering such as terrain avoidance and collision avoidance. The possible effects of pitch attitude limiting on windshear escape and atmospheric disturbances are addressed under § 25.144(d). If pitch attitude protection is available on or near the ground, it should not interfere with adequate pitch control during takeoffs and landings, including aborted landings.

(cc) Negative Attitudes. A pitch attitude protection function should not impede attaining negative pitch attitudes required for normal operations nor interfere with recovery from high angle of attack, collision-avoidance capability, or with attaining and maintaining speeds appropriate for emergency descent plus a suitable margin for speed control.

2 Procedures.

(aa) Positive Attitudes. Demonstrations of aircraft employing pitch attitude protection functions need to show that the function does not interfere with normal operation, including normal all-engines takeoff and go-around. A takeoff and climb should be demonstrated in the condition that results in the smallest margin between climbout attitude and the pitch attitude limit, typically a high T/W condition. If takeoff procedures call for establishing a target speed during climb, an acceptable means to show that the pitch attitude margin allows for satisfactory speed control is to demonstrate the ability to change speed approximately 5 kt below the target speed without changing thrust. If takeoff procedures for some conditions (typically high T/W) involve targeting or not exceeding a specific pitch attitude, it is sufficient for those conditions to demonstrate a takeoff that achieves the specified target attitude and show that the margin between the target atttude and the pitch attitude limit allows for adequate flight path control. Similarly, acceptable speed control or nose-up attitude control during a go-around should be demonstrated with the configuration that results in the smallest pitch attitude margin using recommended go-around procedures. If it is not practical to demonstrate the critical cases for takeoff or go-around in flight due to limitations on minimum weight of the test article, a flight demonstration should be performed as close as practical to the critical case, and a simulator evaluation should be performed at the critical condition. Analysis may be used in lieu of flight or simulator demonstration if it can be shown that the margin between airplane attitude and the pitch attitude limits are clearly large enough to ensure no interference with normal operation in the maneuvers described above, including allowance for speed control and flight path control. The effect of pitch attitude limits on takeoff flare and landing flare will generally be assessed adequately during normal and abuse takeoff and landing conditions performed to show compliance with other Subpart B requirements. Means of showing non-interference in wind shear is discussed in Section (d) of this paragraph.

(bb) Negative Attitudes. It should be shown that normal and emergency operations are not impeded by a negative pitch attitude limit. The condition that typically requires the greatest nose-down attitude is an idle descent with speedbrakes deployed at light weight at Vmo/Mmo. If an alternate speed or target attitude is recommended for emergency descent the evaluation may be performed at that speed/attitude. It should be possible to perform this task with a suitable pitch attitude margin remaining for speed or flight path control. Compliance may be shown by analysis if the margin between the limit and the attitude required to perform the

descent is sufficiently large. If a flight demonstration is employed, this evaluation may require a dedicated condition at light weight since the critical condition for showing compliance with emergency descent cabin pressure regulations is typically at heavy weight. Flight at Vfe with landing flaps, gear down, idle thrust at light weight could result in negative pitch attitudes and should be considered; suitable maneuverability should be available consistent with § 25.143(a). Possible effects of negative pitch attitude protection during recovery from high angles of attack should be evaluated during tests performed to show compliance with § 25.145(a). It is acceptable for pitch attitude protection to be active during the recovery provided the acceleration to trim speed is judged to be prompt. Collision avoidance capability can be established as part of the general maneuverability assessments of § 25.143(a).

(d) Roll Attitude Protection

1 Explanation. Roll attitude protection may be employed to reduce the risk of unintended or excessive roll excursions, possibly due to pilot disorientation or atmospheric disturbances. However, roll attitudeprotection must not interfere with the pilot's ability to perform reasonably rapid changes in flight path. This guidance is provided in support of the requirement of 25.144(a) to "not unduly limit" airplane capability, and is not intended to evaluate how well a roll attitude protection function serves its intended function of protection against excessive roll excursions.

(aa) Roll attitude limits of approximately 66 deg flaps up within the Vmo/Mmo boundary and approximately 60 deg flaps down have been considered acceptable. These bank angles correspond to steady turns of 2.5 g and 2.0 g, respectively. It should be possible to achieve these roll angles without requiring excessive pilot skill or strength. A modest reduction in roll attitude limit at high angle of attack and at speeds above Vfc/Mfc has been considered acceptable, as discussed in (bb) and (cc) below.

(bb) A reduced roll attitude limit has been accepted at high angle of attack conditions to provide protection against low speed roll. The aircraft should be able to perform coordinated turns as per § 25.143(h). A roll attitude limit of approximately 45 degrees at high angle of attack conditions has been considered acceptable.

(cc) A reduced roll attitude limit has been considered acceptable beyond the overspeed warning to provide protection against high-speed combined pitch and roll upsets. The aircraft should be able to perform operational turns at these speeds. A roll attitude limit of approximately 30 degrees at Vdf/Mdf has been considered acceptable.

2 Procedures. Compliance with the requirement that a roll attitude protection function not interfere with required operations can be shown by demonstrating that the airplane can achieve the roll attitudes identified in Section g.2.(d)1 above without undue pilot effort. This can typically be achieved during maneuvers (windup turns or steep turns) performed to show maneuver characteristics, or during maneuvers performed to demonstrate load factor command limits described above in Section 20.g.2.(b)2(aa). Non-interference of roll attitude limits should be demonstrated in flight in each configuration or flight regime that invokes a different limit. A reduced roll attitude limit that may be utilized at high angle of attack can be judged not to interfere with operations by showing compliance with § 25.143(h) and with stall characteristics or

high-angle-of-attack characteristics requirements as appropriate.

(e) High Speed Protection

1 Explanation.

(aa) The High-Speed Protection Functions (HSPF) addressed in this section are intended to provide protection from excursions beyond the normal speed (or Mach) envelope due to an atmospheric disturbance, flight path upset, trim shift, or inadvertent pilot input. While the intent of an HSPF is to limit speed excursions, it should not interfere with normal or emergency operations near Vmo/Mmo nor cause difficulty in controlling the aircraft for larger speed excursions.

(bb) An HSPF should not impede attainment of speeds anticipated in normal operation or impede the pilot's ability to easily maintain flight path in the presence of modest speed excursions beyond Vmo/Mmo. Activation of the HSPF associated with modest excursions beyond Vmo/Mmo due to pilot inputs or atmospheric upsets should come in smoothly and the flight path should be easily controlled. Demonstrating controllability during a speed excursion to overspeed warning is generally considered sufficient to show compliance. It should also be ensured that an HSPF does not interfere with performing an emergency descent procedure.

2 Procedures.

(aa) To demonstrate that the HSPF does not interfere during modest speed excursions beyond Vmo/Mmo, it is sufficient to trim the airplane near Vmo/Mmo, accelerate out to the overspeed warning, stabilize briefly at that speed, then return smoothly to within the Vmo/Mmo boundary. Speed may be changed either by altering thrust while maintaining altitude or by initiating a mild descent to increase speed and a mild climb if necessary to recover to Vmo/Mmo. It should be possible for the pilot to maintain the desired flight path (either level flight or constant descent profile) without significant effort. If the aircraft flight envelope is limited by Mach number at high altitude, this evaluation should be performed in both the Mach-limited regime and also at a lower altitude in the speed-limited regime. Since the HSPF behavior is largely determined by the control law, not aerodynamic characteristics, it is sufficient to perform this demonstration at a representive en-route weight and cg.

(3) Onset Characteristics - § 25.144(b)

(a) Explanation. § 25.144(b) says "Onset characteristics of each envelope protection function must be appropriate to the phase of flight and type of maneuver, and must not conflict with the ability of the pilot to satisfactorily control the airplane flight path, speed, or attitude." The intent of § 25.144(b) is to ensure that when envelope protection functions become active they do not create undesirable or unexpected handling qualities that interfere with the pilot's ability to perform tasks that involve controlling the aircraft in proximity to the onset point or the limit.

(b) Procedures. Flight test conditions should be demonstrated that involve approaching each limit in a fashion that allows the pilot to assess the handling and control characteristics associated with onset of the function. In most cases this may be done in conjunction with other required testing; for example, onset characteristics of a high angle-of-attack limiting function may be evaluated during the demonstrations of § 25.202; onset characteristics of a roll attitude limit may be evaluated during the demonstration of maneuver characteristics under § 25.143(g), and onset characteristics of a high-speed protection function may be evaluated during evaluation of high speed characteristics under § 25.253. If the limits are set at a position that is not approached during normal certification demonstrations it is acceptable to adjust the limit so the onset characteristics can be safely demonstrated in flight, or to show the characteristics in a simulator with the limits set to the normal position.

(4) Margin to Unsafe Characteristics - § 25.144(c)

(a) Explanation. § 25.144(c) states "Excursions of a limited flight parameter beyond its nominal design limit value due to dynamic maneuvering, airframe and system tolerances, and non-steady atmospheric conditions must not result in unsafe flight characteristics or conditions." If an envelope protection function serves to prevent the aircraft from reaching a flight condition that could result in unknown or potentially unsafe flight characteristics, the applicant should show that the performance of the function is sufficient to prevent excursion to a potentially unsafe regime as a result of foreseeable aircraft dynamics, non-steady atmospheric conditions, and system tolerances, in any appropriate combination. This regulation addresses flight characteristics and therefore primarily applies to parameters where aerodynamic characteristics may change significantly for moderate variations in the parameter beyond the limit. Such parameters may include angle of attack and airspeed/Mach number.

(b) Procedures. For an airplane with a high angle of attack limiting function that complies with §§ 25.202 and 25.204, the demonstrations that show compliance with those regulations address the effects of dynamic maneuvers, tolerances, and atmospheric disturbances, and are considered sufficient to satisfy 25.144(b). For an airplane utilizing a high speed protection function, the demonstrations showing compliance to §§ 25.253 and 25.255 at Vdf/Mdf address controllability in the presence of excursions of airspeed and Mach beyond the steady limit values due to dynamics and atmospheric conditions or upsets, and are considered sufficient to satisfy 25.144(b).

(5) Operation in Atmospheric Disturbances and Windshear- § 25.144(d)

(a) Explanation. § 25.144(d) states "Operation of envelope protection functions must not adversely affect aircraft control during expected levels of atmospheric disturbances, nor impede the application of recovery procedures in case of wind-shear." This regulation differs from § 25.144(c) in that (c) specifically addresses characteristics associated with parameter excursions beyond the nominal limit, whereas (d) addresses the potential interference with normal control tasks caused by activation of the EPF due to atmospheric disturbances in conditions where it would not normally be active. Adverse interaction with envelope protection functions is most likely to occur when the airplane is operated in proximity to a protection boundary such as an angle-of-attack limit or a high speed protection limit. These effects should be evaluated in "heavy turbulence". Since it is not practical to find such conditions during a flight test program, the evaluation should be done in an appropriate flight simulator. Evaluation of protection functions in wind shear is called out specifically because wind shear escape procedures typically involve operating at relatively high angle-of-attack. The wind shear profiles described in AC120-41 or another acceptable model may be used for the purpose of showing compliance to this regulation. Additional guidelines for showing compliance with the effect of turbulence on the performance of a high angle-of-attack limiting function are presented in Paragraph 29.d.(3) of this document in conjunction with the means of compliance for § 25.202 and § 25.204.

(b) Procedure.

1 The behavior of the airplane in heavy turbulence in operational tasks should be demonstrated in flight or in an appropriate means of simulation or analysis using an adequate turbulence model If high angle of attack protection is present, suggested evaluation tasks involve a simulated engine-out takeoff at heavy weight, and an approach and landing at the minimum approach speed appropriate for the level of turbulence, including a 30 deg banked turn. If high speed protection is present the suggested task is a descent at Vmo/Mmo. Obviously the turbulence itself increases the difficulty of the task. The standard for evaluation is that when the airplane is operated in turbulence, the EPFs do not introduce unexpected behaviors or create undue difficulty in controlling the flight path. Analysis may be used in lieu of flight test or piloted simulation if the margin to activation of an EPF is sufficiently large that the EPF will not become active due to turbulence in relevant tasks.

2 The effect of EPFs in windshear escape should be evaluated in an appropriate flight simulator using the wind shear profiles described in AC120-41 or another acceptable model. These evaluations may be conducted at the same time as evaluations of windshear warning and guidance systems. The airplane configuration and flight condition should be selected with consideration of what is most likely to cause an adverse effect of envelope protection. This configuration or condition may be different from the critical condition required to evaluate other aspects of the windshear warning and guidance system, in which case the evaluation may need to be repeated specifically to assess the EPF. It is acceptable for EPFs to be active during the maneuver, but the resultant airplane performance must be acceptable.

(6) Priority and Interaction of Protection Functions- § 25.144(e)

(a) Explanation. § 25.144(e) states "Simultaneous action of envelope protection functions must not result in adverse coupling or adverse priority." EFCS control laws may regulate multiple parameters during a maneuver, introducing the potential of inappropriate priority or undesired interaction among protection functions or between protection functions and other control law functions. In showing compliance to § 25.144(e) the applicant must show that the EPFs are prioritized or coordinated so simultaneous action of EPFs results in the proper priority of functions and does not cause hazardous or confusing behaviors. § 25.144(e) is specifically intended to address cases where multiple protection functions are at or near their limits at the same time, particularly if the actions are potentially in conflict. Cross-axis effects should be considered when applicable. It is also essential that envelope protection functions not display adverse interactions or inappropriate priority with other flight control functions such as basic command augmentation or load relief functions. However, these types of interactions are likely to be observed during the basic evaluations of each protection function and are not the subject of § 25.144(e).

(b) Procedures. The applicant should identify through design review if there are any conditions where multiple protection functions could be active, particularly if they are in conflict,

and should explain the prioritization scheme employed in these situations. Airplane behavior should be demonstrated for representative scenarios if envelope protection functions could be in conflict or have potentially undesired interaction. The demonstration may be performed in an appropriate flight simulation. The behavior of the airplane should be conducive to the pilot retaining control and retreating safely from the limits.

(7) Excursions Beyond Protected Boundaries- § 25.144(f)

(a) Explanation. § 25.144 (f) states " In case of abnormal attitude or excursion of any flight parameters outside the protected boundaries, the operation of the EFCS, including the automatic envelope protection functions, must not hinder airplane recovery." This regulation is intended to ensure that the design of an EFCS and any envelope protection functions consider the possibility that the airplane could experience excursions well beyond the intended operating regime due to unforseen events. The full range of potential pilot inputs or strategies for recovery should be considered. It should be shown that for aircraft states well beyond the protection boundaries, the aircraft will either respond in a conventional manner to large pilot inputs, or will recover automatically to within the protected envelope regardless of pilot input.

(b) Procedure. For every protected parameter, an excursion well beyond the protection boundary should be considered. Compliance to § 25.144(f) may be shown by a design review of the control law behavior in these conditions.

21. Longitudinal Control - § 25.145.

a. Explanation.

(1) Section 25.145(a) requires that there be adequate longitudinal control to promptly pitch the airplane nose down from at or near the stall**, or the angle of attack achieved at full aft control input (the AOA limit) when a High Angle-of-Attack Limiting Function is installed and compliance is shown with §§ 25.202 and 25.204,** to return to the original trim speed. The intent is to ensure that there is sufficient pitch control for a prompt recovery if inadvertently slowed **to the minimum achievable airspeed, including** to the point of stall **identification if normally achievable**. Although this requirement must be met with power off and at maximum continuous thrust or power, there is no intention to require stall demonstrations with thrust or power above that specified in § 25.201(a)(2). Instead of performing a full stall at maximum continuous power or thrust **with airplanes for which compliance is shown to § 25.207**, compliance **with § 25.145(a)** may be assessed by demonstrating sufficient static longitudinal stability and nose down control margin when the deceleration is ended at least one second past stall warning during a one knot per second deceleration. The static longitudinal stability during the maneuver and the nose down control power remaining at the end of the maneuver must be sufficient to assure compliance with the requirement.

(2) Section 25.145(b)
[No Change]

(3) Section 25.145(c)
[No Change]

(4) Section 25.145(d)
[No Change]

b. Procedures. The following test procedures outline an acceptable means for demonstrating compliance with § 25.145. These tests may be conducted at an optional altitude in accordance with § 25.21(c). Where applicable, the conditions should be maintained on the engines throughout the maneuver.

(l) Longitudinal control recovery, § 25.145(a).

(a) Configuration:

1 Maximum weight, or a lighter weight if more critical.

2 Critical c.g. position.

3 Landing gear extended.

4 Wing flaps retracted and extended to the maximum landing position.

5 Engine power or thrust at idle and maximum continuous.

(b) Test procedure: The airplane must be trimmed at the speed for each configuration as prescribed in § 25.103(b)(6). The airplane should then be decelerated at 1 knot per second with wings level. For tests at idle power or thrust, the applicant must demonstrate that the nose can be pitched down from any speed between the trim speed and the stall **identification or the AOA limit if a High Angle-of-Attack Limiting Function is installed and compliance is shown with §§ 25.202 and 25.204**. Typically, **with airplanes for which compliance is shown to § 25.201,** the most critical point is at the stall when in stall buffet. The rate of speed increase during the recovery should be adequate to promptly return to the trim point. Data from the stall characteristics testing **(§25.201) or high AOA handling demonstrations (§25.202), as appropriate,** can be used to evaluate this capability. For tests at maximum continuous power or thrust, the maneuver need not be continued for more than one second beyond the onset of stall warning **with airplanes for which compliance is shown to § 25.207**. However, the static longitudinal stability characteristics during the maneuver, and the nose down control power remaining at the end of the maneuver, must be sufficient to assure that a prompt recovery to the trim speed could be attained if the airplane is slowed to the point of stall **identification**.

(2)-(4) [No Change]

(5) Longitudinal control, airspeed variation, § 25.145(b)(6).

(a) Configuration:

1 Maximum landing weight or a lighter weight if considered more critical.

2 Most forward c.g. position.

3 Wing flaps extended to the maximum landing position.

4 Landing gear extended.

5 Engine power or thrust at flight idle.

(b) Test Procedure: The airplane must be trimmed at a speed of 1.3 V_{SR}. The speed should then be reduced to V_{SW}**, or to the higher airspeed of V_{REF} - 5 knots CAS and the minimum airspeed free of a caution or warning alert in accordance with § 25.1322 if a High Angle-of-Attack Limiting Function is installed and compliance is shown with §§ 25.202 and 25.204. The airspeed should then be** increased to 1.6 V_{SR}, or the maximum flap extended speed, V_{FE}, whichever is lower. The longitudinal control force must not be greater than 50 lbs. Data from the static longitudinal stability tests in the landing configuration at forward c.g., § 25.175(d), may be used to show compliance with this requirement.

(6)-(7) [No Change]

Section 5. Stability

26. Static Longitudinal Stability and Demonstration of Static Longitudinal Stability - §§ 25.173 and 25.175.

a. Explanation.

(1) Section 25.173 - Static Longitudinal Stability.

(a) Compliance with the general requirements of § 25.173 is determined from a demonstration of static longitudinal stability under the conditions specified in § 25.175.

(b) The requirement is to have a pull force to obtain and maintain speeds lower than trim speed, and a push force to obtain and maintain speeds higher than trim speed. There may be no force reversal at any speed that can be obtained, except lower than the minimum for steady, unstalled flight or, higher than the landing gear or wing flap operating limit speed or V_{FC}/M_{FC}, whichever is appropriate for the test configuration. The required trim speeds are specified in § 25.175.

(c) When the control force is slowly released from any speed within the required test speed range, the airspeed must return to within 10 percent of the original trim speed in the climb, approach, and landing conditions, and return to within 7.5 percent of the trim speed in the cruising condition specified in § 25.175 (free return).

(d) The average gradient of the stick force versus speed curves for each test configuration may not be less than one pound for each 6 knots for the appropriate speed ranges specified in § 25.175. **This average slope is intended to be assessed within the speed range before any included envelope protections or low/high speed cueing functions engage, if they increase the apparent speed stability of the airplane above that provided within the normal operational speed range.** Therefore, after each curve is drawn, draw a straight line from the intersection of the curve and the required maximum speed, **or the maximum speed before a high speed protection or cueing function engages,** to the trim point. Then draw a straight line from the intersection of the curve and the required minimum speed**, or the minimum speed before a low speed protection or cueing function or High Angle-of-Attack Limiting Function engages,** to the trim point. The slope of these lines must be at least one pound for each 6 knots. The local slope of the curve must remain stable for this range.

(2) Section 25.175, Demonstration of Static Longitudinal Stability, specifically defines the flight conditions, airplane configurations, trim speed, test speed ranges, and power or thrust settings to be used in demonstrating compliance with the longitudinal stability requirements.

b. Procedures.

(1) Stabilized Method.

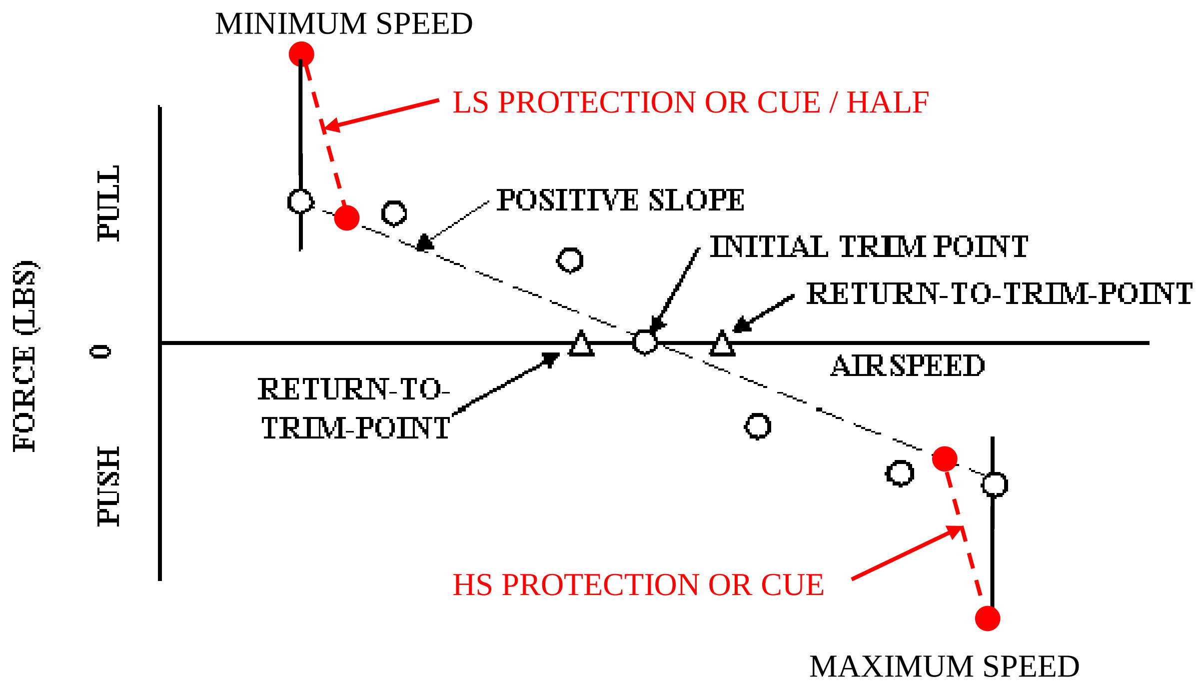
[No Change]

(2) Acceleration-Deceleration Method.

[No Change]

(3) The resulting pilot longitudinal force test points should be plotted versus airspeed to show the positive stable gradient of static longitudinal stability and that there are no “local” reversals in the stick force vs. airspeed relationship over the range of airspeeds tested. **The average slope should be shown for the speed range up to the point at which any included envelope protection or cueing functions engage, if they increase the apparent speed stability of the airplane above that provided within the normal operational speed range.** This plot should also show the initial trim point and the two return-to-trim points to evaluate the return-to-trim characteristics (see Figure 26-1).

Figure 26-1. Longitudinal Static Stability



(4) [No Change]

Section 6. Stalls

Para 29. Stall Testing.

a. The applicable Code of Federal Regulations (CFR) are as follows:

Section 25.21(c) Proof of Compliance
Section 25.103 **Reference** Stall Speed
Section 25.143 Controllability and Maneuverability (General)
Section 25.201 Stall Demonstration
Section 25.202 Handling demonstrations for high angle-of-attack limiting functions
Section 25.203 Stall Characteristics
Section 25.204 Flight characteristics for high angle-of-attack limiting functions
Section 25.207 Stall Warning

b. Explanation.

(1) The purpose of stall **or high angle-of-attack** testing is threefold:

(a) To define the reference stall speeds and how they vary with weight, altitude, and airplane configuration.

(b) To demonstrate that handling qualities are adequate to allow a safe recovery from the highest angle-of-attack attainable in normal flight ~~**(stall characteristics)**~~.

(c) **When stall warning is required, to** determine that there is adequate pre-stall warning (either aerodynamic or artificial) to allow the pilot time to recover from any probable high angle-of-attack condition without inadvertently stalling the airplane.

(2) During this testing, the angle-of-attack should be increased at least to the point where **either, (a)** the behavior of the airplane gives the pilot a clear and distinctive indication through the inherent flight characteristics or the characteristics resulting from the operation of a stall identification device (e.g., a stick pusher) that the airplane is stalled**, or (b) the airplane has reached a stabilized flight condition at the AOA-limit with the longitudinal control at the aft stop with a High Angle-of-Attack Limiting Function (HALF) installed. In addition, if compliance is to be shown to §§ 25.202 and 25.204 in lieu of §§25.201 and 25.203 with a HALF installed, high angle of attack testing beyond the AOA-limit up to the angle of attack corresponding to V_{SR} or the peak angle of attack achieved during dynamic maneuvers to the AOA-limit is required with the High Angle-of-Attack Limiting Function deactivated or adjusted, at the option of the applicant.**

c. Stall Demonstration - § 25.201.

(1) [No change]

(2) [No change]

d. Handling demonstrations for high angle-of-attack limiting functions - § 25.202.

If a High Angle-of-Attack Limiting Function (HALF) is installed that meets the capability and reliability requirements of § 25.202(a), the applicant may choose to show compliance with § 25.202 in lieu of § 25.201.

(1)§ 25.202(a)(1) requires consistent application of the alternative requirements of §§ 25.202 and 25.204 for HALF equipped airplanes to all normal flap and landing gear configurations. If a HALF is used to prevent stall for any normal flap and landing gear configuration under the criteria of §§ 25.202 and 25.204, the airplane must comply with the requirements of §§ 25.202 and 25.204 in all normal

flap and landing gear configurations up to the maximum altitude approved for flaps down operation. Above these altitudes, the HALF must be shown to prevent stall for flaps and gear up configuration in low entry rate maneuvers up to the maximum altitude expected in operation in accordance with § 25.21(c) as described in paragraph 29h(2)(g) of this AC.

(2) § 25.202(a)(2) requires that the airplane not encounter a stall during the maneuvers prescribed in § 25.202(b)-(d) in icing and non-icing conditions. Airplane behavior that is considered indicative of stall includes:

(a) Abnormal or abrupt nose-up pitching;

(b) Uncommanded nose-down pitching (i.e., not commanded by the pilot or the HALF);

(c) Uncommanded lateral or directional motion; or

(d) Buffeting of a magnitude and severity that would act as a deterrent from completing the specified maneuvers.

(3) § 25.202(a)(3) requires that the airplane be protected from stalling and that the High Angle-of-Attack Limiting Function not adversely interfere with or affect airplane control in expected levels of atmospheric disturbances. Compliance with this requirement can be shown using a combination of piloted simulation evaluations and an evaluation throughout the test program during elevated levels of turbulence and gusts, including crosswind takeoff and landing flight testing. It is not intended that flight testing at the AOA limit be conducted in elevated levels of turbulence or gusts. Instead, simulation evaluations should include assessments of level flight in moderate turbulence to assure that stall AOA is not encountered when operating at an airspeed associated with the AOA limit (full aft control input) or if so equipped; at the minimum airspeed free of a continuous and non-cancellable low speed/energy caution or warning alert in accordance with §25.1322 (or equivalent); or activation of a low speed/energy protection system or high AOA alert (e.g. stick shaker)). §25.202(a)(3) also requires that the airplane be protected from stalling and that the High Angle-of-Attack Limiting Function not impede the application of recovery procedures in case of wind shear. Simulation testing (fixed base is considered sufficient) or suitable engineering analysis with wind-shear encounters during takeoff and landing where the airplane may be flown at, or very near, the AOA limit should also be evaluated to assure the HALF does not adversely interfere with recovery and a stall is not encountered when the recovery is flown in accordance with the applicant's recommended procedure. The wind-shear profiles provided in FAA AC120-41 may be used for this assessment. Alternatively, the maneuvers to the AOA limit for compliance with §25.202(d)(4), including rapid application of go-around thrust for approach and landing configurations (if more critical), can be used to show compliance with the requirements of §25.202(a)(3) in case of wind-shear. In order for these flight test results to be considered acceptable for this purpose, it must be assured that the airplane response to pilot inputs demonstrated during the maneuvers to the AOA limit for compliance with §25.202(d)(4) in still air are representative of the pitch response and AOA control at the AOA limit expected during a wind-shear encounter.

(4) §25.202(a)(4) requires that the HALF be provided and be capable of preventing stall in each abnormal configuration of the high lift system resulting from probable failures (on the order of 1E-5/flt-hr or greater). Improbable failures of the high lift system that would result in the HALF being either ineffective or inoperative would be permissible under the requirement of §25.202(a)(4) and (5), provided that a suitable stall warning is provided that complies with the requirements of §25.207(j).

(5) §25.202(a)(5) establishes the failure probability requirement for a High Angle-of-Attack Limiting Function as improbable. *[Dissenting Opinion (6): Airbus does not concur with inclusion of a failure rate requirement for HALF credit in the regulation. Instead 25.1309 compliance should be sufficient and this guidance should be modified to only refer to 25.1309 compliance for failures of the HALF]* *[Dissenting Opinion (7): TCCA agrees that a failure rate requirement should be included, but does not concur with use of the word "Improbable" or "not more probable than remote". Instead, the numerical failure rate of 1E-5/flt-hr should be included in the regulation. The HALF system is being used to substitute for basic aerodynamic characteristics and 1E-5/flt-hr is considered a rock bottom minimum reliability requirement. The 25.1309 reference for interpretation of "Improbable" and "on the order of" should be removed from the guidance]* **Consistent with §25.1309 criteria, this is interpreted to mean a maximum failure rate on the order of 1E-5/flt-hr or less. In addition, the High Angle-of-Attack Limiting Function and its supporting airplane systems must comply with § 25.1309, consistent with identified hazards for failure of the High Angle-of-Attack Limiting Function appropriate for the airplane.**

~~d~~e. Reference Stall Speed - § 25.103.

(1) Background. Since many of the regulations pertaining to performance and handling qualities specify trim speeds and other variables that are functions of **reference** stall speeds, it is desirable to accomplish the **reference** stall speed testing early in the program, so the data are available for subsequent testing. Because of this interrelationship between the **reference** stall speeds and other critical performance parameters, it is essential that accurate measurement methods be used. Most standard airplane pitot-static systems are unacceptable for stall speed determination. These tests require the use of properly calibrated instruments and usually require a separate test airspeed system.

(2) Configuration.

(a) **~~Stall~~ Reference stall** speeds should be determined for all aerodynamic configurations to be certificated for use in the takeoff, en route, approach, and landing configurations.

(b) The c.g. positions to be used should be those that result in the highest **reference** stall speeds for each weight (forward c.g. in most cases).

(c) Sufficient testing should be conducted to determine the effects of weight on **reference** stall speed. Altitude effects (compressibility, Reynolds Number) may also be considered if credit for variations in these parameters is sought by the applicant. If **reference** stall speeds are not to be defined as a function of altitude, then all **reference** stall speed testing should be conducted at a nominal altitude no lower than 1,500 ft. above the maximum approved takeoff and landing altitude. (See paragraph **~~29d~~29e**(5)(g).)

(3) Procedures.

(a) The airplane should be trimmed for hands-off **straight** flight at a speed 13 percent to 30 percent above the anticipated V_{SR}, with the engines at idle and the airplane in the configuration for which the **reference** stall speed is being determined. Then, using only the primary longitudinal control for speed reduction, maintain a constant deceleration (entry rate) until the airplane **has achieved one of the criteria established by § 25.103(c). The airplane should then be recovered using normal techniques. Engine~~is stalled, as defined in § 25.201(d) and paragraph 29c(1) of this AC. Following the stall, engine~~** power or thrust may be used as desired to expedite recovery.

(b) A sufficient number of **~~stalls~~ maneuvers** (normally four to eight) should be accomplished at each critical combination of weight, altitude, c.g., and external configuration. The intent is to obtain enough data to determine the **reference** stall speed at an entry rate not exceeding 1.0 knot/second. During the maneuver for determining **reference** stall speeds, the flight controls should be operated smoothly in order to achieve good data quality rather than trying to maintain a constant entry rate because experience has shown that adjusting the flight controls to maintain a constant entry rate leads to fluctuations in load factor and significant data scatter.

(c) During the **reference** stall speed testing, the ~~**stall**~~ **flight** characteristics of the airplane must also satisfy the requirements of § 25.203(a) and (b**), or § 25.204(f), as appropriate**.

(d) For airplanes that have stall identification devices for which the angle-of-attack for activation is biased by angle-of-attack rate, some additional considerations are necessary. The **reference** stall speeds are normalized against an average airspeed deceleration rate, as described in paragraph ~~**29d**~~**29e**(5)(e). However, stall identification systems generally activate at a specific angle-of-attack, biased by an instantaneous angle-of-attack rate. Therefore, longitudinal control manipulation by the pilot during the stall maneuver, close to the stall identification system activation point, can advance or delay its activation without appreciably affecting the average stall entry airspeed rate. To minimize scatter in the **reference** stall speed versus entry rate data, the pilot should attempt to maintain a stable angle-of-attack rate or pitch rate (not necessarily a fixed airspeed deceleration rate), until the stall identification system activates. The resulting time-history of angle-of-attack data should be smooth and without discontinuities. A cross plot of airspeed deceleration rate, as defined in paragraph ~~**29d**~~**29e**(5)(e), versus angle-of-attack rate for all related test points, will show the general trend of this relationship for each flap setting. Any points that do not follow this general trend should not be used in establishing the **reference** stall speed.

(4) <u>Thrust Effects on **Reference** Stall Speed</u>.

(a) ~~**Stall**~~**Reference stall** speeds are typically determined with the thrust levers at idle; however, it is necessary to verify by test or analysis that engine idle thrust does not result in appreciably lower **reference** stall speeds than would be obtained at zero thrust. Prior to Amendment 25-108, a negative idle thrust at the stall, which slightly increases stall speeds, was considered acceptable, but applicants were not required to base stall speeds on idle thrust. With the adoption of Amendment 25-108, it became a requirement to base **reference** stall speeds on idle thrust, except where that thrust level results in a significant decrease in **reference** stall speeds. If idle thrust results in a significant decrease in **reference** stall speeds, then **reference** stall speeds cannot be based on more than zero thrust.

(b) To determine whether thrust effects on **reference** stall speed are significant, at least three ~~**stalls**~~ **maneuvers** should be conducted at one flap setting, with thrust set to approximately the value required to maintain level flight at 1.5 V_{SR} in the selected configuration.

(c) These data may then be extrapolated to a zero thrust condition to determine the effects of idle thrust on **reference** stall speeds (see Figure 29-1). If the difference between idle thrust and zero thrust **reference** stall speed is 0.5 knots or less, the effect may be considered insignificant.

[Figure 29-1 no change, not included in this draft]

(d) The effects of engine power on **reference** stall speeds for a turbopropeller airplane can be evaluated in a similar manner. **Reference** ~~**Stall**~~**stall** speed flight tests should be accomplished with engines idling and the propellers in the takeoff position. Engine torque, engine r.p.m., and estimated propeller efficiency can be used to predict the thrust associated with this configuration.

(5) <u>Data Reduction and Presentation</u>. The following is an example of how the data obtained during the **reference** stall speed testing may be reduced to standard conditions. Other methods may be found acceptable.

(a) Record the indicated airspeed from the flight test airspeed system throughout the ~~**stall**~~**maneuver**, and correct these values to equivalent airspeed. Also record load factor normal to the flight path. Typically, the load factor data would be obtained from a sufficient number of accelerometers capable of resolving the flight path load factor. It *may* be possible to obtain acceptable data using one accelerometer aligned along the expected 1-g stall pitch angle. More likely, it will take at least two accelerometers, one aligned along the fuselage longitudinal axis and one aligned at 90 degrees to that axis, as well as a means to determine the angle between the flight path and the fuselage longitudinal axis.

(b) Calculate the airplane lift coefficient (C_L) from the equation given below and plot it as a time history throughout the ~~**stall**~~ maneuver.

$$C_L = \frac{n_{zw}W}{qS} = \frac{295.37 n_{zw}W}{V_e^{\ 2} S}$$

Where:

n_{zw} = airplane load factor normal to the flight path
W = airplane test weight - lbs.
q = dynamic pressure - lbs./ft.2
S = reference wing area - ft.2
V_e = knots equivalent airspeed.

(c) The maximum lift coefficient (C_{LMAX}) is defined as the maximum value of C_L achieved during the ~~**stall**~~ test**. At the option of the applicant this testing need only extend to the angle-of-attack and C_L at which the reference stall speed is to be established, except when a stick pusher is installed where testing should extend to the activation of the stick pusher such that compliance with § 25.103(d) can be shown.** Where the time history plot of C_L exhibits multiple peak values, C_{LMAX} normally corresponds to the first maximum. However, the peak corresponding to the highest C_L achieved may be used for C_{LMAX}, provided it represents usable lift, meaning that it does not occur after deterrent buffet or other stall identification cue (ref. § 25.201(d)). There should also typically be a noticeable break in a plot of the load factor normal to the flight path near the point at which is reached. The analysis to determine should disregard any transient or dynamic increases in recorded load factor, such as might be generated by abrupt control inputs that do not reflect the lift capability of the airplane. The load factor normal to the flight path should be maintained at nominally 1.0 until C_{LMAX} is reached. (See Figure 29-2.) [Figure 29-2 no change, not included in this draft]

(d) Correct the C_{LMAX} obtained for each ~~**stall**~~**maneuver**, if necessary, from the test c.g. position to the targeted c.g. position, and for any thrust effects, using the equation:

$C_{LMAX} = C_{LMAX(\text{test c.g. position})}[1 + (MAC/l_t)(CG_{std} - CG_{test})] - \Delta C_{LT}$

Where:

MAC = Wing mean aerodynamic chord length - inches.
l_t = Effective tail length, measured between the wing 25 percent MAC and the stabilizer 25 percent MAC - inches.
CG_{std} = C.G. position resulting in the highest value of reference stall speed (normally the forward c.g. limit at the pertinent weight) - percent MAC/100.
CG_{test} = Actual test c.g. position - percent MAC/100.
ΔC_{LT} = Change in C_L due to engine thrust (if effect of idle thrust is greater than 0.5 knots in stall speed).

(e) Determine the entry rate, which is defined as the slope of a straight line connecting the **reference** stall speed and an airspeed 10 percent above the **reference** stall speed, for each ~~**stall**~~ test. Because C_{LMAX} is relatively insensitive to ~~**stall**~~ entry rate, a rigorous investigation of entry rate effects should not be necessary.

(f-k) [No change except for paragraph reference corrections and (**i.e.,** a stick pusher) in place of (~~**e.g**~~., a stick pusher) in several places.]

f. <u>Minimum Steady Flight Speed - § 25.103(e)</u>.

(1) <u>Background</u>. With a High Angle-of-Attack Limiting Function (HALF) installed, the one-g minimum steady flight speed, V_{MIN1g}, must be established if it is used to determine compliance with a required performance standard or other requirements demonstrations. Otherwise, determination of V_{MIN1g} is at the option of the applicant. V_{MIN1g} is defined as the minimum calibrated airspeed at which the airplane can develop a lift force (normal to the flight path) equal to its weight, while stabilized the limit angle of attack achieved with the High Angle-of-Attack Limiting Function operating normally. If V_{MIN1g} is to be established, it should be determined by flight test as the final stabilized calibrated airspeed obtained when the airplane is decelerated in straight flight until the longitudinal control is on its stop with the HALF operating normally, in such a way that the entry rate does not exceed 1 knot per second.

(2) <u>Configuration</u>.

(a) One-g minimum steady flight speeds, V_{MIN1g}, must be determined for all aerodynamic configurations for which it is to be used to show compliance with a required performance standard or other requirement (e.g., takeoff, en route, approach, and landing configurations).

(b) The c.g. positions to be used should be those that result in the highest V_{MIN1g} for each weight (forward c.g. in most cases).

(c) Sufficient test data should be available to determine the effects of weight on V_{MIN1g}. Altitude effects (compressibility, Reynolds number) may also be considered if credit for variations in these parameters is sought by the applicant.

(3) <u>Procedures</u>.

(a) V_{MIN1g} should be determined by dedicated flight testing if it is used to determine compliance with a required performance standard or other requirements demonstration. If V_{MIN1g} is not used in this manner, it is acceptable to determine V_{MIN1g} by analysis or simulation, provided it is shown to be conservative by comparison to other flight testing required for compliance with §§ 25.103, 25.202 and 25.204.

(b) The airplane should be trimmed for straight flight at a speed 13 percent (or the minimum trim speed, if higher than 1.13 V_{MIN1g}) to 30 percent above the anticipated V_{MIN1g}, with the engines at idle and the airplane in the configuration for which the minimum flight speed is being determined. Then, using only the primary longitudinal control for speed reduction, maintain a constant deceleration (entry rate) not exceeding 1 knot per second until the longitudinal control reaches the aft stop. The control should be maintained at the aft stop until the airplane has reached a stabilized flight condition from which V_{MIN1g} can be determined. Some airspeed variation while maintaining full aft control may occur and data analysis should be used to establish the one-g minimum steady speed.

(c) The High Angle-of-Attack Limiting Function is expected to provide repeatable minimum steady speeds for a particular flight condition. A sufficient number of maneuvers should be accomplished at each critical combination of weight, altitude, c.g., and external configuration to assure that is the case.

(d) During the minimum steady flight speed testing, the flight characteristics of the airplane must also satisfy the requirements of § 25.204(b).

(4) Data Reduction and Presentation. Analysis to determine the one-g minimum steady flight speed should be conducted in a manner similar to that for the reference stall speeds (Paragraph 29e(5) of this AC).

~~e~~ **g**. Stall Characteristics - § 25.203.

(1) Background. **If a High Angle-of-Attack Limiting Function that meets the requirements of §§ 25.202 and 25.204 is not installed, the stall characteristics requirements of § 25.203 must be met.** To assure a safe and expeditious recovery from an unintentional stall, it should not require any unusual piloting technique to successfully demonstrate compliance with § 25.203, nor should it require exceptional skill or repeated practice by the test pilot. The behavior of the airplane during the stall and recovery must be easily controllable using normally expected pilot reactions.

(2) Configuration.

[No change]

(3) Procedures.

[No change]

h. Flight characteristics for high angle-of-attack limiting functions - §25.204

(1) Background. § 25.204 is applicable in lieu of § 25.203 for airplane designs that include a High Angle-of-Attack Limiting Function that meets the capability and reliability requirements of §25.202(a). It should not require any unusual piloting technique to successfully demonstrate compliance with § 25.204, nor should it require exceptional skill or repeated practice by the test pilot. The behavior of the airplane during the maneuvers to the AOA-limit and recovery must be easily controllable using conventional pilot control inputs.

(2) Configuration.

(a) Characteristics to the AOA-limit should be investigated with wings level and in a 30-degree banked turn as prescribed by § 25.202(b)(c) in all configurations approved for normal operations.

(b) The test configurations should include deployed deceleration devices for all flap positions, unless limitations against the use of those devices with particular flap positions are imposed. 'Deceleration devices' include spoilers used as airbrakes, and thrust reversers approved for inflight use. Demonstrations with deceleration devices deployed should normally be carried out with power or thrust off, except where deployment of the deceleration devices with power or thrust on would likely occur in normal operations (e.g., extended spoilers during landing approach).

(c) Characteristics to the AOA-limit should be investigated with the High Angle-of-Attack Limiting Function operating normally, except with the AOA-limit adjusted to the highest value when considering airframe and system tolerances, unless shown to be insignificant. Any other systems or devices that may alter the behavior of the airplane during the maneuvers should also be in their normal functioning mode, except that automatic thrust increase functions should be disabled as specified in §25.202(b)(1). Unless the design of the airplane's automatic flight control system precludes its ability to operate near the AOA-limit, characteristics should be evaluated when the airplane is flown to the AOA-limit under the control of the automatic flight control system.

(d) Engines idling conditions should be conducted at flight idle for the appropriate configuration. For propeller-driven airplanes, the propeller should be set in the normal low pitch (high r.p.m.) position.

(e) For power-on maneuvers, power or thrust should be set to the value required to maintain level flight at a speed of 1.5 V_{SR} at the maximum landing weight with flaps in the approach position, and the landing gear retracted. The approach flap position referred to is the maximum flap deflection used to show compliance with § 25.121(d), which specifies a configuration in which the reference stall speed does not exceed 110 percent of the reference stall speed for the related landing configuration.

(f) Testing is specified in § 25.202(c) to be conducted at the most adverse c.g. and weights throughout the range to be certified. The design of the High Angle-of-Attack Limiting Function and any pitch axis EFCS control law active prior to engagement of the HALF, may result in a critical weight and c.g. condition not traditionally expected. Sufficient weight and c.g. combinations should be tested to ensure that the airplane is compliant throughout the weight and c.g. envelope to be approved. Alternatively, analysis or simulation that has been shown to be valid may be used to identify critical conditions.

(g) In accordance with the intent of § 25.21(c), characteristics to the AOA-limit must be demonstrated up to the maximum approved operating altitude to determine if there are any adverse compressibility effects on characteristics. *[Dissenting Opinion (8): Airbus does not support this testing and has not been required to do this testing in the past to the AOA limit. Instead, it should be sufficient to conduct maneuvers at high altitude to the AOA limit in wind-up turns to cover the range of Mach numbers, but not necessarily at the max approved altitude.]* **This high altitude assessment is intended to assure that stall is prevented during slow, near 1g decelerations at altitudes up to the maximum approved operating altitude. It is not required that the HALF be evaluated at Mach numbers associated with cruise conditions where an AOA-limit may only be achievable in maneuvering flight at elevated load factor. Tests to the AOA limit should be flown with gear and flaps up at the most adverse c.g. Power or thrust may be set, as required, to maintain approximately level flight and a 1 knot/second deceleration. A slight descent rate is permissible as long as the AOA-limit is achieved at approximately the maximum approved altitude. Characteristics should be checked during wings level and in a 30-degree banked turn maneuvers.**

(h) For abnormal high-lift configurations covered by AFM procedures and where the High Angle-of-Attack Limiting Function remains operational and not annunciated as inoperative, characteristics should be evaluated to the AOA-limit with the wings level in a -1 kt/sec deceleration at idle power or thrust (§25.202(a)(4)). It should be possible to produce and to correct pitch, roll, and yaw by unreversed use of the flight controls, and there should be no uncommanded airplane motions due to aerodynamic flow breakdown. The applicant should also demonstrate that the airplane is safely controllable and maneuverable when flown at the recommended operating speed. Alternatively, if the HALF is disabled or annunciated to the flight crew as inoperative due to an improbable failure that results in an abnormal high-lift condition, compliance with 25.207(j) is required.

(i) Characteristics should be demonstrated with the maximum allowable asymmetric fuel loading unless it can be shown that it will not change the results of the test.

(3) Procedures.

(a) The airplane should be trimmed for hands-off flight at the all-engine minimum normal operating speed appropriate for the configuration (e.g., V_2+10, V_{REF}, 1.23V_{SR}), with the appropriate power or thrust setting and configuration. The airplane should then be accelerated as necessary to a speed that provides an angle of attack sufficiently below the AOA-limit to ensure that a steady rate of speed reduction can be established. Then, using only the primary longitudinal control, establish and maintain a steady deceleration consistent with that specified in § 25.202(d)(1) or (d)(4), as appropriate, until the control

reaches the aft stop (see paragraph 29h(3)(d) below). Recovery to the initial trim airspeed must be possible using normal recovery techniques. No change in power/thrust or pilot selectable trim should be made throughout the deceleration to the AOA-limit and recovery (except as done as part of the HALF robustness maneuvers with application simultaneous go-around thrust or power).

(b) The same trim reference (e.g., 1.23 V_{SR}) should be used for both the reference stall speeds and high angle-of-attack characteristics testing.

(c) During the approach to the AOA-limit, the longitudinal control pull force should increase continuously as speed is reduced from the trimmed speed to the AOA-limit subject to the allowances for neutral speed stability of § 25.176. For rates of entry not more than 1 kt/sec to the AOA-limit, there may be no uncommanded airplane response that would be indicative of aerodynamic stall as required by §25.204(b).

(d) Once the longitudinal control stop is reached, the control must be maintained at the stop until the airplane has reached a stabilized flight condition. This does not require steady level flight, but the angle-of-attack should be shown to remain reasonably steady while on the stop. Some level of residual pitch angle and airspeed variations may persist, but these should not present any indications of stall or any characteristics that would prevent the pilot from maintaining the control at the stop. It also must be shown while at the aft control stop that a satisfactory level of lateral and directional control is available to allow corrections to heading and bank angle (in coordinated flight) while at the AOA-limit. The application of small roll rates (10° of bank left and right at approximately 5°/sec) should also not present any indications of stall or any characteristics that would prevent the pilot from maintaining the control at the stop. (§25.202(d)(2) and §25.204(b)(3)). It must then be possible to recover the airplane to the trim condition through normal recovery techniques and use of the controls (§25.202(d)(3)).

(e) § 25.202(d)(4) requires that the high AOA handling demonstrations of § 25.202(b) and (c) also be shown with increased entry rates up to the maximum practical entry rate. For these maneuvers, some transient degradation in characteristics is acceptable, provided that the airplane does not exhibit hazardous characteristics and it is possible to readily correct any uncommanded response with conventional use of the controls. The maneuvers with increased entry rates up to the maximum practical entry rate are intended to demonstrate the robustness of the High Angle-of-Attack Limiting Function. The maximum practical entry rate can be defined according to the type of aircraft longitudinal controller and the corresponding control force characteristics:

(i) For a conventional control wheel and airplane design that complies with the minimum control force requirements of §25.143(g) as applied to airplanes without load factor limiting (refer to paragraph 20e(2)(b) of this AC) and §25.173(c), entry rates up to 3kt/sec have been found acceptable.

(ii) For sidestick controllers where the airplane design does not comply with the minimum control force requirements of §25.143(g) as applied to airplanes without load factor limiting (refer to paragraph 20e(2)(b) of this AC) or §25.173(c), the maximum practical entry rate has included those resulting from an abrupt longitudinal step input in the sidestick, as limited by the aircraft aerodynamics and/or system characteristics.

(iii) Applications with longitudinal controller types and force levels and/or force gradient schemes different than those described in items (i) and (ii) may choose to substantiate a different maximum practical rate between those specified in items (i) and (ii) through pilot-in-the-loop simulation, by similarity to a previous project, or by flight tests.

[Dissenting Opinion (9): TCCA disagrees with allowing "maximum practical rate" tests to the

AOA limit for any type of sidestick to be conducted using less than an abrupt input to full aft control, regardless of stick force characteristics. TCCA feels that there is not currently sufficient flight test experience with different categories of sidesticks and sidestick forces nor with the minimum force values proposed for compliance with 25.143(g) to provide this alleviation.

[Dissenting Opinion (10): Dassault considers that it is not homogeneous to require a maximum entry rate of 3kt/s for aircraft fitted with a conventional column while "an abrupt step" is required for classical sidesticks. In the first case (conventional column) the guidance defines a maximum reasonable manoeuver whereas in the other case (sidestick) it defines a maximum achievable stick movement. For a 3kt/s deceleration it may take several seconds to reach full stick whereas an abrupt step is achieved in much less than a second, which is significantly different.]

(iv) Maneuvers to demonstrate robustness of the High Angle-of-Attack Limiting Function (HALF) should include:

(A) At the conditions specified in §25.202(b), in wings level and 30 degree banked steady decelerations up to maximum practical rate defined according to (e)(i, ii, iii) above to the aft control stop until the angle-of-attack has reached a maximum and the airplane is shown to be constrained by the AOA limit.

(B) At the conditions specified in §25.202(b), except with the airplane trimmed and thrust set for level flight at 1.3Vsr, slowdown turns to the aft control stop with at least 1.5 g load factor and deceleration rates of at least 2 knots per second. Recovery should be delayed until 3 seconds after achieving the aft control stop.

(C) If dynamic application of go-around thrust combined with the maximum practical entry rate maneuver described in paragraph (A) above could result in a higher peak AOA than that experienced during the maneuvers with constant thrust setting, additional testing should be conducted in all normal approach and landing configurations. The airplane should be initially trimmed for a 3 degree glideslope at normal approach/landing speed. The longitudinal control should then be rapidly applied at a rate consistent with that applied per paragraph (A) above to full aft control input combined with rapid application of go-around thrust at the most critical time from initiation of the maneuver to the time at which the control reaches the aft stop. The maneuver should be continued until conditions noted in paragraph (v) below are achieved or the airplane is shown to be constrained by the AOA limit. The go-around power or thrust setting should be the same as is used to comply with the approach and landing climb performance requirements of § 25.121(d) and the controllability requirements of §§ 25.145(b)(3)-(5) and 25.149(f)(g).

(v) Flight testing of each of the HALF robustness maneuvers described in paragraph (iv) may not be necessary if it can be determined (e.g., by design review, analysis or simulation) that one or more of the maneuvers is less critical than another. The robustness maneuvers may be limited by other factors such as the achievement of unreasonable pitch attitude (e.g., beyond the threshold for unusual attitude primary display cues) or control force levels, or control system imposed pitch limits or pitch rate limits which would prevent continuation of the maneuver.

(f) § 25.204(e) requires that the airplane's response to pilot inputs while trimmed at speeds within the normal flight envelope (down to V_2 and V_{REF} as appropriate) not be unusually damped or sluggish in response. The intent is to assure reasonably expected corrective

inputs to maintain airspeed or landing flare and go-around inputs by the pilot result in acceptable airplane response. This should be evaluated during the increased entry rate maneuvers required by §25.202(d)(4).

(g) § 25.202(e) requires testing be conducted up to the angle-of-attack corresponding to V_{SR} or the maximum angle-of-attack achieved during the dynamic maneuvers of § 25.202(d)(1)-(4), and the resulting characteristics shown to comply with the requirements of § 25.204(f). This is to be done wings-level and in 30 deg banked turns (for non-icing conditions only) with a deceleration from the trim speed of not more than 1 kt/sec, for all flap, landing gear and decelerations device combinations to be approved for operation. At the option of the applicant, this testing may be conducted with the High Angle-of-Attack Limiting Function deactivated (disabled) or adjusted to a higher AOA-limit to allow full development of the angle-of-attack described above in this paragraph. This testing is not intended to evaluate the AOA Limiting Function behavior at this increased AOA, but rather demonstrate that the AOA used to define the reference stall speed and that achieved during highly dynamic maneuvers can be achieved in a slow, steady entry without encountering hazardous or otherwise unacceptable characteristics. As such, airframe or system tolerances need not be considered when conducting this testing.

~~**f**~~**i**. Stall Warning - § 25.207.

(1) Explanation. The purpose of these stall warning requirements is to provide an adequate spread between warning and stall to allow the pilot time to recover without inadvertently stalling the airplane**. If a High Angle-of-Attack Limiting Function (HALF) is installed that meets the requirements of §§ 25.202 and 25.204, the ability to prevent stall has been achieved without the provision of natural or artificial stall warning. As such, compliance with §25.207(a)-(i) is not required for such designs. However, for all failures of the HALF not shown to be extremely improbable, the stall warning requirements of §25.207 (j) must be met following failure of the function.**

(2) Background. [No Change]

(3) Procedures. [No change]

(4) Data Acquisition and Reduction. [No change]

~~**g**~~**j**. Accelerated Stall Warning. [No change]

~~**h**~~**k**. Maneuver Margins. [No change]

~~**i**~~**l**. Additional Considerations for Airplanes Equipped with Stall Identification Systems. [No change]

~~**j**~~**m**. Reliability of Artificial Stall Warning and Stall Identification Systems. Additional guidance material related to the testing and approval of artificial stall warning and stall identification systems is presented in paragraph 228 of this AC.

n. Considerations for Airplanes Equipped with a High Angle-of-Attack Limiting Function. A High Angle-of-Attack Limiting Function (HALF) is a type of Flight Envelope Limiting System that operates directly and automatically on the airplane's flying controls to limit the maximum angle of attack that can be attained to a value below that at which an aerodynamic stall would occur. As such, the system consists of everything from the sensing devices that supply inputs to the system to the activation of the system commands to the cockpit controllers or control surfaces. Section 25.1309(a) requires that such a system, when it is used to show compliance with the high angle-of-attack related requirements, must be designed to perform its intended function under any foreseeable operating condition. Section 25.202(a) requires that the system meet availability requirements as explained in paragraph 29d(5) of this AC. In addition, § 25.207(j) specifies that a satisfactory stall warning "must be provided" for any failures of the HALF that are not shown to be extremely improbable. This regulation not only requires satisfactory stall warning if the HALF fails, but also requires that combined loss of HALF and

an effective stall warning be extremely improbable. *[Dissenting Opinion (11) Boeing and Dassault disagree with proposed guidance that states that in order to certify a HALF system under §25.202 and § 25.204 and 25.207(j), not only must stall warning be provided for failures of HALF that are not extremely improbable, but the regulation "also requires that combined loss of HALF and stall warning be extremely improbable." This interpretation is significantly more stringent than current guidance for stall warning and stall ID functions on conventional aircraft. Boeing understands this guidance to be intended for airplanes that have not demonstrated stall characteristics so that these systems are viewed as replacing aerodynamic characteristics. Boeing feels this interpretation is overly prescriptive and only gives credit for a warning system although good aerodynamic characteristics might be preferable. Alternate means of compliance should be acceptable, such as a stall warning function having sufficient reliability that loss of both HALF and stall warning is "extremely remote" (<10-7/fh), combined with stall characteristics that are shown not to be hazardous (consistent with 25.204(f)(1)-(3)) in the airplane state corresponding to loss of HALF and stall warning; alternatively a low speed alerting function could be provided in event of loss of stall warning..]* **To be acceptable, this stall warning must have the following features:**

(1) Distinctiveness. The stall warning indication must be clear and distinct to a degree that will ensure positive pilot recognition of an impending stall.

(2) Timeliness. For one knot per second entry rate decelerations, the stall warning must begin at a speed with a sufficient margin to allow the deceleration to continue below the stall warning activation speed for the greater of 5 kts or 5% CAS without encountering stall or encountering unacceptable characteristics as defined by § 25.207(j)(4). For turning flight decelerations at entry rates up to 3 kt/sec, the stall warning must begin at a speed with sufficient margin to allow the pilot to prevent stall when the recovery input is initiated not less than 1 second after stall warning activation.

(3) Consistency. The stall warning should be reliable and repeatable. The warning must occur with flaps and landing gear in all normally approved positions in both straight and turning flight (§ 25.207(a)) and should continue throughout the recovery maneuver until the angle-of-attack is reduced to approximately that at which the stall warning was initiated (§ 25.207(j)(3)). The warning may be furnished naturally through the inherent aerodynamic characteristics of the airplane, or artificially by a system designed for this purpose. If artificial stall warning is provided for any airplane configuration, it must be provided for all configurations (§ 25.207(b)).

(4) An artificial stall warning indication that is a solely visual device which requires attention in the cockpit, inhibits cockpit conversation or, in the event of malfunction, causes distraction that would interfere with safe operation of the airplane, is not acceptable.

(5) If the stall warning required by § 25.207(j) is provided by an artificial stall warning system, the effect of production tolerances on the stall warning system should be considered when evaluating the margins required by § 25.207(j)(1).

Section 8. Miscellaneous Flight Requirements

31. Vibration and Buffeting - § 25.251.

a. Explanation.

(1) – (7) [no change]

(8) If a high speed protection function (HSPF) is installed and that function prevents the aircraft from readily achieving the selected VDF/MDF, the HSPF may be adjusted or disabled to permit demonstrations showing compliance to § 25.251(b) provided the aerodynamic configuration of the airplane during the demonstration is the same as would be present if the HSPF were functioning normally. *[See corresponding Dissenting Opinion (14) under Paragraph 32.7.a.(7)(b), § 25.253]*

b. Procedures

(1) [No Change]

(2) Section 25.251(b). The airplane should be flown at V_{DF}/M_{DF} at several altitudes from the highest practicable cruise altitude to the lowest practicable altitude. The test should be flown starting from trimmed flight at V_{MO}/M_{MO} at a power or thrust setting not exceeding maximum continuous power or thrust. The airplane gross weight should be as high as practicable for the cruise condition, with the c.g. at or near the forward limit. In addition, compliance with § 25.251(b) should be demonstrated with high drag devices (i.e., speed brakes) deployed at V_{DF}/M_{DF}. Thrust reversers, if designed for inflight deployment, should be deployed at their limit speed conditions**. A high-speed protection function, if installed, may be adjusted or disabled as discussed in paragraph 31.a.(8) if necessary to permit demonstrations at VDF/MDF.**

(3) – (5) [No Change]

32. High Speed Characteristics - § 25.253.

a. Explanation.

(1) – (6) [No Change]

(7) Considerations for Aircraft Employing a High Speed Protection Function

(a) Some aircraft may utilize a High Speed Protection Function (HSPF) which acts to reduce speed excursions beyond the normal operating envelope. An HSPF is likely to become active during maneuvers described in paragraph 32.c. If an HSPF of suitable availability is installed, the upset maneuvers specified in paragraphs 32.c.(1) through (5) below can be limited to that which is achievable with the HSPF functioning normally and the pilot's pitch control full forward, and a load factor in excess of 1.5 g may be used during recovery if applied automatically by the HSPF with the pilots pitch control at the neutral (zero force) position. *[Dissenting Opinion (12): Load factor during recovery from maneuvers described in 32.c(1)-(5) should be no greater than 1.5 g even with HSPF active because these recoveries are considered to be performed with the pilot in the loop and 1.5 g represents a reasonable manual recovery technique. (FAA, EASA, TCCA, Boeing)]* **For the purposes of compliance with § 25.253, suitable availability of an HSPF means that the probability of loss of the function should be improbable**

(no greater than 10^{-5} per flight hour). *[Dissenting Opinion (13): An availability requirement for HSPF is unnecessary. Failure conditions are adequately covered by 25.1309. (Airbus)]*

(b) An HSPF when functioning normally may, by design, limit the airspeed the airplane can achieve even with full forward pitch control; however, an applicant may choose to demonstrate high-speed flight characteristics at a selected Vdf/Mdf speed higher than can be achieved with full forward pitch control. This might be done in order to meet requirements for margin from Vmo/Mmo to Vdf/Mdf. If an HSPF is installed and an applicant chooses to demonstrate high speed characteristics at a selected Vdf/Mdf that can not readily be achieved with the nominal HSPF settings, the HSPF may be adjusted or disabled to permit achievement of that higher speed for demonstrations of control characteristics and speedbrake extension at Vdf/Mdf showing compliance to § 25.253(a)(3) – (5). The aerodynamic configuration during the demonstration at Vdf/Mdf should be the same as would be present if the HSPF were functioning normally. In this way the underlying aerodynamic control capability and buffet characteristics are demonstrated to Vdf/Mdf. *[Dissenting Opinion (14): The provision to demonstrate characteristics at a speed greater than can be achieved with full forward control is unnecessary and not applicable to aircraft utilizing HSPF, because typically Vdf/Mdf for such aircraft is defined as maximum speed achievable with full forward control. This opinion also applies to the corresponding proposed change in Paragraph 31.a.(8). (Airbus)]* **Demonstrations showing compliance to § 25.253(a)(1) and (2) (handling qualities, speed excursion and load factor control and buffeting during recovery from specified maneuvers) should be performed with the HSPF functioning normally.**

b. Regulations Affected.
[No Change]

c. Procedures. Using the speeds V_{MO}/M_{MO} and V_{DF}/M_{DF} determined in accordance with §§ 25.1505 and 25.251, respectively, and the associated speed margins, the airplane should be shown to comply with the high-speed characteristics of § 25.253. Unless otherwise stated, the airplane characteristics should be investigated beginning at the most critical speed up to and including V_{MO}/M_{MO}, and the recovery procedures used should be those selected by the applicant, except that the normal acceleration during recovery should be no more than l.5 g (total). **The force limits of § 25.143(d) for short term application apply during the recovery. If a high speed protection function as described in paragraph 32.a.(7)(a) is installed, a load factor in excess of 1.5 g may be used during recovery if applied by the automatic function with the pilots pitch control at the neutral (zero force) position**. *[See corresponding Dissenting Opinion (12) in Section 32.a.(7)(a).]* Testing should be conducted with the c.g. at the critical position and generally perpendicular to local wind aloft.

(1) [No Change].

(2) Inadvertent Speed Increase. Simulate an evasive control application when trimmed at V_{MO}/M_{MO}, by applying sufficient forward force to the pitch control to produce 0.5 g (total) for a period of 5 seconds, after which recovery should be initiated ~~**at not more than 1.5 g (total)**~~. **If an HSPF as described in paragraph 32.a.(7)(a) is installed, the aircraft may not be able to maintain 0.5 g for 5 seconds; load factor may be limited to that achieved at full forward control.**

(3) Gust Upset. In the following three upset tests, the values of displacement should be appropriate to the airplane type and should depend upon airplane stability and inertia characteristics. The lower and upper limits should be used for airplanes with low and high maneuverability, respectively.

(a) [No Change].

(b) Perform a longitudinal upset from normal cruise. Airplane trim is determined at V_{MO}/M_{MO} using power/thrust required for level flight but with not more than maximum continuous power/thrust. (If V_{MO}/M_{MO} cannot be reached in level flight with maximum continuous power or thrust, then the airplane should be trimmed at V_{MO}/M_{MO} in as shallow a descent as practicable that allows V_{MO}/M_{MO} to be reached.) This is followed by a decrease in speed, after which a pitch attitude of 6-12 degrees nose down, as appropriate for the airplane type, is attained using the same power/thrust and trim. The airplane is permitted to accelerate until 3 seconds after V_{MO}/M_{MO}. **The force limits of § 25.143(d) for short term application apply. For airplanes equipped with a high speed protection function as described in paragraph 32.a.(7)(a), the nose down pitch attitude is permitted to diminish if it cannot be sustained with the pilot's pitch control full forward.**

(c) [No Change].

(4) Leveling Off from Climb. Perform transition from climb to level flight without reducing power or thrust below the maximum value permitted for climb until 3 seconds after V_{MO}/M_{MO}. **Recovery should be accomplished by applying not more than 1.5 g (total).**

(5) Descent from Mach Airspeed Limit Altitude. A descent should be performed at the airspeed schedule defined by M_{MO} and continued until 3 seconds after V_{MO}/M_{MO} occurs**, at which time recovery should be accomplished without exceeding 1.5 g (total).**

(6) Roll Capability, § 25.253(a)(4).
[No Change]

(7) Extension of Speedbrakes.
[No Change]

Chapter 6 – Equipment

Section 2. Instruments: Installation

177. Airspeed Indicating System - § 25.1323.

a. Explanation.

(1) Methods. Unless a calibrated reference system is provided, the airspeed system should be calibrated throughout as wide a range as necessary to cover the intended flight tests. The procedures of this section are for the purpose of showing compliance with § 25.1323(b) and are not intended to cover the speed range of the flight tests. If an alternate airspeed indicating system is provided, it should be calibrated. The airspeed indicating system should be calibrated in accordance with the following methods:

(a), (b), (c) [No Change]

(d) An acceptable means of compliance when demonstrating a perceptible speed change between 1.23 V_{SR} to stall warning speed **or the airspeed achieved at full aft control input if**

compliance is shown with §§ 25.202 and 25.204 (§~~23.1223~~**25.1323**(d)) is for the rate of change of IAS with CAS to be not less than 0.75.

(note: change from 23.1223 to 25.2323 corrects apparent typographical error in AC25-7C)

(e) An acceptable means of compliance when demonstrating a perceptible speed change between V_{MO} to V_{MO} + 2/3 (V_{DF} - V_{MO}) (§~~23~~**25**.1323(e)) is for the rate of change of IAS with CAS to be not less than 0.50.

(note: corrects apparent typographical error in AC25-7C)

(f) Airspeed Lag.

[No Change]

(2) Configuration.

[No Change]

b. Procedures.

[No Change]

Appendix 2 Topic 2 Adaptation for Flight in Icing Final Report

FAA Aviation Rulemaking Advisory Committee

FTHWG Topic 2

Adaptation for flight in icing

for High Angle of Attack Limiting Function airplanes

Recommendation Report

January, 2017

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Executive Summary

The Flight Test Harmonization Working Group has been tasked to recommend appropriate revisions to flight in icing regulatory and guidance material for airplanes with High Angle of Attack Limiting Function (HALF) (refer to Task Plan in Attachment 2A).
The task consisted of reviewing IPs/CRIs published for recent certifications (FAA, EASA, TCCA, ANAC…) and OEMs best practices based on their different designs of Flight control systems, Flight control laws and Flight envelope protections to adapt the current standard FAR Amendment 25-140 for high Angle of Attack limited aircraft.
The FTHWG provides in this report standard and guidance updates for HALF airplanes that have been considered reaching an equivalent level of safety compared to the conventional airplanes (i.e. not fitted with High Angle of Attack Limiting Functions).

As a conclusion of this in-depth review, the FTHWG recommends to amend several FAR 25 subpart B paragraphs addressing Performance and Handling Characteristics in Icing Conditions, Appendix C & O addressing Icing envelopes standards, together with FAA AC 25-25A related Guidance Material updates.

Background

The Flight in icing (25.21g) has been introduced for conventional airplanes (not fitted with a High Angle of Attack Limiting Function) in several steps and has been applied to Appendix C (14 CFR Amendment 25-121) and later Appendix O (Super Cooled Large droplets) (14 CFR Amendment 25-140) .
Transport airplanes incorporating fly-by-wire systems and High Angle of Attack Limiting Functions, have been certified and in service since the late 1980's. The basis on which the airworthiness was determined for adaptation for flight in icing of this kind of aircraft has been Special Conditions (in Europe and in US).

The Working Group has been tasked to develop and recommend standards in the area of: High Angle of Attack protected airplane in icing and non-icing conditions. This includes developing regulatory requirements and associated guidance material for airworthiness certification of airplane designs using fly-by-wire technology to remove the need for longstanding, repetitively-used fly-by-wire special conditions, including High Angle of Attack protection.

Details of the task have been defined at the working level in the work plan (Topic 2, Adaptation for flight in icing for HALF airplanes) resulting from Phase 1 final report, included as Attachment 2A.

A. What is the underlying safety issue addressed by the JAR/FAR? Or alternatively (use the alternative in our appendices)

While the stated task is to remove the need for repetitively used Special Conditions, the result will be a single, harmonized set of standards which will have the effect of ensuring a consistent safety standard.

The established standard of safety is taken to be the current airworthiness requirements applied to a conventional (not HALF protected) configurations.

B. What is the task ?

The task consisted of reviewing IPs/CRIs published for recent certifications (FAA, EASA, TCCA, ANAC…) and OEMs best practices based on their different designs of flight control systems, flight control laws and flight envelope protections to adapt the current standard FAR Amendment 25- 140 for high Angle of Attack protected aircraft.

The FTHWG provides in this report standard and guidance updates for HALF airplanes that have been considered reaching an equivalent level of safety compared to the conventional airplanes (i.e. not fitted with High Angle of Attack Limiting Function).

The credit and equivalence of requirements applicable to conventional aircraft may depend on the flight control & limiting system design and characteristics.

The activity included the following topics:

- Identify and address existing CRIs/IPs differences
- Establish harmonized High Angle of Attack limiting robustness check maneuvers
- Vsr versus Vmin1g in icing demonstration
- Minimal operating speed factor (factored Vmin1g versus factored Vsr in icing)

C. Why is this task needed ?

Existing flight in icing standard & guidance do not adequately address airplane designs using Fly-By-Wire technology to prevent stall (e.g it does not address designs providing non overrideable protections).

The only available standard/material guidance is provided through existing CRIs and IPs that are different and may be invalid for the likely range of high Angle of Attack limiting designs for future models.

The goal is to build a common standard & guidance for high Angle of Attack limited aircraft that would provide, regardless of the design, the main objectives that need to be satisfied to achieve an equivalent level of safety to conventional aircraft.

D. Who has worked the task ?

This task has been worked by the Topic 2 sub-team of specialists on Stability and Control, Performance and Icing specialists from the following organisations:

- Authorities : FAA, EASA, TCCA, JCAB*, CAAI*
- Manufacturers : Airbus, Boeing, Bombardier, Dassault, Embraer, Gulfstream, Textron
- Airlines : American Airlines, Delta Airlines*

- Labour Union: ALPA

(*) non-voting members

E. Any relation with other topics?

Topic 2 – Adaptation for flight in icing for High Angle of Attack Limiting Function airplanes is tightly linked to Topic 1 – Flight Envelope Protection and specifically the part dedicated to High Angle of Attack Limiting Function in non-icing. Actually, the icing case is built on the non-icing case, therefore those two Topics cannot be treated separately; this is the reason why the recommended rule text in Attachment 2B is covering both icing and non-icing for consistency and clarity.

Historical Information

A. What are the current regulatory and guidance material CS 25 and FAR 25?

CS 25/FAR 25 paragraphs :
25.21g,25.103,25.105,25.107,25.121,25.123,25.125,25.143,25.145,25.201,25.203,25.207,25.1309,25.1323, Appendix C
Material Guidance : FAA AC 25-25A and AMC CS 25 Amdt 18 (book 2)

B. What, if any, are the differences in the existing regulatory and guidance material CS 25 and FAR 25?

There are no differences between the CS 25 and the FAR 25 but they address conventional (non HALF) airplanes only. The HALF airplanes are treated by Special Conditions and MoCs (via CRIs/IPs).

C. What are the existing CRIs/IPs (SC and MoC)?

Latest CRIs/IPs including latest adaptation from 25.21g (FAR Amdt 25-140) are :
A350 FAA IP and CRIs, Dassault Falcon SMS CRI/IP, TCCA IP Bombardier CSeries, Embraer-550 EV-25 /EV-46, Sukhoï SuperJet CRI

D. What, if any, are the differences in the Special Conditions (CRIs/IPs) (SC and MoC) and what do these differences result in?

The FTHWG has conducted a mapping and a comparison of the basic standard for conventional aircraft (non HALF – FAR Amdt 25-140/CS 25 Amdt 18) and the various existing Special Conditions for HALF airplanes : EASA-FAA (A350 SC), ANAC (Embraer SC), TCCA (Bombardier C-series SC) . **Attachment 2D** of this report summarises the rule/ Special Conditions differences for each relevant subpart B paragraph.

The FAA/EASA are fully harmonized (ref A350 SC), the major differences between EASA/FAA SC and ANAC and TCCA SCs are mentioned in red characters in the table in Attachment 2D of this report.

For example: Different deceleration rates required for HALF robustness checks:
EASA/FAA HALF: Max deceleration rate in non-icing, 3kt/s in icing
ANAC HALF: Max deceleration in icing and non-icing
TCCA HALF: Max deceleration rate in non-icing, 3kt/s in icing + additional 3 robustness maneuvers.

This is to be compared to Non HALF airplanes requirements: 3kt/s in non-icing, 2kt/s in icing (for Stall Warning checks)

It results in different standards used in certification that can put some manufacturers at a competitive disadvantage from a cost and performance perspective.

Consensus

The proposed Rule and Material Guidance updates respectively in Attachments 2B and 2C of this report represent, unless otherwise noted, the majority position of the FTHWG members. Nevertheless they are 2 dissenting opinions from single organizations and 1 minority position expressed by 5 OEMs to specific parts of the proposed rule amendment and their associated material guidance, and 1 section where a Majority or consensus position could not be established.

To summarize, the FTHWG majority position believes that a common harmonized standard for HALF airplanes can be adopted by implementing new paragraphs §25.202 (Handling demonstrations for High Angle of Attack Limiting Functions), § 25.204 (Flight characteristics for High Angle of Attack limiting functions) and 25.207(j) (Stall warning with HALF inoperative) in alternative to §25.201, § 25.203 and § 25.207(a)-(i) (for non HALF).

The 3 dissenting opinions, and 1 Minority opinion are as follows:

Dissenting Opinion 1: Embraer does not agree with the "more critical power setting" for pre-activation ice as specified by § 25. 202 (d)(5) while the comparable test procedure in AC 25-25A for 25.207(h) compliance says "Idle" thrust for conventional airplanes. This should be the same for HALF equipped airplanes.

FTHWG answer: FTHWG thinks the recommended thrust settings are appropriate.

Dissenting Opinion 2: TCCA believes that the alleviation in 105(a)(2)(i), should read "(This requirement does not apply if compliance is shown to 25.202 and 25.204 and Vsr is not used in the determination of reference speeds in icing)"
Also the wording in 25.121(b)(2)(ii)(A), 25.121(c)(2)(ii)(A), 25.123(b)(2)(i) should read "…and reference speeds in icing are based on Vsr" instead of "if compliance is not shown to 25.202 and 25.204"

FTHWG Answer: FTHWG considers the proposed wording acceptable. The Majority considers the TCCA recommendation to retain the VSR icing accountability threshold if VSR is used in the determination of reference speeds in icing conditions to be counterproductive if robust high AOA protection is demonstrated with compliance to proposed 25.202 and 25.204. This is based on the acknowledgement that under this situation, VSR in icing conditions is in fact not required to be demonstrated and any reference speed determined using VSR in icing conditions, in this case, would exceed the minimum certification standards. Applicants should not be penalized or discouraged from determining VSR in icing conditions.

Minority Position 3 from Dassault (supported by Boeing, Textron, Embraer, Airbus) dealing with proposed FTHWG AC 25-25A new §2.6 :

The Minority proposes the following changes relative the Majority proposal for changes to AC 25-25A :

2.6 Takeoff, §25.105 and Climb: One-engine-inoperative, §25.121:

2.6.1 Performance - Takeoff Path Determination

> *Inclusion of the effects of ice during the determination of the takeoff path and takeoff performance parameters must be in accordance with §§ 25.105(a) and 25.121(b) and (c) which include ice accountability thresholds based on a relative increase in the reference stall speed or degradation in climb gradient due to ice. If any of the applicable ice accountability thresholds are exceeded, the airplane performance for the entire takeoff path, including takeoff speeds and distances, must be determined with ice accretions on the airplane. If any of the applicable ice accountability thresholds are exceeded, the airplane performance for the entire takeoff path, including takeoff speeds and distances, as applicable, must be determined ~~with ice accretions on the airplane~~ considering the effects of those performance parameters related to the exceeded threshold(s)*

The aim of this above updates is to state that the effect of ice has to be taken into account only for affected parameters. This wording is not considered in contradiction with the excerpt from the NPRM preamble to Amendment 25-121 saying that the entire takeoff path needs to be calculated considering icing, if one threshold is exceeded. The material is actually silent on the question of whether it's appropriate to use the thresholds as indicators of what degradation rises to the level of needing to be accounted for.

> *"Proposed § 25.105(a) would require applicants to determine airplane takeoff performance for icing conditions if the ice that can accrete during takeoff results in increasing the reference stall speed (VSR) or degrading climb performance beyond specified limits. Section 25.105(a) references all regulations related to the takeoff path. As a result, the performance for **the entire takeoff path**, including takeoff speeds and distances, must be determined for icing conditions if the stall speed or climb performance degradation limits are exceeded."*

Moreover, the NPRM discussion about the "entire takeoff path" is meant to ensure that the parameter exceeding the particular tolerance is appropriately accounted throughout all takeoff segments as opposed to just the flight segment associated with the icing accountability threshold. This is necessary considering the segmented definition of the takeoff path and the fact that the icing accountability thresholds are only based only on ice accretions between 35ft and 400ft, as discussed in the NPRM:

> *"Part 25 divides the takeoff climb performance requirements into several segments. To establish the allowable limit for takeoff climb performance degradation in icing conditions, Sec. 25.105(a)(2)(ii) would consider the effect of ice accretions on just the takeoff climb segment defined by Sec. 25.121(b). For most transport category airplanes, this segment most often limits the allowable takeoff weight, and therefore is the most critical to safety. If the effects of ice accretions during the takeoff climb segment defined in Sec. 25.121(b) are beyond specified limits, the airplane performance for the entire takeoff path must be determined with ice accretions on the airplane. This would include from the beginning of the takeoff roll until the airplane is at least 1,500 feet above the takeoff surface."*

FTHWG Answer: The preamble to amendment 25-121 (Performance and Handling Qualities in icing) states that if any thresholds are exceeded, the takeoff performance must be re-computed with effects of ice.

Consensus could not be reached regarding the addition of new icing accountability thresholds 25.105(a)(2)(iii) and 25.121(b)(2)(ii)(C). The two primary positions (for and against) are summarized as follows:

Position 1 (for): The faction of members (FAA, TCCA, EASA, Bombardier and Gulfstream) in support of these additions consider the result to be consistent with HALF Special Conditions which currently include a V2 accountability criteria. Additionally, this position considers the proposed V2 accountability to reflect the CFR Amdt 25-121 intent for conventional airplanes as explained in the preamble material.

Position 2 (against): A faction of members (Boeing, Textron, Embraer, Airbus and Dassault) were opposed to the proposal for new subparagraphs 25.105(a)(2)(iii) and 25.121(b)(2)(ii)(C) on the basis that it introduces a new icing accountability threshold resulting in a change to the current airworthiness standards introduced at Amendment 25-121 without addressing a clear safety concern identified in service for aircraft with or without a HALF. Furthermore, acceptance of the Position 1 proposal will hinder the development of viable design solutions worthy of consideration that would otherwise be capable of demonstrating equivalent safety; an example is provided below.

Position 2 acknowledges that the Position 1 proposal is consistent with the Special Conditions used to certify aircraft with a HALF, however-Special Conditions are not required to address all kinds of design implementation. It is also noted that 25.21(g), introduced at Amendment 25-121, recognizes specific operating procedures in showing compliance with flight in icing conditions.

Position 2 understands that the Position 1 proposal is meant to address a concern that a speed increase (e.g., V2) in icing conditions may not be reflected in other related AFM takeoff performance (e.g., VR, accelerate-stop distance, etc.) resulting in the AFM performance not reflecting the actual speeds flown in icing conditions. An alternative way to address this specific concern without impeding viable design solutions is through expansion of guidance material since it is not obvious that a new regulation is warranted. Specifically, a new paragraph 4.4.3 could be added to AC25-25A for the takeoff path:

> "4.4.3 Any takeoff speed increase should be accounted for in the AFM takeoff performance."

An example is provided to illustrate the difference between the positions. Assuming;

- Neither VSR nor climb gradient reduction accountability thresholds are exceeded with critical takeoff ice
- A minimum non-icing V2 is insufficient to provide minimum maneuver capability in icing conditions
- Rather than increasing the non-icing speed such that a single speed can be flown in non-icing and icing conditions, a separate (increased) speed schedule is provided in icing conditions to ensure minimum maneuver capability when in icing conditions
- AFM performance is adjusted in icing conditions to reflect the increased speed schedule in icing conditions

Contrary to the existing certification standards introduced at Amendment 25-121, the Position 1 proposal would require the takeoff path determination in this example to include the effects of ice drag. However, for aircraft that benefit from an increase in climb performance as speed is increased, the climb gradient capability is actually improved. Thus, it would not be necessary to include the effects of ice drag for this instance because climb performance is improved with the separate flight in icing procedure and at least equivalent safety can be demonstrated. Conversely, existing criteria 25.105(a)(2)(ii) and 25.121(b)(2)(ii)(C) would continue to ensure adequate climb gradient in icing conditions in the event climb capability is reduced as speed is increased."

Dissenting Opinion 4: Gulfstream

The proposed AC25-25A paragraph 2.6.1 does not align with the proposed 25.105(a)(2) or 25.121(b)(2)(ii). Specifically, the proposed guidance doesn't address the V2 accountability threshold and doesn't refer to the exception of relative increase in the reference stall speed accountability threshold if compliance is shown to 25.202/204. This should be corrected to the following:

2.6.1 Performance - Takeoff Path Determination

Inclusion of the effects of ice during the determination of the takeoff path and takeoff performance parameters must be in accordance with §§ 25.105(a) and 25.121(b) and (c) which include ice accountability thresholds based on an increase in V2 in icing, a relative increase in the reference stall speed (does not apply if a HALF is installed and compliance is shown to 25.202 & 25.204) or degradation in climb gradient due to ice. If any of the applicable ice accountability thresholds are exceeded, the airplane performance for the entire takeoff path, including takeoff speeds and distances, must be determined with ice accretions on the airplane.

FTHWG Answer : FTHWG considers that the original proposed wording is acceptable .

Recommendation

FAA should adopt the harmonized standard and guidance. Further, the FAA should liaise with EASA, TCCA, and ANAC to ensure consistent implementation in their jurisdictions.

A. Rulemaking

1. What is the proposed action?

The FTHWG recommends changes to 14CFR25 paragraphs 25.103, 105, 107, 121, 123, 125, 143, 207 and Appendix C Part II e), and the addition of 2 new paragraphs 25.202 and 25.204. Further, the FTHWG recommends identical changes to similar paragraphs of the EASA Certification Standard CS-25, TCCA AWM 525, ANAC part 25.

In addition FTHWG recommends concomitant changes to the relevant guidance material and that identical changes are made to the guidance published by the counterpart authorities.

2. What should the harmonized standard be?

The FTHWG believes that a single standard of airworthiness can be achieved which produces a level of safety equivalent to that seen by conventional (non HALF) airplanes complying with the current airworthiness standards. Attachment 2B provides the FTHWG recommended Rulemaking text, presents the changes to existing regulatory paragraphs and offers FTHWG Comments and Rationale for adopting these changes.

3. How does this proposed standard address the underlying safety issue?

The single, harmonized set of proposed standard will have the effect of ensuring a consistent safety standard for all HALF airplanes in icing conditions.
Moreover, it has been found to have an equivalent level of safety compared to the current airworthiness requirements applied to conventional airplanes (non HALF airplanes).

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

The proposed standard for certifying HALF airplanes in icing conditions is based on existing CRIs/IPs that have been recognized to achieve an Equivalent Safety Level to basic 25.21g for non HALF airplanes relying on:

- § 25. 202/204 Robustness checks of the high incidence protection system in icing, ensuring that the airplane is adequately protected against stall.
- §25.103 reference stall speed in icing need not to be determined (or at the choice of the applicant) since it is replaced by the demonstration that HALF are efficient enough to protect the airplane against stall. Vmin1gice or VSR ice is required to be determined if used for establishing a performance standard.
- Minimum AFM operational speeds in icing (25.105, 107, 121,123,125) need not to be based on factored Vsr ice (at the choice of the applicant) but based on manoeuvrability criteria (25.143h) with associated potential V2 increase and potentially climb gradient requirement (25.105, 121, 123)
- In addition to the requirement existing in current FAA and EASA Special Condition, minimum landing speed in icing is proposed to be based on factored Vmin1g ice (at the choice of the applicant).
- In addition, 25. 207 has been amended for HALF airplanes with no Stall Warning under normal system operation and requiring the presence of adequate Stall Warning with HALF failure conditions.

HALF airplanes complying with §§ 25.202 and 25.204 in icing conditions provide an Equivalent Level of Safety to conventional non HALF airplanes fitted with Stall warning and using factored Vsr ice in icing conditions.

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

The proposed standard for certifying HALF airplanes in icing conditions has been found to have an equivalent level of safety compared to the current airworthiness requirements applied to conventional airplanes (non HALF airplanes).

Although the proposed standard was built on existing CRIs/IPs/SCs for HALF and OEMs best practice used to certify HALF airplanes, some manufacturers may need to conduct additional flight tests to comply with the proposed standard although these tests might be conducted, in certain cases in combination with other already existing flight tests.

Also to be noted that the additional HALF reliability/availability requirement being set to be Improbable, might affect the HALF Change Product Rule Airplanes as this requirement was not specifically considered in the existing Special Conditions.

6. Who would be affected by the proposed change?

Manufacturers developing new or derivative transport category airplanes fitted with HALF and other organizations (e.g., companies developing after-market improvements/upgrades to existing HALF airplane models and certifying them through STC).

7. Does the proposed standard affect other HWG's and what is the result of any consultation with other HWGs?

No. The proposed standard does not affect other HWGs.

B. Advisory Material

1. Is existing FAA advisory material adequate? If not, what advisory material should be adopted?

The FTHWG believes that the current FAA advisory material is not adequate. Proposed changed material is provided in AC 25-25A. See Attachment 2C.

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

For Harmonization, EASA , TCCA and ANAC updated standards (e.g EASA CS-25 book 1) and Material guidance (e.g CS-25 book 2) should be updated the same way and Special conditions and Interpretative Material Guidance should be cancelled .

Economics

A. What is the cost impact of complying with the proposed standard?

The proposed standard will allow elimination of the existing Special Conditions that will reduce the certification burden and associated cost for FAA and OEMs.

Nevertheless, despite the proposed standard being built on existing CRIs/IPs/SCs for HALF and OEMs best practice used to certify HALF airplanes, some manufacturers may need to conduct additional flight tests to comply with the proposed standard although these tests might be conducted, in certain cases in combination with other already existing flight tests.

Also to be noted that the additional HALF reliability/availability requirement being set to be Improbable, might affect the HALF Change Product Rule Airplanes as this requirement was not specifically considered in the existing Special Conditions.

B. Does the HWG want to review the draft NPRM prior to publication in the Federal Register?

Yes.

ICAO Standards
How does the proposed standard compare to the current ICAO standard?

There are no known ICAO standards relating to flight in icing Handling and Performance Standards

Attachment 2A Phase 1 Final Report- Work Plan

Work Plan – Adaptation for flight in icing (Amdt 25-135)

1. What is the task?

- Recommend appropriate revisions to flight in icing regulatory and guidance material for airplanes with high incidence protection system (vs FAR 25-135 see 25.21g implementation historic in §8 below)

- Review IPs/CRIs published for recent certifications (FAA, EASA, TCCA, ANAC…) and OEMs best practices based on their different designs of Flight control systems , Flight control laws and Flight envelope protections to adapt the current standard FAR 25. 135 for high Angle of Attack protected aircraft (overrideable and non-overrideable protections).

- The objective is to provide guidance to adapt new flight in icing requirements in order to reach an equivalence of safety level to conventional aircraft for any design that would be acceptable candidate for it.

2. Who will work the task?

- The Flight Test Harmonization Working Group (FTHWG) will have primary responsibility for this task. The group should be supported as necessary by the FCHWG, or appropriate flight controls subject matter experts within the FTHWG, for clarification on Flight control system design aspects.

- Coordination within FTHWG is expected with other subteams established to work on " topic1- Flight envelope protection" and "topic 6-lateral/directional/longitudinal stability" as the "topic2- adaptation for flight in icing" will update portions of the subpart B Requirements for icing conditions.

3. Why is this task needed? (Background information)

- Existing flight in icing standard & guidance do not adequately address airplane designs using fly-by-wire technology to protect against stall (it should address designs providing either overrideable and non-overrideable protections)

- The only available standard/material guidance is provided through existing CRIs and IPs that may be invalid for the likely range of high Angle of Attack protection designs for future models.

- The goal is to build a common standard & guidance for high Angle of Attack protected aircraft that would provide, regardless of the design, the main objectives that need to be satisfied to achieve an equivalent level of safety to conventional aircraft.

- The credit and equivalence of requirements applicable to conventional aircraft may depend on the flight control & protection system designs and characteristics.

- The activity will include the following topics :
    - Provide a definition of overrideable/ non overrideable Angle of Attack protection
    - Address in priority existing CRIs/IPs differences , eg :
        - Angle of Attack protection robustness check maneuver,
        - VSR vs. Vmin1g in icing demonstration,
        - Minimal operating speed factor (kVmin1g vs. kVSR in icing)

4. References (existing regulatory and guidance material, including special conditions, CRIs, etc.)

25.21g,25.105,25.107,25.121,25.123,25.125,25.143,25.145,25.201,25.203,25.207,25.1309,25.1323

A350 FAA IP F-5 and CRI B-01/B-09, Dassault Falcon SMS CRI B-01, TCCA IP Bombardier C-series, Embraer-550 EV-25 /EV-46, Sukhoï CRI B-06/B-09

TCCA &ANAC comments to A350 -900 Special condition :

Brazilian_National_Civil_Aviation_Agency_-_ Transport_Canada[1].pdf FAA-2012-1207-0001[1].pdf

5. Working method

It is envisioned that 4-5 face-to-face meeting days will be needed to facilitate the discussion needed to complete these tasks. Telecons and electronic correspondence will be used to the maximum extent possible.

6. Preliminary schedule (How long?)

Provide recommendations to ARAC Transport Airplanes and Engines Subcommittee within 18 months of the initiation of work on these tasks.

7. Regulations/guidance affected

25.21g, 25.105, 25.107, 25.121, 25.123, 25.125, 25.143, 25.145, 25.201, 25.203, 25.207, 25.1309, 25.1323, AC 25-7C

8. Additional information

Implementation Historic :The Flight in icing (25.21g) has been introduced in several steps and relates only to app. C ice shapes :

- FAR 25 Amendment 121 (CS-25 Amendment 3) : introduce new 25.21g aiming at addressing icing conditions for all subpart B paragraphs except 25.121(a), 25.123(c), 25.143(b)(1) and (b)(2) ,25.149, 25. 201 (c)(2), 207(c) and (d) and 25.251(b) through(e)

- FAR 25 Amendment 135 (CS-25 Amendment 6) : 207c) and 207d) have been re-introduced to be considered in icing conditions for landing configuration only

- FAR 25 Amendment 129 (CS-25 Amendment 7) : 25.1419 has been amended to ensure that flight crew are provided with a clear means to know when to activate the airframe Ice Protection System. As a consequence, minor conforming changes have been made to 25.143(j) and207(h) to remove references to activating the Icing Protection System in response to the pilot seeing a specified ice accretion on a reference surface. Additional minor changes have been made to 25.207(h) to improve readability and a portion of existing 25.207(h)(2)(ii) has been moved to a new 207 (i).

Attachment 2B Recommended Rulemaking Text

Existing regulatory text in Black, new text in Blue for HALF airplanes and specificities for icing conditions in Blue

High Angle of Attack Limiting Function airplanes in icing and non icing

Proposed Regulatory Changes	Comments/Rationale
§25.103 Reference Stall 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: $$V_{SR} \geq \frac{V_{CL_{MAX}}}{\sqrt{n_{zw}}}$$ where: V_{CLMAX} = Calibrated airspeed obtained when the load factor-corrected lift coefficient ($\frac{n_{zw}W}{qS}$) is first a maximum during the maneuver prescribed in paragraph (c) of this section. 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.	Proposal keeps this general and same as existing reg for conventional airplanes. Those who choose to define Vsr in icing would comply with this paragraph for icing conditions as well as non-icing. (b)(3) provides allowance for determining Vsr only in non-icing conditions. See draft AC25-25A guidance para 4.2.2. This leaves V_{CLmax} rather than changing to V_{CLmax_demo} or V_{CL_demo}, etc. It needs to remain general for all applicants and stall systems. Current stick pusher designs may limit AOA below aero stall, so it is already understood that V_{CLmax} used here doesn't necessarily mean C_L at aerodynamic stall. See para (c) below and draft AC25-7X guidance para 29.e.(5)(c).
(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 takeoff 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; (6) The airplane trimmed for straight flight at a speed selected by the applicant, but not less than $1.13V_{SR}$ and not greater than $1.3V_{SR}$; and (7) If installed, the High Angle-of-Attack Limiting Function disabled or adjusted, at the option of the applicant, to allow	"Ice accretion" in (b)(3) is noted as an example of "other respects" and would be applicable only in the case where a "performance standard in which Vsr is being used". So, if Vref in icing is based upon 1.23 Vsr_ice, then the appropriate ice accretions must be included in determining V_{CLmax_ice}. See draft AC25-25A guidance para 4.2.2.

reaching the angle of attack corresponding to V_{SR}.	
(c) Starting from the stabilized trim condition, apply the longitudinal control to decelerate the airplane in straight flight so that the speed reduction does not exceed one knot per second, until stall as defined in Section 25.201(d) or the angle of attack corresponding to V_{SR} is reached; or until activation of a stall identification device (e.g., stick pusher), if installed. (d) In addition to the requirements of paragraph (a) of this section, when a device that abruptly pushes the nose down at a selected angle of attack (~~e.g.,~~i.e., a stick pusher) is installed, the reference stall speed, V_{SR}, may not be less than 2 knots or 2 percent, whichever is greater, above the speed at which the device operates.	This clarification is added to allow stall speed testing for a HALF airplane or conventional airplane with natural stall Identification (ID) to end at the AOA for Vsr rather than a stall ID. However, for an airplane that must comply with 25.103(d) because it includes a stick pusher or similar stall ID device, the test would be continued to the stall ID. This requirement applies only to a pusher type stall ID.
(e) In addition to the requirements of paragraph (a) of this section, when a High Angle-of-Attack Limiting Function is installed and compliance is shown with §§25.202 and 25.204, the one-g minimum steady flight speed, V_{MIN1g}, must be established if it is used to determine compliance with a required performance standard or other requirements demonstrations in non-icing or icing conditions. (1) The one-g minimum steady flight speed, V_{MIN1g}, is the minimum calibrated airspeed at which the airplane can develop a lift force (normal to the flight path) equal to its weight, while stabilized at the limit angle of attack achieved with the High Angle-of-Attack Limiting Function operating normally. (2) V_{MIN1g} is determined with: (i) Engines idling; (ii) Flaps and landing gear in any likely combination of positions approved for operation; (iii) The weight used when the reference stall speed, V_{SR}, is being used as a factor to determine compliance with a required performance standard; (iv) The center of gravity position that results in the highest value of V_{MIN1g}; (v) The airplane trimmed for straight flight at a speed selected by the applicant, but not less than 1.13 V_{MIN1g} (or the minimum trim speed if higher than 1.13 V_{MIN1g}), and not greater than 1.3V_{MIN1g}, and (vi) The ice accretions appropriate for the condition existing in the performance standard for which V_{MIN1g} is being used.	This only requires Vmin1g (Vmin no longer mentioned) be determined in icing or non-icing if it is used to show compliance elsewhere. There is an assumption that Vref in icing may have a required minimum ratio of Vmin1g. Otherwise, there will be no requirement to determine Vmin1g. Vmin1g is the speed corresponding to a theoretical steady CL at the AOA limit. The method for determining Vmin1g by test or analysis of other test data is addressed in guidance.
§25.202 Handling demonstrations for high angle-of-attack limiting functions (a) Applicability: If a High Angle-of-Attack Limiting Function is installed that meets the capability and reliability requirements of paragraphs (a)(1) through (a)(5) of this section, compliance with the high angle-of-attack handling demonstrations defined by paragraphs (b) through (e) of this section and the high angle of attack characteristics requirements of Section 25.204 can be shown in lieu of compliance with Sections 25.201 and 25.203. (1) The HALF must be provided for all configurations used for normal operation, in icing and non-icing conditions;	Guidance is included that makes it clear that 25.202 does not apply in maneuvering flight in the cruise regime (see para 29h(2)(g)).

(2) It must not be possible to encounter a stall during the pilot induced maneuvers required by paragraphs (b)-(d) of this section in icing and non-icing conditions; (3) The airplane must be protected against stalling and the operation of the High Angle-of-Attack Limiting Function must not adversely affect airplane control during expected levels of atmospheric disturbances, nor may it impede the application of recovery procedures in case of wind-shear; (4) The High Angle-of-Attack Limiting Function must be provided in each abnormal configuration of the high lift devices following high lift system failures not shown to be improbable; and (5) Failure of the High Angle-of-Attack Limiting Function must be improbable. (b) Maneuvers to the limit of the longitudinal control, in the nose up sense, must be shown in straight flight and in 30° banked turns with: (1) The High Angle-of-Attack Limiting Function operating normally and the automatic power or thrust increase system inhibited, if applicable; (2) Initial power or thrust conditions of: (i) Engines idling; and (ii) Power or thrust necessary to maintain level flight at 1.5 V_{SR1} (where V_{SR1} corresponds to the reference stall speed at maximum landing weight with flaps in the approach position and the landing gear retracted in non-icing conditions). (c) In each condition required by paragraph (b) of this section, it must be possible to meet the applicable requirements of §25.204(b)-(e) with – (1) Flaps, landing gear and deceleration devices in any likely combination of positions approved for operation; (2) Representative weights within the range for which certification is requested; (3) The most adverse center of gravity; and (4) The airplane trimmed for straight flight at the all-engine minimum normal operating speed appropriate for the configuration.	Guidance included describing "minimum normal operating speed" in Para 29h(3)(a).
(d) The following procedures must be used to show compliance with §25.204(b)-(e) in icing and non-icing conditions: (1) Starting at a speed such that the angle of attack is sufficiently below the AOA-limit to ensure that a steady rate of speed reduction can be established, apply the longitudinal control so that the speed reduction does not exceed one knot per second until the control reaches the aft stop. (2) The longitudinal control must be maintained at the stop until the airplane has reached a stabilized flight condition. With the control at the aft stop it must be shown that the airplane	

presents a satisfactory level of lateral control. (3) The airplane must be recovered by normal recovery techniques. (4) The demonstrations of paragraphs (b) & (c) of this section must also be conducted with increased entry rates, up to the maximum practical entry rate in non-icing conditions, and up to 3 knots per second in icing conditions. For approach and landing configurations, rapid application of go-around power or thrust at any time following initiation of the maneuver to the time at which the longitudinal control reaches the aft stop must also be considered, if more critical.	
(5) For flight in icing conditions before the ice protection system has been activated and is performing its intended function, the handling demonstration requirements identified in paragraphs (b) and (c) of this section, except with all automatic protection functions operating normally, at the more critical power (or thrust) setting of paragraph (b)(2) of this section, must be met with the ice accretion defined in appendix C, part II(e) of this part in a steady deceleration up to 1 knot per second. The deceleration must be continued until the first of (i)-(iii) is reached: (i) A suitable warning alert, in accordance with §25.1322, followed by normal recovery input delayed by 1 second; (ii) A suitable caution alert, in accordance with §25.1322, combined with engagement of an automatic protection function that operates to deter further reduction in airspeed, followed by normal recovery input delayed by 3 seconds; or (iii) The aft control stop, followed by normal recovery input delayed by 3 seconds. If the time from entry into icing conditions until the ice protection system is activated and performing its intended function is not sufficiently brief, the requirements of paragraph (d)(1)-(4) are applicable in lieu of this paragraph.	Dissenting Opinion : Embraer does not agree with the "more critical power setting" as AC25-25A says "Idle" thrust for conventional airplanes. This should be the same for HALF equipped airplanes. For the recovery delay time, guidance explains that the pilot force input trend is to be continued during the noted time prior to recovery input. This does not require that the airplane continue to decelerate at 1 kt/sec after activation of protection function.
(e) In addition to the requirements outlined by paragraphs (b) through (d) of this section, maneuvers with a deceleration of not more than 1 knot per second up to the greater of the angle of attack corresponding to V_{SR} obtained per § 25.103(a) (if determined) and that reached during maneuvers from § 25.202(d)(1)-(4) must be shown be shown to meet the characteristics requirements of § 25.204(f) in straight flight (non-icing and icing conditions) and in 30° banked turns (non-icing conditions only) with: (1) The High Angle-of-Attack Limiting Function deactivated or adjusted, at the option of the applicant, to allow the airplane to achieve the angle of attack specified above; (2) Automatic power or thrust increase system inhibited (if	

applicable); (3) Engines idling; (4) Flaps, landing gear and deceleration devices in any likely combination of positions approved for operation; (5) The most adverse center of gravity; and (6) The airplane trimmed for straight flight at the speed prescribed in § 25.202(c)(4).	
§25.204 Flight characteristics for high angle-of-attack limiting functions (a) Applicability: If a High Angle-of-Attack Limiting Function is installed and compliance is being shown to §25.202 in lieu of §25.201, the high angle-of-attack flight characteristics during the handling demonstrations required by §25.202 must meet the requirements of paragraphs (b) through (f) in lieu of §25.203. (b) Throughout maneuvers with a deceleration of not more than 1 knot per second, both in straight flight and in 30° banked turns, and with the High Angle-of-Attack Limiting Function operating normally, the airplane's characteristics must be as follows: (1) There must be no abnormal nose-up pitching; (2) There must be no uncommanded nose-down pitching indicative of stall. Reasonable attitude changes associated with stabilizing the angle-of-attack at the AOA-limit as the longitudinal control reaches the stop are acceptable; (3) There must be no uncommanded lateral or directional motion indicative of stall, and the airplane must exhibit good lateral and directional control by conventional use of the controls throughout the maneuver; and (4) The airplane must not exhibit buffeting of a magnitude and severity that would act as a deterrent from completing the maneuvers. (c) In maneuvers with increased rates of entry some degradation of characteristics is acceptable, associated with a transient excursion beyond the stabilized AOA-limit. However, the airplane must not exhibit hazardous characteristics or characteristics that would deter the pilot from holding the longitudinal control on the stop for a period of time appropriate to the maneuver. (d) It must always be possible to reduce angle-of-attack by conventional use of the controls. (e) The High Angle-of-Attack Limiting Function must not unduly damp airplane pitch rate capability preventing achievement of decelerations deemed necessary for normal operation and for showing compliance with §25.202. (f) Throughout the maneuvers with the High Angle-of-Attack	

Limiting Function deactivated or adjusted for demonstration of §25.103(a)-(c) and §25.202(e) the following characteristics must be shown: (1) The airplane must not exhibit hazardous characteristics; (2) It must always be possible to reduce angle of attack by conventional use of the controls; and (3) The airplane must exhibit good lateral and directional control by conventional use of the controls.	
§25.207 Stall warning. *… no change (a) through (i) …* (j) If a High Angle-of-Attack Limiting Function is installed and compliance is shown with §§25.202 and 25.204, the stall warning requirements of paragraphs (a) through (i) are not required when the High Angle-of-Attack Limiting Function is operating normally. Following failures affecting the High Angle-of-Attack Limiting Function not shown to be extremely improbable, such that the capability of the function no longer satisfies §§25.202 and 25.204, stall warning must be provided that meets the requirements of § 25.207(a) & (g), and the requirements of § 25.207(b) except that the speed margins of the required stall warning must be as prescribed in (1) and (2) below. In addition, (1) In non-icing conditions, stall warning must provide sufficient margin to prevent encountering unacceptable characteristics or encountering stall in the following conditions: (i) In engines idling straight deceleration not exceeding one knot per second to a speed 5 knots or 5 percent CAS, whichever is greater, below the warning onset; and (ii) In engines idling turning flight deceleration at entry rates up to 3 knots per second when recovery is initiated not less than one second after the warning onset. (2) In the icing conditions identified in paragraphs (e)(3)-(5) of this section, stall warning must provide sufficient margin to prevent encountering unacceptable characteristics and encountering stall, in engines idling straight and turning flight decelerations not exceeding one knot per second, when the pilot starts a recovery maneuver not less than three seconds after the onset of stall warning. (3) Once initiated, stall warning must continue until the angle of attack is reduced to approximately that at which stall warning began. (4) For paragraphs (1) & (2) above, indications of a stall encounter include uncommanded nose-down pitching that cannot be readily arrested or buffeting of a magnitude and severity that would act as a deterrent to further speed reduction. An airplane exhibits unacceptable characteristics during straight or turning flight decelerations if it is not	

always possible to produce and to correct roll and yaw by conventional use of lateral and directional controls, or if abnormal nose-up pitching occurs.	
Appendix C: Part II: (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), 25.202(d)(5), ~~and~~ 25.207(h)~~,~~ and 25.207(i).	
§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 used to show compliance with §25.121(b), and with the most critical of the takeoff ice accretion(s) defined in appendices C and O of this part, as applicable, in accordance with §25.21(g):	
(i) The **reference** 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} **(This requirement does not apply if compliance is shown to §§ 25.202 and 25.204); or**	(a)(2)(i) Applicable to conventional a/c; not applicable to HALF Dissenting opinion TCCA believes that the alleviation in 105(a)(2)(i), should read "(This requirement does not apply if compliance is shown to 25.202 and 25,204 and Vsr is not used in the determination of reference speeds in icing)"
(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)**; or**	(a)(2) (ii) Applicable to all a/c
(iii) V_2 exceeds the non-icing V_2.	(a)(2) (iii) Technically applicable to all a/c that separate icing and non-icing V2; specifically addresses curtailment of permissible V2 increase for HALF a/c with a separate icing speed to be consistent with (a)(2)(i) standard for conventional a/c before performance needs to be recomputed in icing Refer to Absence of consensus in "consensus section of this report" -(Position 2)(Boeing, Textron, Embraer, Airbus and Dassault) (against) 25.105(a)(2)(iii) and 25.121(b)(2)(ii)(C) introducing a new icing accountability threshold for HALF and non HALF.

§25.107 Takeoff speeds.	
(b) V_{2MIN}, in terms of calibrated airspeed, may not be less than— (1) 1.13 V_{SR} **(applicable in non-icing conditions; also applicable in icing conditions if compliance is not shown to 25.202 and 25.204),** 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 stall speed; (2) 1.08 V_{SR} **(applicable in non-icing conditions; also applicable in icing conditions if compliance is not shown to 25.202 and 25.204),** 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 stall speed; and (3) 1.10 times V_{MC} established under §25.149.	Changes result in VSR criteria only being applicable when compliance is not shown to 25.202 and 25.204
(c) V_2, in terms of calibrated airspeed, must be selected by the applicant to provide at least the gradient of climb required by §25.121(b) but may not be less than— (1) V_{2MIN}; (2) V_R plus the speed increment attained (in accordance with §25.111(c)(2)) before reaching a height of 35 feet above the takeoff surface; and (3) A speed that provides the maneuvering capability specified in §25.143(h)	No change
…	
(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}, **(applicable in non-icing conditions; also applicable in icing conditions if compliance is not shown to 25.202 and 25.204);** and (2) A speed that provides the maneuvering capability specified in §25.143(h).	Same logic as 107(c)
§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	Same logic as 25.105

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 most critical of the takeoff ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g), if in the configuration used to show compliance with §25.121(b) with this takeoff ice accretion: (A) The **reference** 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}**. (This requirement does not apply if compliance is shown to §§ 25.202 and 25.204);** **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)**; or** **(C) V_2 exceeds the non-icing V_2.**	Refer to Absence of consensus in “consensus section of this report” –(Position 2) (Boeing, Textron, Embraer, Airbus and Dassault) (against) 25.105(a)(2)(iii) and 25.121(b)(2)(ii)(C) introducing a new icing accountability threshold for HALF and non HALF.
(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.	Same logic as 25.105 but for VFTO instead of V2

(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 most critical of the final takeoff ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g), if ~~in the configuration used to show compliance with §25.121(b) with the takeoff ice accretion used to show compliance with §25.111(c)(5)(i)~~: (A) The **reference** stall speed at maximum takeoff weight, in the configuration used to show compliance with §25.121(b) with the takeoff ice accretion used to show compliance with §25.111(c)(5)(i), exceeds that in non-icing conditions by more than the greater of 3 knots CAS or 3 percent of $V_{SR..}$ **(This requirement does not apply if compliance is shown to §§ 25.202 and 25.204);** or (B) The degradation of the gradient of climb determined in accordance with §25.121(b), with the takeoff ice accretion used to show compliance with §25.111(c)(5)(i), is greater than one-half of the applicable actual-to-net takeoff flight path gradient reduction defined in §25.115(b); or **(C) V_{FTO} with final takeoff ice exceeds the non-icing V_{FTO}.**	Dissenting opinion : TCCA believes that also the wording in 25.121(b)(2)(ii)(A), 25.121(c)(2)(ii)(A), 25.123(b)(2)(i) should read "…and reference speeds in icing are based on Vsr" instead of "if compliance is not shown to 25.202 and 25.204"
(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 most critical of the approach ice accretion(s) defined in Appendices C and O of this part, as	

applicable, in accordance with §25.21(g)**–** **(A)** 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**; or** **(B) If compliance is shown to §§ 25.202 and 25.204, the climb speed established with normal landing procedures, but not more than 1.4 V_{SR} (V_{SR} determined in non-icing conditions), may be used if in a configuration corresponding to the normal all-engines-operating procedure the V_{MIN1G} for this configuration does not exceed 110% of the V_{MIN1G} for the related all-engines-operating landing configuration in icing conditions.**	This permits a HALF a/c use either the VSR criteria or the Vmin1g criteria based on concerns that this may drive a requirement to determine Vmin1g. Language in (B) was modified slightly from the special conditions for readability.
§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 VFTO~~ **V_{ER}, in terms of calibrated airspeed, selected by the applicant,** 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; and (4) The means for controlling the engine-cooling air supply in the position that provides adequate cooling in the hot-day condition**; and** **(5) A minimum speed not less than a speed that provides the maneuvering capability specified in § 25.143(h); and** **(6) A minimum speed not less than 1.18 V_{SR} (in non-icing and icing conditions if compliance is required under §(b)(2)(i) of this section) applicable for altitudes up to the lower of 20,000 feet or the pressure altitude at which the gradient of the one-engine-inoperative actual flight path is zero for the en route configuration. (This requirement does not apply in icing conditions if compliance is shown to §§25.202 and 25.204).**	After examining the minimum en route speed requirement, it is concluded that there is no safety concern associated with trading airspeed for altitude in transition from the final takeoff to the en route climb segment, provided the en route climb speed provides sufficient maneuver capability and margin to stall; changes to 25.123 are aimed at differentiating VFTO and the en route speed which is proposed to be defined as "V_{ER}" later in 25.143. In particular, comparing the en route speed to VFTO is inappropriate and incorrect since VFTO only needs to be defined several thousand feet above the highest airport elevation, whereas en route speeds are applicable to much higher altitudes. Resolving this issue benefits both conventional and HALF a/c. 25.123(a)(6) rationale is : lower of 20,000 ft or the altitude where the actual flight path is zero. 20,000 ft allows several thousand ft above the highest airports in the world but would avoid having to define VSR at arbitrarily high altitudes.
(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	

<table>
<tr><td>
(2) In icing conditions with the most critical of the en route ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g), if:

(i) A speed of 1.18 **V_{SR}, applicable for altitudes in accordance with paragraph (a)(6) of this section,** 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} (This requirement **does not apply if compliance is shown to §§ 25.202 and 25.204)**; 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**; or**

(iii) **V_{ER}** exceeds the non-icing **V_{ER}**
</td><td></td></tr>
<tr><td>
(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.
</td><td></td></tr>
<tr><td>**§25.143 General.**</td><td></td></tr>
<tr><td>
(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:

<table>
<tr><td>Configuration</td><td>Speed</td><td>Maneuvering bank angle in a coordina ted turn</td><td>Thrust/power setting</td></tr>
<tr><td>Takeoff</td><td>V_2</td><td>30°</td><td>Asymmetric WAT-Limited.[1]</td></tr>
<tr><td>Takeoff</td><td>[2]V_2 + XX</td><td>40°</td><td>All-engines-operating climb.[3]</td></tr>
<tr><td>**Final Takeoff**</td><td>V_{FTO}</td><td>40°</td><td>Asymmetric WAT-Limited.[1]</td></tr>
<tr><td>[4]**En route**</td><td>[4]**V_{ER}**</td><td>**40°**</td><td>**Asymmetric Thrust for Level Flight.**[4]</td></tr>
<tr><td>Landing</td><td>V_{REF}</td><td>40°</td><td>Symmetric for -3° flight path angle</td></tr>
</table>
[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
</td><td>
Modifications to 25.143 reflect the intent to require minimum maneuver capability at the en route speed and not just the en route configuration.

The final takeoff (V_{FTO}) and en route ("V_{ER}" defined in 25.123) speeds are not required to be contiguous and as a result may not be equivalent; at some weights V_{FTO} may be expected to be faster than the speed selected for en route climb.
</td></tr>
</table>

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 takeoff condition at V_2, or any lesser thrust or power setting that is used for all-engines-operating initial climb procedures. **[4]The en route maneuvering capability requirement is applicable at all altitudes up to the pressure altitude at which the gradient of the one-engine-inoperative actual flight path is zero for the en route configuration.**	
§25.125 Landing.	
(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_{SR0} with the most critical of the landing ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with § 25.21(g), if that speed exceeds V_{REF} selected for non-icing conditions by more than 5 knots CAS; and~~ **A speed determined by one of the following;** **(1)** 1.23 V_{SR0} with the most critical of the landing ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with § 25.21(g), if that speed exceeds V_{REF} selected for non-icing conditions by more than 5 knots CAS**; or** **(2) 1.17 V_{MIN1G} or, at the option of the applicant, 1.23 V_{SR0} – 5 knots CAS, with the most critical of the landing ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with § 25.21(g), if compliance is shown to §§ 25.202 and 25.204.** (C) A speed that provides the maneuvering capability specified in § 25.143(h) with the most critical of the landing ice accretion(s) defined in Appendices C and O of this part, as applicable, in accordance with § 25.21(g).	(B)(1) is the basic requirement for non HALF (B)(2) For HALF: minimal Vref icing value based on , at the choice of the applicant, either 1.17 Vmin1g ice or **1.23 $V_{SR0\ ice}$ – 5 knots CAS** . These values are based on OEMs best practice and are covering both options that may take an applicant : either produce for certification a VSR ice or a Vmin1gice

Attachment 2C Recommended Guidance Material

Proposed changes to AC 25-25A

Note: At the option of the applicant VSR in non icing may be used when showing compliance for conditions specified as a factor of VSR for the following paragraphs : 25.145(b)(c), 25.147(a)(b)(c)(e), 25.161(b)(c)(d), 25.175(a)(b)(c)(d), 25.177(a)(b), 25.181(a)(b), and 25.231(a)(2)

CHAPTER 2. REQUIREMENTS AND GUIDANCE

2.1 Overview

2.1.12 SLD icing conditions, or runback ice in any icing condition, can cause a ridge of ice to form aft of the protected area on the upper surface of the wing. This can lead to separated airflow over the aileron. Ice-induced airflow separation upstream of the aileron can have a significant effect on aileron hinge moment. Depending on the extent of the separated flow and the design of the flight control system, ice accretion upstream of the aileron may lead to aileron hinge moment reversal, reduced aileron effectiveness, and aileron control reversal. Although airplanes with deicing boots and unpowered aileron controls are most susceptible to this problem, all airplanes should be evaluated for roll control capability in icing conditions. Acceptable flight test procedures for checking roll control capability are presented in paragraphs 4.9.3, 4.15, and 4.17.2.5 (or 4.18.2.5 for airplanes where compliance is shown to §§25.202 and 25.204) of this AC and consist of bank-to-bank roll maneuvers, steady heading sideslips, and rolling maneuvers at stall warning speed or AOA limit, as applicable.

2.2 Proof of Compliance, §25.21(g)

2.2.3 If different stall warning system or stall identification system activation settings, or different High Angle-of-Attack Limiting Function AOA limits, if so equipped, are used for flight in icing conditions (for example, if the stall warning or stall identification system activation settings or AOA limits are changed when the ice protection system is activated), it is acceptable to return to the non-icing settings/AOA limits when the critical wing surfaces are free of ice. The applicant should validate that the means for determining when the critical wing surfaces are free of ice accretions is reliable under all expected operating conditions.

2.5 Reference Stall Speed, § 25.103.

Certification experience in meeting this requirement has shown that, for airplanes of conventional design, the effects of Mach number on stall speeds is unaffected by the presence of ice accretions. For airplanes equipped with a High Angle-of-Attack Limiting Function (HALF) that meets the requirements of §§ 25.202 and 25.204, determination of reference stall speeds in icing conditions is at the option of the applicant and would only be necessary if V_{SR} in icing conditions is used as a factor to determine compliance with a required performance standard, as allowed by § 25.103(b)(3) and the performance standards of sections 25.105(a)(2), 25.107(c)(g), 25.121(b)(2)(ii), 25.121(c)(2)(ii), 25.121(d)(2)(ii), 25.123(a), 25.123(b)(2), 25.125(b)(2)(ii).

§25.103(e) for High Angle-of-Attack Limiting Function (HALF) equipped airplanes requires that the 1g minimum steady flight speed, V_{MIN1g}, be determined in icing conditions if it is used to determine compliance with a required performance standard or other requirement in icing conditions.

If V_{SR} or V_{MIN1g} is to be established, it must be determined for all aerodynamic configurations for which it is to be used to show compliance (e.g., takeoff, en route, approach, and landing configurations) with the appropriate ice accretion for that flight phase specified in Part II of Appendix C.

2.6 Takeoff, §25.105 and Climb: One-engine-inoperative, §25.121:

2.6.1 Performance - Takeoff Path Determination

Inclusion of the effects of ice during the determination of the takeoff path and takeoff performance parameters must be in accordance with §§ 25.105(a) and 25.121(b) and (c) which include ice accountability thresholds based on a relative increase in the reference stall speed or degradation in climb gradient due to ice. If any of the applicable ice accountability thresholds are exceeded, the airplane performance for the entire takeoff path, including takeoff speeds and distances, must be determined with ice accretions on the airplane.

2.6.2 The gradient degradation threshold contained in these sections only refers to the degradation due to aerodynamic effects of ice accretion. Propulsive effects are accounted for separately when computing of the takeoff thrust with anti-ice operating.

2.~~6~~7 **Failure Conditions, § 25.1309.**

2.~~6~~7.1 The applicant should analyze failure modes of the ice protection………..
2.~~6~~7.2 The guidance in this AC for a normal (that is, non-failure)……….
2.~~6~~7.3 For probable ice protection failure conditions annunciated ………..
2.~~6~~7.4 For failure conditions that are improbable……….

2.~~7~~8 Flight Related Systems.

2.~~7~~8.1 Ice protection systems …
2.~~7~~8.2 Ice may block control surface gaps …
2.~~7~~8.3 Ice may block unprotected inlets …
2.~~7~~8.4 Airspeed, altitude, or angle-of-attack sensing errors …

2.~~7~~8.5 There may be an effect on operation of stall warning, stall identification and/or a High Angle-of-Attack Limiting Function ~~reset features~~ for flight in icing conditions, including effects of failure to operate.

2.~~7~~8.6 Operation of icing condition …
2.~~7~~8.7 Flight guidance …
2.~~7~~8.8 There may be an effect on installed thrust …

2.~~8~~9 Airplane Flight Manual, § 25.1581 through § 25.1587.

2.~~8~~9.1 Section 25.1581 states …
2.~~8~~9.1.1 The limitations required …
2.~~8~~9.1.2 Performance limitations …
2.~~8~~9.1.3 All airspeed limitations …
2.~~8~~9.1.4 As applicable …
2.~~8~~9.1.5 For turbojet airplanes …
2.~~8~~9.2 To comply with § 25.1583(e)…
2.~~8~~9.3 For airplanes not certified …
2.~~8~~9.4 To comply with § 25.1585…
2.~~8~~9.4.1 Flight in icing conditions …
2.~~8~~9.4.2 Normal operating procedures …
2.~~8~~9.4.3 For turbojet airplanes without …
2.~~8~~9.4.4 Non-normal operating procedures …
2.~~8~~9.5 Performance information …

2.~~8~~ 9.6 Examples of AFM limitations …

4.2 Reference Stall Speed and V_{MIN1g} Determination, § 25.103.

4.2.1 The reference stall speed, V_{SR}, or the minimum steady flight speed, V_{MIN1g}, for intermediate high lift configurations (for takeoff configurations, for example) can normally be obtained by interpolation. However, additional tests may be necessary if—

4.2.1.1 A stall identification system (for example, a stick pusher) activation point or High Angle-of-Attack Limiting Function (HALF) AOA limit is set as a function of the high lift configuration,

4.2.1.2 The activation point or HALF AOA limit ~~is reset~~ adjusted for icing conditions, or

4.2.1.3 Significant configuration changes occur with extension of trailing edge flaps (such as extension of wing leading edge high lift devices).

4.2.2 Acceptable Test Program.

The following specifications represent an example of an acceptable test program subject to the provisions outlined paragraph 4.2.1 of this AC.

Maneuvers

4.2.2.1 Load the airplane to a forward center-of-gravity position appropriate to the airplane configuration.

4.2.2.2 Conduct the test at the reference stall speed test altitude used in non-icing tests.

4.2.2.3 Trim in level flight at an initial speed of 1.13 to 1.30 V_{SR} or 1.13 to 1.3 V_{MIN1g}, as applicable. If determining VSR, decrease speed at a rate not to exceed 1 knot per second until an acceptable stall identification as defined in § 25.201(d) or the angle of attack corresponding to V_{SR} is obtained; or until activation of a stall identification device (e.g., stick pusher), if installed. If determining V_{MIN1g}, decrease speed at a rate not to exceed 1 knot per second until the longitudinal control reaches the aft stop and the airplane has reached a stabilized flight condition from which V_{MIN1g} can be determined. Perform this maneuver with the following ice accretions:

4.2.2.3.1 In high lift devices retracted configuration—final takeoff ice.

4.2.2.3.2 In high lift devices retracted configuration—en route ice.

4.2.2.3.3 In holding configuration—holding ice.

4.2.2.3.4 In lowest lift takeoff configuration—holding ice.

4.2.2.3.5 In highest lift takeoff configuration—takeoff ice.

4.2.2.3.6 In highest lift landing configuration—holding ice.

4.4 **Takeoff Path, § 25.111.**

In accordance with § 25.105(a), the applicant should conduct takeoff evaluations to substantiate the speed schedule and distances for takeoff in icing conditions if the following applies:

4.4.1 VSR in the configuration defined by § 25.121(b) with the takeoff ice accretion exceeding VSR for the same configuration without ice accretions by more than the greater of 3 knots or 3 percent, if compliance is not shown to §25.202 and § 25.204

4.4.2 Any need for a takeoff speed increase, and any effects of thrust loss or drag increase on the takeoff path, may be determined by a suitable analysis.

4.9 Controllability and Maneuverability -- General, § 25.143.

4.9.3 Evaluation of Lateral Control Characteristics.

Aileron hinge moment reversal and other lateral control anomalies have been identified as causal factors in icing accidents and incidents. The following maneuvers, along with the following two evaluations, are intended to determine susceptibility of the airplane to aileron hinge moment reversals or other adverse effects on lateral control characteristics due to ice accretion.

Evaluations

4.9.3.1 Evaluate lateral controllability during deceleration to the stall warning speed (covered in paragraph 4.17.2.5 of this AC) or to the AOA Limit if a High Angle-of-Attack Limiting Function is included and compliance is shown with §§25.202 and 25.204 (covered in paragraph 4.18.2.5 of this AC), and

4.9.3.2 Evaluate static lateral-directional stability (covered in paragraph 4.15 of this AC).

4.9.5 Controllability Prior to Activation and Operation of the Ice Protection System.

The following is an example of an acceptable test program for showing compliance with § 25.143(j).

During the pull-up maneuvers, controllability must be acceptable throughout the maneuver. At no time should airplane exhibit hazardous characteristics, and the airplane must maintain good lateral and directional control and it must always be possible to reduce AOA by conventional use of the controls. During the push-over maneuvers, the longitudinal control forces must not reverse and there should be no uncommanded pitch response. If necessary, the pull-up maneuvers may be limited to the point at which stall warning occurs (if compliance is shown with §25.207) or to activation of another suitable warning alert in accordance with §25.1322, to the point where control inceptor constraints are encountered or as limited by a High Angle-of-Attack Limiting Function, if installed.

Maneuvers

4.9.5.1 For the configurations, speeds, and power settings listed below, with the ice accretion specified in the requirement, trim the airplane at the specified speed, conduct a pull-up maneuver to 1.5 g and pushover maneuver to 0.5 g, and show that longitudinal control forces do not reverse.

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

4.9.5.1.2 Landing configuration, V_{REF} for non-icing conditions, power or thrust for landing approach. ~~If necessary, limit the pull-up maneuver to the point at which stall warning occurs.~~

4.9.6 Maneuver Margin in Icing Conditions.

The following is an example of an acceptable test program for showing compliance with § 25.143(h).

Maneuvers

4.9.6.1 Load the airplane to a forward center-of-gravity position appropriate to the airplane configuration.

4.9.6.2 Trim the airplane at the specified test speed to be used for operation in icing conditions at the gross weight and thrust as specified, accounting for drag due to the applicable ice accretion and any thrust effects due to ice protection operation, as appropriate.

4.9.6.3 Achieve the specified bank angle in a coordinated turn and confirm that stall warning or any other characteristic (including the envelope protection features of fly-by-wire flight control systems or automatic power or thrust increases) that might interfere with normal maneuvering are not encountered. Perform the maneuvers specified by § 25.143(h) with the following configurations and ice accretions at the scheduled operating speeds for operating in icing conditions:

4.9.6.3.1 30º deg banked turn at V_2 for each approved takeoff configuration — takeoff ice.

4.9.6.3.2 40º banked turn at V_{2+XX} for each approved takeoff configuration — takeoff ice.

4.9.6.3.3 40º banked turn at V_{FTO} in the en route configuration — final takeoff ice.

4.9.6.3.4 40º banked turn at V_{ER} in the en route configuration — en route ice.

4.9.6.3.5 40º banked turn at V_{REF} for each approved landing configuration — holding ice.

4.10 Longitudinal Control, § 25.145.

4.10.1 No specific quantitative evaluations are required for demonstrating compliance with § 25.145(b) and (c). Qualitative evaluations should be combined with the other testing. Review results of tests on the uncontaminated airplane for any cases of marginal compliance. All tests showing marginal compliance should be repeated with ice accretions on the airplane.

4.10.2 Acceptable Test Program.
The following specifications represent an example of an acceptable test program for compliance with § 25.145(a).

Maneuvers

4.10.2.1 The holding ice accretion should be used.

4.10.2.2 The airplane is at a medium to light weight, aft center-of-gravity position, with symmetric fuel loading.

4.10.2.3 In the configurations listed below, trim the airplane at 1.3 V_{SR}. Reduce speed approximately 1 knot per second using elevator control to 1 second past stall warning with airplanes for which compliance is shown to § 25.207 or one second after achieving full aft control input with airplanes for which compliance is shown with §§ 25.202 & 25.204, and demonstrate prompt recovery to the trim speed using elevator control.

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

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

4.17 Stall Demonstration, § 25.201/Stall Characteristics, § 25.203.

4.17.1 For an airplane where compliance is shown to §§ 25.201 & 25.203, t~~T~~he applicant should conduct sufficient stall testing to demonstrate that the stall characteristics comply with the requirements of §§ 25.201 and 25.203…..

4.18 Handling demonstrations for high angle-of-attack limiting functions, § 25.202/Flight Characteristics for High angle-of-Attack Limiting Functions, § 25.204.

4.18.1 For an airplane where compliance is shown to §§ 25.202 & 25.204, the applicant should conduct sufficient testing with simulated ice accretions to demonstrate that the flight characteristics up to the AOA limit comply with the applicable requirements of §§ 25.202 and 25.204 in icing conditions.

In addition, § 25.202(e) requires that flight characteristics up to the angle-of-attack corresponding to V_{SR} (if determined) or the maximum angle-of-attack achieved during the dynamic maneuver of § 25.202(d)(1)-(4) be conducted in icing conditions per the procedures described below in sections 4.18.2.1-4.18.2.4 and the resulting characteristics shown to comply with the requirements of § 25.204(f). At the option of the applicant, this testing may be conducted with the High Angle-of-Attack Limiting Function deactivated (disabled) or adjusted to a higher AOA-limit.

In general, it is not necessary to conduct a test program that encompasses all weights, center-of-gravity positions, altitudes, high lift configurations, deceleration device configurations, straight and turning flight attitudes, and thrust or power settings. The applicant can establish a reduced test matrix based on a review of the high AOA characteristics of the uncontaminated airplane. However, additional tests may be necessary if --

4.18.1.1 The high AOA characteristics with ice accretion show a significant difference from those on the uncontaminated airplane,

4.18.1.2 The testing indicates borderline compliance, or

4.18.1.3 The AOA limit of the HALF is adjusted for icing conditions.

4.18.2 Acceptable Test Program.

The requirements of 25.202(d)(4) specify maneuvers with increased entry rates to the AOA limit in icing conditions up to 3 kts/sec. If dynamic application of go-around thrust at any time following initiation of the deceleration to the time at which the longitudinal control reaches the aft stop would result in higher peak angle-of-attack during this increased entry rate test, these tests for landing configuration must also be conducted with the most critical dynamic thrust application.

Note that slower decelerations (much slower than 1 knot per second) may be critical on airplanes with anticipation logic in their HALF design or on airplanes with low directional stability, where large sideslip angles could develop. The following specifications represent an example of an acceptable test program subject to the provisions outlined above.

Maneuvers

4.18.2.1 The holding ice accretion should be used.

4.18.2.2 The airplane should be loaded to a medium to light weight, aft center-of-gravity position, with symmetric fuel loading.

4.18.2.3 The tests should be conducted at the normal high AOA handling test altitude.

4.18.2.4 In the configurations listed in paragraphs 4.18.2.4.1 through 4.18.2.4.4 below, and each other configuration if deemed more critical, trim the airplane at the same initial airspeed ratio as was used for stall reference speed or V_{MIN1g} determination in icing. For power on maneuvers, use the power setting as defined in § 25.202(b)(2)(ii), but with ice accretions on the airplane.

Decrease speed at entry rates of 1 and 3 knots per second to the AOA limit and recover using the same recovery maneuver as for the uncontaminated airplane.

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

4.18.2.4.2 Lowest lift takeoff configuration: Straight/Power On, Turning/Power Off.

4.18.2.4.3 Highest lift takeoff configuration: Straight/Power Off, Turning/Power On.

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

4.18.2.5 For the configurations listed in paragraphs 4.18.2.4.1 and 4.18.2.4.4 above, and each other configuration if deemed more critical, at a stabilized condition at the AOA limit with wings level and power off, roll the airplane left and right up to 10° of bank using the lateral control using approximately 5°/sec roll rate.

4.18.2.6 If considered more critical, the increased entry rate (3 knots per second) tests of 4.18.2.4 should be repeated for the highest lift landing configuration with rapid application of go-around power or thrust at any time following initiation of the maneuver to the time at which the longitudinal control reaches the aft stop.

4.18.2.7 For compliance with §§ 25.202(e) and 25.204(f), flight characteristics testing to the applicable maximum AOA should be conducted for the configurations listed in paragraphs 4.18.2.4.1 and 4.18.2.4.4 above. This is to be done in wings-level flight with a deceleration from the trim speed of not more than 1 kt/sec.

4.18.3 Flight in Icing Conditions Prior to Activation and Operation of the Ice Protection System

Provided that the time from entry into icing conditions until the ice protection system is activated and performing its intended function is sufficiently brief, as described in Appendix A paragraph A.2.3 of this AC, the following represents an acceptable means for showing compliance with §25.202(d)(5). The deceleration maneuvers below are to extend until encountering the first of the following, representing the lowest operational airspeed under normal operation:

d) A suitable warning alert, in accordance with §25.1322, followed by normal recovery input delayed by 1 second;
e) A suitable caution alert, in accordance with §25.1322, combined with engagement of an automatic protection function that operates to deter further reduction in airspeed, followed by normal recovery input delayed by 3 seconds; or
f) The aft control stop, followed by normal recovery input delayed by 3 seconds.

§25.1322(c)(2) specifies that warning and caution alerts must provide cues through at least two different senses with a combination of aural, visual or tactile indications. A stick shaker, used in combination with a High Angle-of-Attack Limiting Function, that includes clearly distinguishable aural component, or that is combined with warning level display cues, is considered an example of a suitable warning alert consistent with (a) above. When combined with a caution level alert, an automatic low speed or low energy protection system that engages to deter further airspeed reduction, either through automatic thrust/power advance or control system characteristics that deter further deceleration, are considered examples of designs consistent with (b) above.

Depending on the included automatic systems or if the maneuver is to be continued until achieving the aft control stop, it is not expected that the specified deceleration can be continued for the 1 or 3 seconds beyond engagement of the automatic protection or limit. During the 1 or 3 seconds prior to normal pilot recovery inputs, the pilot force inputs should be continued in the sense and rate as that applied approaching the engagement point.

Maneuvers

4.18.3.1 In the configurations listed in paragraphs 4.18.3.1.1 and 4.18.3.1.2 below, with the ice accretion specified in the requirement, trim the airplane at 1.3 V_{SR} or 1.3 V_{MIN1g} for non-icing conditions, as applicable.

4.18.3.1.1 High lift devices retracted configuration: Straight Flight/Power Off or Power On, if more critical.

4.18.3.1.2 Landing configuration: Straight Flight/Power Off or Power On, if more critical.

4.18.3.2 At deceleration rates of up to 1 knot per second, reduce the speed until encountering the first of the following and demonstrate that stalling can be prevented using a normal recovery technique without encountering any adverse characteristics (for example, rapid wing roll-off).

d) A suitable warning alert, followed by normal recovery input delayed by 1 second;
e) A suitable caution alert, combined with engagement of an automatic protection function that operates to avoid further reduction in airspeed, followed by normal recovery input delayed by 3 seconds; or
f) The aft control stop, followed by normal recovery input delayed by 3 seconds.

4.~~18~~ 19 Stall Warning, § 25.207.

4.~~18~~ 19.1 To show compliance with § 25.207(a)-(i), the applicant should assess stall warning in conjunction with stall speed testing and stall demonstration/characteristics testing (§§ 25.103, 25.201, and 25.203, and paragraphs 4.2 and 4.17 of this AC, respectively), and in tests with faster entry rates, as defined in Section 4.19.2 below.
For airplanes equipped with a High Angle-of-Attack Limiting Function that meets the requirements of §§ 25.202 and 25.204, the stall warning requirements of §25.207 (j) must be met following failure of the function. In icing conditions, the stall warning must be shown to provide sufficient margin to prevent encountering unacceptable characteristics and encountering stall. An example of an acceptable test program for showing compliance with §25.207(j)(2) is provided in Section 4.19.4 below.

4.~~18~~ 19.2 Normal Ice Protection System Operation
The following specifications represent an example of an acceptable test program for stall warning in slow-down turns of at least 1.5 g and at entry rates of at least 2 knots per second: ……..

4.~~18~~ 19.3 Stall Warning Prior to Activation and Operation of the Ice Protection System
The following represents an acceptable means for showing compliance with § 25.207(h)………..

4.19.4 Stall Warning Following Failure of a High Angle-of-Attack Limiting Function
The following represents an acceptable means for showing compliance with § 25.207(j).

Maneuvers

4.19.4.1 The holding ice accretion should be used.

4.19.4.2 The airplane should be loaded to a medium to light weight, aft center-of-gravity position, with symmetric fuel loading.

4.19.4.3 The test should be conducted at the normal high AOA handling test altitude.

4.19.4.4 In the configurations listed in paragraphs 4.19.4.4.1 through 4.19.4.4.3 below, and each other configuration if deemed more critical, trim the airplane in straight flight at the minimum recommended airspeed following failure of the HALF, with idle power/thrust. In both straight and 30º banked turning flight, decrease speed at a rate not exceeding 1 kt/sec until 3 second after stall warning and recover using the same recovery maneuver as for the uncontaminated airplane.

4.19.4.4.1 High lift devices retracted configuration.

4.19.4.4.2 Approach configuration appropriate to the highest lift landing configuration.

4.19.4.4.3 Highest lift landing configuration.

4.~~21~~ 22 Natural Icing Conditions, § 25.1419(b).

To show compliance with this requirement, the applicant should perform additional flight testing…..

4.~~21~~ 22.3 Acceptable Test Program.

During each of the maneuvers specified in paragraph 4.21.4 below, the behavior of the airplane should be consistent with that obtained with simulated ice accretions. 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.

Maneuvers

4.~~21~~ 22.4 Ice Accretion Maneuvers.

4.~~21~~ 22.4.1 Holding scenario.

4.~~21~~ 22.4.1.1 The maneuvers specified in table 4-4 below should be carried out with ice accretions defined in paragraphs 4.21.4.1.2 and 4.21.4.1.3 below, which is representative of normal operation of the ice protection system:

4.~~21~~ 22.4.1.2 Ice on unprotected parts. A target accretion thickness equivalent to the 45-minute dry air ice accretions on an unprotected part of the wing should be the objective. (A thickness of 2 inches is normally a minimum value, unless a lesser value is agreed to with the responsible ACO).

4.~~21~~ 22.4.1.3 Ice on protected parts. The ice accretion thickness should be that resulting from normal operation of the ice protection system.

4.~~21~~ 22.4.1.4 For airplanes with control surfaces that may be susceptible to jamming due to ice accretion (for example, elevator horns exposed to the air flow), the holding speed that is critical with respect to this ice accretion should be used.

Table 4-4. Holding Scenario—Maneuvers

Airplane Configuration	Center-of- Gravity Position	Trim Speed**	Maneuver
Flaps up, Gear up	Any position in the aft range	Holding, except 1.3 V_{SR} or 1.3 V_{MIN1g} for the stall maneuver	Level, 40° banked turn; Bank-to-bank rapid roll, 30° - 30°; Speedbrake extension, retraction; Full straight stall Wings level deceleration at 1 knot per second to stall ID or HALF AOA limit (1 knot per second deceleration rate, wings level, power off)
Flaps in Intermediate positions, gear up	Any position in the aft range	1.3 V_{SR} or 1.3 V_{MIN1g}	Deceleration Wings level deceleration at 1 knot per second to the speed reached 3 seconds after activation of stall warning in a 1knot per second deceleration, or to full aft control input for 3 second if no §25.207 compliant stall warning is provided
Landing flaps, gear down	Any position in the aft range	V_{REF}	Level, 40° banked turn; Bank-to-bank rapid roll, 30° - 30°; Speedbrake extension, retraction (if approved); Full straight stall Wings level deceleration at 1 knot per second to stall ID or HALF AOA limit (1 knot per second deceleration rate, wings level, power off)

4. .21 22.4.2 Approach/Landing Scenario.

4. .21 22.4.2.1 The maneuvers specified in table 4-5 of this AC should be carried out with successive accretions in different configurations on unprotected surfaces.

4. .21 22.4.2.2 Each test condition should be accomplished with the ice accretion that exists at that point.

4. .21 22.4.2.3 The final ice accretion (Test Condition 3) represents the sum of the amounts that would accrete during a normal descent from holding to landing in icing conditions.

Table 4-5. Approach/Landing Scenario—Maneuvers

Test Condition	Ice Accretion Thickness*	Airplane Configuration	Center-of-Gravity Position	Trim Speed**	Maneuver
—	First 0.5 inch	Flaps up, gear up	Any position in the aft range	Holding	No specific test
1	Additional 0.25 inch (0.75 inch total)	First intermediate flaps, gear up	Any position in the aft range	Holding, except 1.3 V_{SR} or 1.3 V_{MIN1g} for the deceleration maneuver	Level 40° banked turn; Bank-to-bank rapid roll, 30°- 30°; Speed brake extension and retraction (if approved); Wings level deceleration at 1 knot per second ~~Deceleration~~ to the speed reached 3 seconds after activation of stall warning ~~in a 1 knot per second deceleration~~, or to full aft control input for 3 second if no §25.207 compliant stall warning is provided.
2	Additional 0.25 inch (1.00 inch total)	Further intermediate flaps, gear up (as applicable)	Any position in the aft range	1.3 V_{SR} or 1.3 V_{MIN1g}	Bank-to-bank rapid roll, 30° - 30°; Speed brake extension and retraction (if approved); ~~Deceleration~~Wings level deceleration at 1 knot per second to the speed reached 3 seconds after activation of stall warning ~~in a 1 knot per second deceleration~~, or to full aft control input for 3 second if no §25.207 compliant stall warning is provided.
3	Additional 0.25 inch (1.25 inch total)	Landing flaps, gear down	Any position in the aft range	V_{REF}	Bank-to-bank rapid roll, 30° - 30°; Speed brake extension and retraction (if approved), Bank to 40°; ~~Full straight stall~~ Wings level deceleration at 1 knot per second to stall ID or HALF AOA limit (~~1 knot per second deceleration rate, wings level,~~power off).

* The indicated thickness is that accumulated on the parts of the unprotected airfoil most likely to accumulate ice.

**In Tables 4-4 and 4-5 above, the applicant may use non icing VSR for scheduling the trim speed conditions

4.~~22~~ 23 Failure Conditions, § 25.1309.
To show compliance with this requirement:

4.~~22~~ 23.1 For failure conditions that are annunciated to the flightcrew, the applicant may take credit for flightcrew action to follow the established operating procedures provided in the AFM.

4.~~22~~ 23.2 Acceptable Test Program.
In addition to a general qualitative evaluation, the applicant should carry out the following test program for the most critical, probable failure condition for which the associated procedure requires the airplane to exit the icing condition. The test program should be modified as necessary to reflect the specific operating procedures.

Maneuvers

4.~~22~~ 23.2.1 The ice accretion is defined as a combination of the following:

4.~~22~~ 23.2.1.1 Ice on unprotected surfaces. The holding ice accretion described in paragraph A.2.1.3 of appendix A of this AC.

4.~~22~~ 23.2.1.2 Ice on normally protected surfaces that are no longer protected. The failure ice accretion described in paragraph A.3.2 of appendix A of this AC.

4.~~22~~ 23.2.1.3 Ice on normally protected surfaces that are still protected following segmental failure of a cyclical deice system. The ice accretion that will form during the rest time of the deice system following the critical failure condition.

4.~~22~~ 23.2.2 The airplane should be loaded to a medium to light weight, at aft center-of-gravity position, with symmetric fuel loading.

4.~~22~~ 23.2.3 In the configurations listed in paragraphs 4.~~22~~ 23.2.3.1 through 4.~~22~~ 23.2.3.3 below, trim the airplane at the specified speed. Conduct 30° banked turns left and right with normal reversals. Conduct a pull-up maneuver to 1.5 g and a pushover maneuver to 0.5 g.

4. ~~22~~ 23.2.3.1 High lift devices retracted configuration (or holding configuration if different): Holding speed, power or thrust for level flight. In addition, deploy and retract the deceleration devices.

4.~~22~~ 23.2.3.2 Approach configuration: Approach speed, power or thrust for level flight.

4.~~22~~ 23.2.3.3 Landing configuration: Landing speed, power or thrust for landing approach (limit pull-up to 1.3 g). In addition, conduct steady heading sideslips to the angle of sideslip appropriate to the airplane type and the AFM landing procedure.

4.~~22~~ 23.2.4 In the configurations listed in paragraphs 4.~~22~~ 23.2.4.1 and 4.~~22~~ 23.2.4.2 below, trim the airplane at the estimated 1.3 V_{SR} (the applicant may use non icing Vsr) or 1.3 V_{MIN1g}. Decrease speed at approximately 1 knot per second until 1 second after stall warning or until the High Angle-of-Attack Limiting Function AOA limit is reached if so equipped and no §25.207 compliant stall warning is provided, and demonstrate prompt recovery using the same recovery maneuver as for the uncontaminated airplane. It is acceptable for stall warning to be provided by a different means (for example, by the behavior of the airplane rather than by stick shaker) for failure cases not considered probable.

4.~~22~~ 23.2.4.1 High lift devices retracted configuration: Straight Flight/Power Off.

4.~~22~~ 23.2.4.2 Landing configuration: Straight Flight/Power Off.

4.~~22~~ 23.2.5 Conduct an approach and go-around with all engines operating using the AFM approach and go-around procedure.

4.~~22~~ 23.2.6 Conduct an approach and landing with all engines operating (unless the one-engine-inoperative condition results in a more critical probable failure condition) using the appropriate AFM approach and landing procedure.

4.~~22~~ 23.3 For improbable failure conditions, flight testing may be required to demonstrate that the effect on safety of flight (as measured by degradation in flight characteristics) supports the system safety analysis, or to verify results of analyses or wind tunnel tests. The extent of each required flight testing should be similar to that described in paragraph 4.22.3 above, or as agreed to by the responsible ACO for the specific failure condition.

APPENDIX A. AIRFRAME ICE ACCRETIONS

A.2.3 Ice Accretions Before Activation and Effective System Operation

A.2.3.1 When considering the ice accretion before the ice protection system has been activated and is performing its intended function, you should take into account the means of activating the ice protection system and the system response time. However, if artificial stall warning or a High Angle-of-Attack Limiting Function is provided and the point at which stall warning is initiated or the AOA limit changes when the ice protection system is activated, then the pre-activation ice accretion used to evaluate the “clean” stall warning or AOA Limit schedule does not need to include consideration of the ice protection system response time. System response time is defined as the time interval between activation of the system and its effective operation (for example, for a thermal ice protection system used for deicing, the time to heat the surface and perform its deicing function). If activation of the ice protection system depends on flightcrew recognition of icing conditions or response to a cockpit annunciation, appropriate delays in identifying the icing conditions and activating the ice protection system should be taken into account. For the icing conditions of Appendix C, the airplane should be assumed to be in continuous maximum icing conditions during the time between entering the icing conditions and effective operation of the ice protection system.

It is intended that the time from entry into icing conditions until activation and normal operation of the ice protection system is brief, such that exposure to the reduced standards for stall prevention permitted with this ice accretion is minimal. For compliance with §25.202(d)(5), if this time is not sufficiently brief and consistent with the intent, it is required that compliance with the requirements of §25.202(d)(1)-(4) in icing conditions be met in lieu of §25.202(d)(5). For the purposes of §25.202(d)(5) compliance, the "brief" exposure time should not be more than approximately 5 minutes while operating in any icing condition within the Appendix C Continuous Maximum envelope.

A.4.2 Ice Accretions for Encounters with Appendix O Conditions Beyond those in Which theAirplane is Certified to Operate

A.4.2.1 Use the ice accretions in table A-1 below, to evaluate compliance with the applicable subpart B requirements for operating safely after encountering Appendix O atmospheric icing conditions for which the airplane is not approved, and then safely exiting all icing conditions.

A.4.2.2 These ice accretions apply when the airplane is not certified for flight in any portion of Appendix O atmospheric icing conditions, when the airplane is certified for flight in only a portion of Appendix O conditions, and for any flight phase for which the airplane is not certified for flight throughout the Appendix O icing envelope.

A.4.2.3 Table A-1 shows the scenarios to be used for determining ice accretions for certification testing of encounters with Appendix O conditions beyond those in which the airplane is certified to operate (for detecting and exiting those conditions).

Table A-1. Appendix O Detect-and-Exit Ice Accretions per Flight Phase

Flight Phase/ Condition	**Appendix O Detect-and-Exit Ice Accretion**
Ice Accretion Before the Ice Protection System Has Been Activated and is Performing its Intended Function	Ice accreted on protected and unprotected surfaces during the time it takes for icing conditions (either Appendix C or Appendix O) to be detected, the ice protection system to be activated, and the ice protection system to become fully effective in performing its intended function. (Note: If artificial stall warning or a High Angle-of-Attack Limiting Function is provided and the initiation point of that warning or the AOA limit changes when the ice protection system is activated, this ice accretion does not need to include consideration of the time it takes for the ice protection system to be effective in performing its intended function.)

Attachment 2D Rule/ Special Conditions differences summary Table

Paragraph	FAR 25/CS25 – basic conventional a/c	A350 SC paragraphs	Harmonised criteria SC A350 EASA/FAA	ANAC -SC Embraer	TCCA-SC C-Series
25.103 : Stall speed	Determination of reference stall speed in non icing and in icing conditions	Minimum steady flight speed and Reference stall speed (Part I §3)	- Non icing : determination Vclmax/VSR and Vmin1g	same A350 Vclmax/VSR and Vmin1g	same A350 but VCLdemo → used to determine VSR
			- Icing : determination Vmin1gice	Vclmaxice /VSRice and VMin1g ice	VMin1g ice
25.201 : stall demonstra tion	Non icing : - 1kt/s straight & turning - 3kt/s turning Power Off and On	High incidence Handling demonstration (robustness protection check) (Part I§5.1)	Non icing : - 1kts straight & turning - max decel rate* with & without power application (§5.1) (*) straight + avoidance maneuver(stick in the corner)	1kts straight & turning max decel rate	1kts straight & turning max decel rate +3 additional maneuvers : - 2kts/s Slowdown turn 1.5g -Slow decel at hi pitch -MCT &hi pitch rate/hi AOA/hi thrust application
	Icing : -1 kt/s straight & turning Power Off and On		Icing : -1 kt/s straight and turning - 3 kt/s straight & turning with & without power application Pre activation ice :-1kt/s up to FBS with & without power application	-1 kt/s straight and turning Max decel rate Pre activation ice : -1kt/s up to FBS	-1 kt/s straight and turning -3 kts/s straight & turning, +3 additional maneuvers : -2kts/s Slowdown turn 1.5g -Slow decel at hi pitch -MCT &hi pitch rate/hi AOA/hi thrust application Pre activation ice : -1kt/s up to FBS

25.203 : stall characteristics	Non icing & icing : 1kt/s Non icing: 3kt/s No reversed controls No abnormal pitch-up Ability to promptly recover straight f<20º 1tk/s Turning: 30 º < f<60º 3tk/s Turning: 60 º < f<90º	Characteristics in High Incidence (Part I§5.2)	Non icing : 1kt/s & max decel rate straight & turning	Non icing : 1kt/s & max decel rate	Non icing : 1kt/s & max decel rate
			Icing : 1kt/s & 3kt/s straight & turning with & without power application Non icing and icing : increased rates Some degradations OK No abnormal pitch up No uncommanded pitch dwn Maintain good lat/dir control No deterrent buffet High decel: no deterrence from holding control on the aft stop	1kt/s & max decel rate	3 kts/s straight & turning, +3 additional maneuvers : -2kts/s Slowdown turn 1.5g -Slow decel at hi pitch -MCT &hi pitch rate/hi AOA/hi thrust application
		Characteristics up to maximum lift angle of attack (PartI§5.3) (HAP deactivated or shifted)	Non icing : decel 1kt/s up to Clmax Straight and turning No dangerous characteristics Maintain good control – all axes	Non icing : decel 1kt/s up to Clmax straight & turning	Non icing : decel 1kt/s up to Clmax/Cldemo straight & turning
			Icing : decel 1kt/s up to max AOA achieved during all robustness checks with ice (3 kt/sec condition) Straight only No dangerous characteristics Maintain good control – all axes	Icing : 1kt/s up to the max AOA achieved in non icing	decel 1kt/s up to max AOA achieved during all robustness checks with ice:

25.207 : stall warning	Non icing : -1 kt/s, V_{SID}+5%, power off and On - 1 kt/s, V_{SR} +3%, idle - 2kt/s turning 1.5g SW+1s	High incidence protection system failure (Part I §4.2) Stall warning Must be provided and protect against encountering unacceptable characteristics and against encountering stall	Non icing: - 1 kt/s straight V_{SW}–5% idle - 3 kt/s turning, SW +1s (*) (*) idle	same A350	same A350
	Icing : -1 kt/s, V_{SID}+5%, in landing configuration - 1 kt/s, V_{SR} +3%, idle in landing configuration - 1 kt/s straight & turning, SW + 3s - 2kt/s turning 1.5g SW+ 1s Pre activation ice 1kt/s straight SW+1s 1kt/s turning , SW +1s if SW provided by same mean as for on icing Pre activation ice 1kt/s SW+3s if SW provided by different mean as for on icing		Icing: - 1 kt/s straight & turning, SW+ 3s, idle	same A350	same A350
105 Take-off	Take-off perfo in icing conditions to be provided in AFM if: - Effect of "Take-off" ice on VSR is more than max (3kt ; 3%) - Effect of "Take-off" ice on second segment climb gradient is more than ½ of actual-to-	Part II § 2	Take-off perfo in icing conditions to be provided in AFM if: - V2 scheduled in non-icing condition does not provide manoeuvring capability specified in CS/FAR 25.143(h) with "Take-off" ice shapes accreted - Effect of "Take-off" ice	same A350	same A350 + add: -If V2 non ice less than 1.08 Vmin1g ice*

	net take-off flight path reduction		on second segment climb gradient is more than ½ of actual-to-net take-off flight path reduction		
107 Take-off speeds	Same regulation in icing & non icing K VSR.	Part II §3	In addition to the basic requirement, clarification that V2 & VFTO in icing conditions: - Should not be lower than V2 & VFTO scheduled in non-icing conditions - Should meet manoeuvring capability of 143(h) requirement considering respectively "take-off" and "Final Take-off" ice shapes	same A350	same A350 + add : - takeoff V2 icing not less than 1.08 Vmin1g ice* - final takeoff VFTO icing not less than 1.16 Vmin1gice*
121(b) Climb OEI – 2nd segment	2nd segment climb perfo in icing conditions to be provided in AFM if: - Effect of "Take-off" ice on VSR is more than max (3kt ; 3%) - Effect of "Take-off" ice on second segment climb gradient is more than ½ of actual-to-net take-off flight path reduction	Part II §4	2nd segment perfo in icing conditions to be provided in AFM if: - V2 scheduled in non-icing condition does not provide manoeuvring capability specified in CS/FAR 25.143(h) with "Take-off" ice shapes accreted - Effect of "Take-off" ice on second segment climb gradient is more than ½ of actual-to-net take-off flight path reduction	2nd segment perfo in icing conditions to be provided in AFM if: - V2 scheduled in non-icing condition does not provide manoeuvring capability specified in CS/FAR 25.143(h) with "Take-off" ice shapes accreted	same A350 + add - If V2 non ice is less than 1.08 Vmin1g ice*

121(c) Climb OEI – Final Take-off	Final Take-off climb perfo in icing conditions to be provided in AFM if: - Effect of "Take-off" ice on VSR is more than max (3kt ; 3%) - Effect of "Take-off" ice on second segment climb gradient is more than ½ of actual-to-net take-off flight path reduction	Part II § 4	Final Take-off climb perfo in icing conditions to be provided in AFM if: - VFTO scheduled in non-icing condition does not provide manoeuvring capability specified in CS/FAR 25.143(h) with "Final Take-off" ice shapes accreted - Effect of "Take-off" ice on second segment climb gradient is more than ½ of actual-to-net take-off flight path reduction	similar 121(b)	same A350 + add - If VFTO non ice is less than 1.16 Vmin1g ice*
121(d) Climb OEI – Approach climb	- The VSR of approach (go-around) configuration should not be higher than 110% of the VSR of landing configuration - The approach (go-around) climb speed should be established in connection with normal landing procedure but not more than 1.4VSR - The approach (go-around) climb speed selected in non-icing conditions may be used in icing condition if the effect of "Approach" ice on the climb speed is lower than max (3kt, 3%)	Part II § 4	In icing conditions: - The Vmin1g of approach (go-around) configuration should not be higher than 110% of the Vmin1g * of landing configuration - The approach (go-around) climb speed should be established in connection with normal landing procedure but not more than 1.4VSR (VSR determined in non icing conditions)	same A350	same A350 + Approach climb speed Not less than 1.08 Vmin1gice *

123 En-route flight path	En-route flight path in icing conditions to be provided in AFM if: - Effect of “En-route ice” ice on VSR is more than max (3kt ; 3%) - Effect of “En-route” ice on en-route climb gradient is more than ½ of actual-to-net en-route flight path reduction	Part II §5	En-route flight path in icing conditions to be provided in AFM if: - Min En-route speed scheduled in non-icing condition does not provide manoeuvring capability specified in CS/FAR 25.143(h) with “En-route” ice shapes accreted - Effect of “En-route” ice on en-route climb gradient is more than ½ of actual-to-net en-route flight path reduction	similar 121(b)	same A350 + add - If min en-route speed is less than 1.16 Vmin1g ice*
125 Landing	Landing perf in icing conditions to be provided in AFM if : Effect of ‘landing ice’ on VREF is more than 5 kt In icing conditions, VREF may not be less than: - VREF determined in non-icing conditions - 1.23 VSR0 with the “landing ice” accretion - A speed that provides the manoeuvring capability defined in CS/FAR 25.143(h) with landing ice accretion	Part II § 6	Landing perf in icing conditions to be provided in AFM if : Effect of ‘landing ice’ on VREF is more than 5 kt In icing conditions, VREF may not be less than: - VREF determined in non-icing conditions - A speed that provides the manoeuvring capability defined in CS/FAR 25.143(h) with landing ice accretion	same A350	same A350 + add Vref icing not less than 1.17 Vmin1g ice*

143(j) Controllability and maneuverability	For flight in icing before ice protection system activated : (1) a/c controllable in pull-up maneuver up to 1.5g , and (2) no pitch control force reversal during push-over maneuver down to 0.5 g	Part II §7	In icing conditions, (1) a/c controllable in pull-up maneuver up to 1.5g or lower if limited by AOA prot , and (2) no pitch control force reversal during push-over maneuver down to 0.5 g	same A350	Basic req apply
143 (h)	Operating speed not less than - V2+XX AEO 40° bank angle maneuvrability		Basic req apply	Basic req apply	Operating speed not less than : - V2+XX AEO in non icing 40°bank angle maneuverability, or - V2 +XX not less than 1.16 Vmin1g ice*

Note: (*) performance criteria on factored Vmin1g (CSeries) are only applicable to twin turbojets might be different for other aircraft engine configuration

Appendix 3 Topic 6 Stability

FAA Aviation Rulemaking Advisory Committee
FTHWG Topic 6
Stability

Recommendation Report

January, 2017

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Executive Summary

Many new airplanes incorporate advanced Electronic Flight Control Systems (EFCS). These systems have architectures and features which do not exhibit static stability in the same way conventional airplanes do, or comply with the static stability regulations of 14CFR25. Yet, these airplanes, having been evaluated under Special Conditions, have been found to be safe. The Flight Test Harmonization Working Group (FTHWG) was tasked to recommend standards for accommodating airplanes which embody modern EFCS and which do not exhibit static stability in accordance with the current 14CFR25.171-177 regulations.

The FTHWG has considered the relevant standards and guidance material, the relevant Special Conditions and Certification Review Items (CRI's), and engaged in discussion regarding the nature of the special features provided by these modern systems. The working group devised a structured method of evaluating what standards would be required of airplanes using these EFCS features to ensure safe operation. Further, the group found a way to incorporate those standards into the current structure of the 14CFR25 regulatory structure.

The group has drafted both regulations and guidance material, as appropriate, to ensure a safe certification path. This includes the creation of a new regulation (14CFR25.176) specifically covering the requirements for airplanes not meeting classical stability measures. This, along with necessary modifications to the other regulations in the Stability series (25.171-181), forms a coherent standard against which new configurations can be evaluated.

Recommendations are made that the FAA enact these new regulations (and associated guidance), and that these be adopted by EASA and other national authorities as well.

Background

As a result of the 20 March, 2014 ARAC meeting, FAA has assigned and ARAC has accepted a tasking which would use the existing Flight Test Harmonization Working Group (FTHWG). The part of the tasking described in this Appendix is:

> The working group should develop recommended standards in the following topic areas. If there are disagreements within the working group, these should be documented, including the reasons for the disagreement and rationale from each party. The following subject areas should be worked upon within this task:
>
> 1. Fly-by-wire Flight Controls.
>
> Regulatory requirements and associated guidance material for airworthiness certification of airplane designs using fly-by-wire technology to remove the need for longstanding, repetitively-used fly-by-wire special conditions. Specific areas include:
>
> a.…
> b. Lateral/directional/longitudinal stability,

Details of the task have been defined at the working level in the work plan (Topic 6, Stability) resulting from Phase 1. The approved work plan is included as Attachment 6A.

While transport airplanes incorporating fly-by-wire systems and flight envelope protection features have been certified and in service since the late 1980's, the basis on which the airworthiness was determined has always been Special Conditions (CRI's in Europe). These have evolved over the years, were each written against specific system architectures and feature sets, and were not necessarily intended to provide broad airworthiness coverage, as this task is asking the FTHWG to do.

A. What is the underlying safety issue addressed by the JAR/FAR?

While the stated task is to remove the need for repetitively used Special Conditions, the result will be a single, harmonized set of standards which will have the effect of ensuring a consistent safety standard. The established standard of safety is taken to be the current airworthiness requirements applied to conventional (not-flight-envelope-protected) configurations as well as the current industry practice achieved via SC's and CRI's for those aircraft with modern EFCS architectures.

B. What is the task?

The task assigned by ARAC in the above cited Federal Register tasking statement has been further refined in the Work Plan, as developed in Phase 1 of this tasking. The task in the work plan is:

> "Recommend revisions to regulations and guidance material to include criteria, which are harmonized across FAA/TCCA/EASA/ANAC, to be used in the assessment of airplanes incorporating electronic flight control systems (EFCS) which may not exhibit explicit stability as defined in the current regulations".

C. Why is this task needed?

Many new transport category aircraft include control system designs which include stability and/or command augmentation and which may not exhibit stable characteristics in the same way that airplanes with conventional, mechanical control systems do. These augmentation systems are not required by the current regulatory requirements, nor are they accommodated by them. These many airplanes have been certificated using Special Conditions written against very specific systems implementations. It is the intent of FAA to generate regulations and associate guidance material which will appropriately address all envisioned implementations. Harmonization of FAA, EASA, TCCA, and ANAC requirements should be addressed.

Because of the inability of current regulations to accommodate these new architectures, and the large number of Special Conditions/CRI's required, harmonizing on a specific set of regulations and associated guidance material will reduce the administrative burden on the authorities and reduce both administrative and testing burden for applicants seeking certification across authorities.

D. Who has worked the task?

This task has been worked by the Flight Test Harmonization Working Group (FTHWG) specialists on Stability and Control from the following organisations:

- Authorities : FAA, EASA, TCCA, JCAB*, CAAI*
- Manufacturers : Airbus, Boeing, Bombardier, Dassault, Embraer, Gulfstream, Textron
- Airlines : American Airlines,
- Labour Union: ALPA

(*) non-voting members

While the work plan (Attachment A) allows consideration for consultation with other Harmonization Working Groups, that was not found necessary for this topic. One reason for this is the fact that the Flight Controls HWG is currently inactive. More important, though, is that individual members of the FTHWG were in more-or-less continuous consultation on matters associated with this topic with their colleagues, many of whom were associated with the FCHWG.

E. Any relation with other topics?

This Topic, Stability is closely linked to:

- Topic 1, (Envelope Limiting) because the introduction of Electronic Flight Control Systems (EFCS) allows the introduction of features which will accommodate lower stability levels and still assure adequate handling,
- Topic 2, (Adaptation to Flight in Icing), for the same reasons, and
- Topic 7, (Side Stick Controls), as the measure of static stability in the regulations is based on stick forces.

Historical Information

The FTHWG met to discuss this topic during 3 face-to-face meetings, encompassing 6 days of detailed discussion. In addition 15 teleconferences were dedicated to this topic. The most challenging aspects were the branching structure and correcting the inconsistency in 25.177. The final editing (debate) of the proposed material occupied additional full meetings via telecon. These, along with numerous e-mail exchanges led to the consensus recommendations presented herein.

The FTHWG considered the differences between 14CFR25 and CS25 and the various SC's and CRI's. They also received briefings from various OEM's regarding the specific systems architectures employed (in conjunction with their appropriate SC's and CRI's). The FTHWG also invited briefings from members regarding potential strategies for accommodation of airplanes with modern EFCS architectures into the structure of the regulation. These various strategies were compared during a workshop exercise in which the competing concepts for implementation were worked out hypothetically. In consideration of the various EFCS implementations already in service and the potential for others, the group decided that the best course of action would be to employ a "branching" structure within Subpart B, essentially providing parallel certification paths for configurations which might meet the current stability requirements and for those configurations which are designed specifically to provide different characteristics. Moreover, it was decided that the choice of which branch to follow for certification (in the longitudinal axis) should be available at the applicant's choice based on flight phase. This branching structure is illustrated in Figure 1.

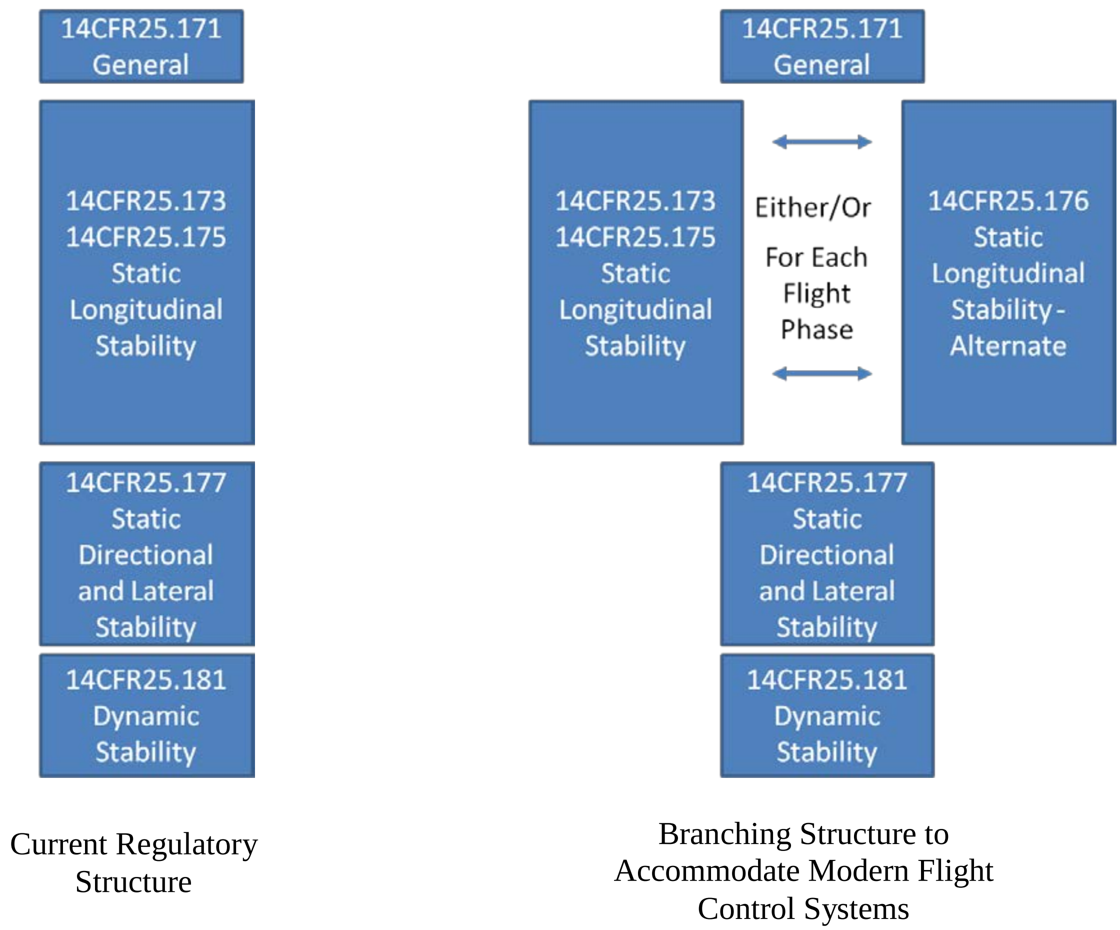


Figure 1. Branching Structure for Stability

The FTHWG concluded that the regulatory content and scope of 14CFR25.171, 177, and 181 is already sufficiently broad that they could be adapted to apply to new EFCS architectures. 14CFR25.173 and 175, however, currently require explicit static stability as demonstrated by a stable longitudinal stick force vs. speed, a characteristic which new architectures simply do not exhibit (and yet have been found safe via SC's and CRI's). In order to make 14CFR25.171, 173, 175, and 181 fit into this new structure, though, some modification to the wording and relevant guidance material would be required.

- 14CFR25.171 and 181 would need some additional guidance to ensure that the applicability to modern architectures is properly understood by applicants.
- 14CFR25.173 and 175, while applying strictly to configurations which exhibit classical speed stability would require some modification to ensure that the branching structure would be appropriately applied.
- 14CFR25.177 has lived with some significant internal inconsistencies for decades, and these will be corrected, both for conventional airplanes and for applicability to modern architectures. As a result, no additional changes (beyond correcting the inconsistency) are needed to accommodate new architectures.

- Finally, a new regulation, 14CFR25.176 will be required specifically to accommodate new EFCS architectures.

In considering the regulatory content necessary to ensure safety in the alternate path (for a proposed 14CFR25.176), the FTHWG evaluated the explicit and implicit characteristics provided to conventional statically stable airplanes by the presence of static longitudinal stability which contribute to safety. The FTHWG then documented parallel characteristics for EFCS configurations which would be independent of the particular architecture employed (as long as it provided the identified elements which contribute to safety). These were then compared to and ultimately combined with similar elements in the relevant CS's and CRI's. These elements are captured in the newly proposed 14CFR25.176 (below). This proposed regulation provides coverage for all envisioned implementations of flight control system architectures which would not meet the static stick-force vs speed criteria of 14CFR25.173 and 175, and specifies what characteristics and features must be provided. In addition, new guidance material has been generated which would provide explanatory guidance and a means of compliance for this new regulation.

The requirement for Static Lateral and Directional Stability (14CFR25.177) has been significantly modified over the years, and this history was seen as significant. This history is summarized in Table 1.

Requirement comparisons	(a) Static Directional Stability – recover from skid	(b) Static Lateral Stability - Raise low wing w/controls free	(c) Lateral and Directional Controller in sideslip	(d) contents change with Amdt level
25.177 Original 11/03/64	Must be positive	Must be positive	Proportional	N/A
25.177 Amdt 42 05/29/75	Must be positive	May not be negative Lateral may be negative above Vmo/Mmo	Proportional	N/A
25.177 Amdt 72 09/21/84	Removed	Removed	Proportional in stable sense	Rudder to Vfc/Mfc Lateral may be negative above Vmo/Mmo
25.177 Amdt 135 12/1/2011	Must be positive	May not be negative Lateral may be negative above Vmo/Mmo	Proportional in stable sense	Beta greater than (c), force may not reverse, rudder must increase

Table 1. Summary of 14CFR25.177 History

This history generated some glaring inconsistencies, which are addressed in this proposal.

- As can be seen in the table, the requirement for lateral stability was to be positive in the original incarnation of the regulations.
- At Amendment 42 in 1975, the requirement for lateral stability was relaxed from positive to “may not be negative”, allowing neutral lateral stability, and the controller requirements in sideslip were still required to have proportional (with sideslip) characteristics. There is no mention of “stable sense” in (c) to this point. The justification was, “FAA flight test experience has indicated that positive static lateral stability in large airplanes is not necessary and that such a requirement would not appreciably increase safety.” This allowed stick-free to be neutral and stick-fixed (i.e. the test in (c)) to be unstable provided the instability was “between limits found necessary for safe operation.”
- In 1984 (Amdt 72), as part of a directive to reduce regulatory burden, paragraphs (a) and (b) were [Reserved] in favor of a single requirement for lateral-directional stability in (c). This is the origin of the words “in a stable sense” in (c). The justification was, “It is not considered necessary to define directional and lateral stability parameters as separate entities to determine that an airplane has satisfactory directional-lateral stability. By evaluating the force and deflection of the ailerons and rudder, and the bank and yaw angles required to maintain steady heading sideslips, the lateral-directional characteristics of an airplane may be determined. Section 25.177 would, therefore be revised accordingly to eliminate the present requirement for unnecessary testing.” This demonstrates that the people at the time saw no benefit for testing both stick-free and stick-fixed. Two commenters objected to the NPRM because it no longer allowed lateral stability to be “not negative”. The FAA response in the Final Rule indicates that the FAA missed the point that the commenters were making. The FAA did remove the words “provide positive stability and” from the NPRM version of (c) but did not address the stability requirement in the words “in a stable sense.” The JAA and EASA never deleted (a) and (b).
- In 2011 (Amdt 135), 25.177 was harmonized along with many other rules. This reinstated (a) and (b) but did not remove the “in a stable sense” wording in (c). There are no comments in either NPRM or Final Rule documentation that justify keeping “in a stable sense” in (c). The net result is that the neutral stability allowance of (b) is incompatible with “in a stable sense” in (c).
- Moreover, even after Amendment 135, the guidance in AC 25-7C allows satisfying (a) and (b) by measuring the forces and deflections during the (c) demonstration, but does not address the inconsistency.

FTHWG felt that the inconsistency between (b) and (c) should be corrected, and that is dealt with by the wording change in the proposal for 14CFR25.177. In addition, the wording of all of 14CFR25.177 refers to “aileron” and “rudder” when in reality the lateral and directional control effectors might be combinations of many different surfaces. After some discussion, it was decided to harmonize on “lateral control” and “directional control” to appropriately describe the cockpit controller.

The requirements of 14CFR25.181, Dynamic Stability were evaluated because of the possibility that various flight control system modes may interact with each other or with airplane structures at any number of relevant frequencies. After vigorous debate, it was decided that 14CFR25.181 is already written broadly enough to be applicable to and regulating of the safety considerations generated by these additional modes, so the regulation itself would not need modification. Additional guidance material is proposed to ensure that appropriate application of 14CFR25.181 is made to these additional modes, and to correct what was assumed to be a typographical error regarding the applicable speed range in the CS(Book2) for this paragraph.

Finally, the general requirement for stability (14CFR25.171) has been reworded to accommodate neutral lateral stability and the branching structure and to ensure applicability to both conventional and EFCS architectures. Guidance material for non-icing conditions has been created where previously it was absent.

A. What are the current regulatory and guidance material CS 25 and FAR 25?

Current FAA regulatory and guidance material explicitly addressing stability (excluding maneuver stability (stick force vs load factor)) include:

- 14CFR25.171 General [Stability]
- 14CFR25.173 Static Longitudinal Stability
- 14CFR25.175 Demonstration of Static Longitudinal Stability
- 14CFR25.177 Static Lateral-Directional Stability
- 14CFR25.181 Dynamic Stability

Guidance and means of compliance for these are given in FAA AC25-7C (latest revision)

EASA regulatory and guidance material addressing stability (excluding maneuver stability (stick force vs load factor)) include:

- CS25.171 General
- CS25.173 Static longitudinal stability
- CS25.175 Demonstration of static longitudinal stability
- CS25.177 Static directional and lateral stability
- CS25.181 Dynamic Stability

Guidance material for these are given in Book 2 of CS25.

Although the work plan made reference to additional Subpart D and F regulations (25.671, 672, and 1309), and these were referred to many times in the course of the discussions, it were determined that it was not necessary to propose modifications for the purpose of this topic’s work.

B. What, if any, are the differences in the existing regulatory and guidance material CS 25 and FAR 25?

The FTHWG thoroughly discussed the various regulations regarding stability. The current 14CFR25.171-181 and CS25.171 and 181 are harmonized; there are no appreciable differences. Neither, however, accommodates modern EFCS architectures which display stability characteristics not meeting the current requirements. To date, all aircraft with these architectures have been certified via SC’s and CRI’s.

The guidance material in AC 25-7C (FAA) and CS 25(Book 2) demonstrate some contrasts in content.

> CS25(Book2) is silent regarding CS25.171, as is AC25-7C regarding 14CFR25.171 (the paragraph is [Reserved]).
>
> CS25(Book2) for Static Longitudinal Stability (CS25.173 and 175) contains only a comment about the average gradient over the speed range. AC 25-7C provides a detailed description of the maneuvers to be flown, the data reduction, and compliance finding, including more than one test technique. The AC also discusses the phenomenon of local slope reversals.

CS25(Book2) for Static Directional and Lateral Stability (CS25.177) is silent on subparagraphs (a) and (b), while AC 25-7C provides as an explanation only a regurgitation of the regulation paragraphs themselves. For the steady sideslip cases of paragraph 25.177(c), the guidance material wording is not precisely the same, and the organization of the material is slightly different, but the content is substantially identical. The only difference is that in discussing flight test safety, an additional item of concern noted in AC 25-7C is rudder loads, particularly those that may occur with dynamic rudder inputs. This item is not in listed CS25(Book2).

The guidance in CS25(Book2) for CS25.181, Dynamic Stability consists only of one sentence, pointing out that "The requirements of CS 25.181 are applicable at all speeds between the stalling speed and V_{FE}, V_{LE} or V_{FC}/M_{FC} as appropriate." The minimum speed cited here is in conflict with that cited in the CS25 regulation (1.13Vsr), and is different from that in AC 25-7C (1.13Vsr). It is assumed that this speed cited in the CS25(Book2) is a typographical error, and deserves to be corrected.

In contrast, the guidance provided by AC 25-7C for 14CFR25.181 includes a description of the intent of the regulation, definitions of what is meant by "heavily damped", and procedures for evaluating these conditions.

Of course, none of this guidance material addresses the evaluation of stability for airplanes which, by reason of their EFCS architecture do not exhibit classical speed stability, as was the case with the regulations.

C. What are the existing CRIs/IPs (SC and MoC)?

The applicable Special Conditions and CRI's evaluated by the FTHWG included:

- 25-316-SC Airbus A380-800
- 25-483-SC Embraer S. A., Model EMB-550 Airplane, Electronic Flight control System, Lateral-Directional and Longitudinal Stability and Low Energy Awareness
- EV-08-EMB-550s4 - FICHA DE CONTROLE DE ASSUNTOS RELEVANTES (FCAR)

D. What, if any, are the differences in the Special Conditions (CRIs/IPs) (SC and MoC) and what do these differences result in?

The FTHWG evaluated these documents to determine if significant differences exist. The Special Conditions for the A380 and EMB-550 have essentially the same requirements. Due to the 7 year difference in their issue date, the primary difference is that the changes to 14 CFR 25.177 at Amendment 135 are the basis for the lateral-directional stability requirements in the EMB-550 SC where they are not in the A380 SC. This difference has little effect on the characteristics that are required. There may be some small difference in compliance methods based on the Amendment 135 changes to 25.177. There is no difference in the relief from compliance to 25.171, 25.173 and 25.175 or the Special Conditions for "suitable static lateral, directional, and longitudinal stability in any condition normally encountered in service" and "adequate awareness to the pilot of a low energy."

Consensus

The FTHWG arrived at a consensus position on the recommended regulations and recommended guidance for 14CFR25.171, 173, 175, 177(a), (b), and (d), and 181 unanimously; everyone agreed with the conclusion (that new material should be provided) and with the recommendation (the new material proposed).

The consensus position on recommended regulation wording for 14CFR25.177(c) was not unanimous; there was one dissenting opinion, and agreement could not be reached by the deadline. This disagreement is centered wholly on the specific choice of words to be used in the regulation. It is important to note that there was no disagreement on the intent of the regulation, the level of safety to be implied, or even the means of compliance. In matter of fact, the reason for recommending changes to this sub-paragraph revolve around the long-standing inconsistency within paragraph 25.177 itself, and this is common between FAA and EASA versions. The majority position was that the wording should be:

> (c) The following requirement must be met for the configurations and speed specified in paragraph (a) of this section. In straight, steady sideslips over the range of sideslip angles appropriate to the operation of the airplane, the directional control movements and forces must be substantially proportional to the angle of sideslip in a stable sense. The factor of proportionality must lie between limits found necessary for safe operation. During these straight, steady sideslips, necessary lateral control movements and forces must not be in the unstable sense with the exception of speeds above Vmo/Mmo per 25.177(b)(2). The range of sideslip angles evaluated must include those sideslip angles resulting from the lesser of:
>
> > (1) One-half of the available directional (pedal) control input; and
> >
> > (2) A directional (pedal) control force of 180 pounds (801 N).

The dissenting opinion and the majority response to this is given as
:

Dissenting Opinion	Majority Response
(c) The following requirement must be met for the configurations and speed specified in paragraph (a) of this section. In straight, steady sideslips over the range of sideslip angles appropriate to the operation of the airplane, the lateral and directional control movements and forces must be substantially proportional (which includes neutral lateral stability) to the angle of sideslip. This factor of proportionality must be found sufficient for safe operation. The range of sideslip angles evaluated must include those sideslip angles resulting from the lesser of: (1) One-half of the available directional (pedal) control input; and (2) A directional (pedal) control force of 180 pounds (801 N).	The voting members that selected the majority proposal had a variety of reasons for preferring it over the dissenting proposal. The primary reason is that the members felt the majority proposal was more clear and straightforward and less likely to be mis-read in application. One commenter said that the majority position is more complete and correct since the dissenting proposal could be interpreted to contradict the allowance of negative lateral stability (that is gradual and easily recognizable & controllable by the pilot) as per 25.177(b)(2) between VMO/MMO and VFC/MFC. . Several of commenters preferred the majority proposal but did not oppose the dissenting proposal. Several had the view that the dissenting proposal would contradict the allowance of negative lateral

	stability as per 25.177(b)(2). This is primarily due to the words “substantially proportional” being commonly interpreted as a requirement for positive stability. One commenter stated that the deletion of the proportionality requirement for lateral controls was not intended and proposed a modification to retain it.
Rationale for Dissenting Opinion	
• The words “must be substantially proportional” describe the character of the proportionality and not the slope of the stability. Therefore, neither neutral stability nor slight instability are ruled out by those words. • The words “in a stable sense,” that were added in Amendment 72 to retain a stability requirement when 25.177(a) and (b) were removed, are the words that are not compatible with neutral lateral stability. Therefore, these words should be removed. Directional and lateral stability requirements are already covered in 25.177(a) and (b). • The majority proposal removes requirements for proportionality of lateral control movements and forces for the purpose of being clearer that neutral stability is allowed. A better solution would be to clarify what is unclear rather than deleting it.	

The majority proposal listed above is included in the recommendation below.

Recommendation

FAA should adopt the harmonized standard provided in Attachment 6B. Further, the FAA should liaise with EASA, TCCA, and ANAC and other national authorities to ensure consistent implementation in their jurisdictions.

In addition, the FAA should adopt and liaise with EASA, TCCA, and ANAC and other national authorities to similarly adopt the proposed guidance material provided in Attachment 6C.

The FTHWG agreed in principle that the harmonized regulation should include an evaluation of the effects of flight in atmospheric disturbances. This was written into the various SC’s and CRI’s, but the detailed means of compliance were not published with those documents. The FTHWG believes that the effects of atmospheric disturbances are significant in terms of stability and, importantly, in the presence of stability augmentation systems because if the augmentation becomes saturated, the underlying bare airframe, which may not be stable by itself, could be exposed. However this subject, while discussed and agreed in principle, was not progressed to the point of generating harmonized guidance material including the level of disturbance to be evaluated, the pass/fail criteria, the specific maneuvers to be flown and the specific configurations and flight/loading conditions to be evaluated. This subject matter (the effects of atmospheric disturbances) is common among a number of topics worked by the FTHWG.

Therefore, the FTHWG recommends that they be tasked to resume work on this particular aspect of Stability to more completely define what is meant by the terms “including effects of atmospheric turbulence” in the proposed regulation and the associated MOC and guidance material.

A. Rulemaking

1. What is the proposed action?

The FTHWG recommends that FAA modify 14CFR25 paragraphs 171-181, and adopt a new regulation 14CFR25.176, as proposed in Attachment 6B.

Further, the FTHWG recommends that FAA liaise with EASA, TCCA, and other aviation authorities to adopt the same regulatory changes. Because the structure of CS 25 is the same as 14CFR25 in this section, and the fact that EASA participated in this harmonization, the adoption of this proposal for EASA should be easy.

2. What should the harmonized standard be?

The FTHWG believes that a single standard of airworthiness can be achieved which produces a level of safety equivalent to that seen by conventional, statically stable airplanes complying with the current airworthiness standards for EFCS aircraft not meeting 25.173 and .175. The intent was to generate a single certification standard which could be applied to as broad a range of envelope protection features and combinations of those features as possible, as well as those exhibiting conventional static stability. The FTHWG believes this intent has been achieved in the proposed regulations in Attachment 6B.

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

The FTHWG believes that as a result of the process taken - that of analyzing the implicit safety elements provided to conventional airplanes under 14CFR25.173 and that of collecting the best industry practices utilized in certifying EFCS airplanes via SC’s and CRI’s and creating a branched structure within the 14CFR25.170 series regulations - that the current level of safety will be maintained under the proposed harmonized regulations. In addition, when the regulations are harmonized, both industry and authorities will realize cost benefits due to reduced administrative burden.

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

The FTHWG believes that the proposed regulations and associated guidance material will maintain the same level of safety as seen now for both conventional airplanes certified under 14CFR25.171-181 and those not meeting 14CFR173 and 175 but certified via Special Conditions or CRI’s. The proposed standard was derived based on evaluation of the explicit and implicit characteristics provided by static longitudinal stability which contribute to safety and documented a parallel characteristic for EFCS configurations, which would be independent of the particular architecture employed (as long as it provided the identified elements which contribute to safety). EFCS airplanes meeting the proposed 14CFR25.176 are expected to produce the same safety level as conventional airplanes meeting 14CFR25.173 and 175.

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

Since the proposed new 14CFR25.176 for EFCS airplanes not meeting 14CFR25.173 and 175 was derived from analysis of the various SC's and CRI's used in the industry, the FTHWG believes that the level of safety will be equivalent to the current industry practice for these airplanes.

6. Who would be affected by the proposed change?

Any OEM proposing to certify an airplane with EFCS architectures which would not provide static longitudinal stability meeting the requirements of 14CFR25.173 and 175 would be affected, but largely to the extent of the certification basis. Under the proposed changes, instead of negotiating Issue Papers and CRI's, the applicants would be able to certify to the new proposed regulations.

Certifying authorities would be affected by the proposed change in a similar way.

7. Does the proposed standard affect other HWG's and what is the result of any consultation with other HWGs?

The FTHWG does not believe other HWG's will be affected. There was no consultation with other HWG's, although Subject Matter Experts (SME's) from other disciplines at both the OEM's and the authorities were consulted during the course of the development of the material.

B. Advisory Material

1. Is existing FAA advisory material adequate? If not, what advisory material should be adopted?

The FTHWG believes that the current FAA advisory material is not adequate. Since the FTHWG has concluded that a branching structure with a new regulation, 14CFR25.176 would be the best way to accommodate both conventional and modern EFCS configurations which don't meet 14CFR25.173 and 175, the guidance material for existing regulations will need to be modified to accommodate the new structure. In addition, new guidance material will be required for the new regulation. Finally, guidance material for 14CFR25.171 and 181 will need to be modified to ensure appropriate application to both conventional and modern EFCS architectures.

Proposed changed material is provided in Attachment 6C.

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

The FTHWG believes that the proposed changes to 14CFR25.171-181 and associated proposed guidance material will afford equal levels of safety to both conventional and EFCS equipped airplanes with regard to stability. With these changes, nothing more need be included.

Economics

A. What is the cost impact of complying with the proposed standard (it may be necessary to get FAA Economist support to answer this one)?

Because the approach taken by the FTHWG on this topic was to marry the experiences of current SC's and CRI's to the current regulatory structure, the FTHWG does not believe the cost impact will be significant for the same level of safety. Further, the FTHWG believes there may be a modest cost savings in administrative burden to OEM's as a result collecting the harmonized requirements and means of compliance in one place and eliminating the need to negotiate Issue papers and CRI's.

In addition, the FTHWG believes similar administrative cost savings should be available to each of the participating authorities for the same reasons.

If FAA economists are employed to generate specific analyses, the FTHWG would like to be engaged in that activity as it happens.

B. Does the HWG want to review the draft NPRM prior to publication in the Federal Register?

Yes, please.

ICAO Standards
How does the proposed standard compare to the current ICAO standard?

ICAO Annex 8, at Amendment 105b, Part IIIB specifies international standards for airworthiness for large airplanes. The standard of Annex 8 is written quite broadly. Paragraph 4.2.1, Stability, discusses the level of stability "in relation to its other characteristics, performance, structural strength and most probable operating condition…as to ensure that demands on the pilot's powers of concentration are not excessive…" and "The stability of the aeroplane, shall not, however, be such that excessive demands are made on the pilot's strength or that the safety of the airplane is prejudiced by lack of maneuverability…" The ICAO standard goes on to accommodate artificial or hybrid stability and points out the need to comply with paragraph 4.2 in such cases.

None of these are at odds with the proposed changes to requirements or guidance materials. The FTHWG believes that the proposed regulations and guidance materials are compatible with the ICAO standard.

Paragraph 3.5.1, Design Airspeeds, however, has a slightly different focus, and while it is also appropriate to discuss under Tasks 1 (Envelope limiting) and 2 (Adaptation for Flight in Icing), and 13 (Out of Trim), it is relevant to Stability. In the case of conventional, mechanical airplanes, the stability plays an important role in limiting airspeed excursions, as pointed out in ICAO Annex 8, Part IIIB, paragraph 3.5.1. In considering the case of an airplane with envelope limiting and various levels of stability (including zero), the “margin” referred to may be provided by system features and functions not envisioned by Annex 8. Nevertheless, the FTHWG recognizes the intent of the standard in 3.5.1 and have included the need for robustness of limiting functions against both pilot action and atmospheric disturbances. Therefore, FTHWG believes that the proposed regulations and guidance are compatible with this aspect of Annex 8, even if limiting functions, required by the proposed regulations are not explicitly called out.

Attachment 6A Topic 6 Work Plan

Work Plan – Lateral/Directional/Longitudinal Stability

1. What is the task?
Recommend revisions to regulations and guidance material to include criteria, which are harmonized across FAA/EASA/TCCA/ANAC, to be used in the assessment of airplanes incorporating electronic flight control systems which may not exhibit explicit stability as defined in the current regulations .
2. Who will work the task?
The Flight Test Harmonization Working Group (FTHWG) will have primary responsibility for this task. Consideration will be given for consultation with SME's representing flight controls, propulsion, and loads/dynamics disciplines.
3. Why is this task needed? (Background information)
Many new transport category aircraft include control system designs which include stability and/or command augmentation and which may not exhibit stable characteristics in the same way that airplanes with conventional, mechanical control systems do. These augmentation systems are not required by the current regulatory requirements, nor are they accommodated by them. These many airplanes have been certificated using Special Conditions written against very specific systems implementations. It is the intent of FAA to generate regulations and associated guidance material which will appropriately address all envisioned implementations. Harmonization of FAA, EASA, TCCA, and ANAC requirements should be addressed.
4. References (existing regulatory and guidance material, including special conditions, CRIs, etc.)

<u>FAA 14 CFR Part25 SubPart B:</u>

a) 25.143 General Controllability & Maneuverability
b) 25.145 Longitudinal Control
c) 25.147 Directional and Lateral Control
d) 25.171 General [Stability]
e) 25.173 Static Longitudinal Stability
f) 25.175 Demonstration of Static Longitudinal Stability
g) 25.177 Static Lateral-Directional Stability
h) 25.153 High Speed Characteristics
i) 25.155 [Out of Trim Characteristics]
j) 25.671 [Control Systems] General
k) 25.672 Stability Augmentation and Automatic and Power-operated Systems
l) 25.1309 Equipment, Systems and Installations

<u>EASA CS-25 A-13:</u>

a) 25.143 General Controllability & Maneuverability
b) 25.145 Longitudinal Control
c) 25.147 Directional and Lateral Control
d) 25.171 General [Stability]
e) 25.173 Static Longitudinal Stability
f) 25.175 Demonstration of Static Longitudinal Stability
g) 25.177 Static Lateral-Directional Stability
h) 25.153 High Speed Characteristics
i) 25.155 [Out of Trim Characteristics]
j) 25.671 [Control Systems] General
k) 25.672 Stability Augmentation and Automatic and Power-operated Systems

l) 25.1309 Equipment, Systems, and Installations

FAA Special Conditions

a) FAA Final SC No. 25-316-SC Airbus A380-800
b) FAA Final SC No. 25-479-SC Embraer S.A., Model EMB-550 Airplane, Limit Pilot Forces for stick shaker control
c) FAA Final SC No. 225-483-SC, Embraer S. A., Model EMB-550 Airplane, Electronic Flight Control System, Lateral-Directional and Longitudinal Stability and Low Energy Awareness

EASA CRIs

a) CRI B-XX Initial Draft Stqatic Directional, Lateral, and Longitudinal Stability and Low Energy Awareness

ANAC Equivalent Levels of Safety

a) ANAC Equivalent Level of Safety ELOS EV-08-EMB-550s4, EFCS: Lateral-Directional and Longitudinal Stability and Low Energy Awareness

AC 25-7C Flight Test Guide for Certification of Transport Category Airplanes

EASA CS25 Book 2 (Advisory Material)

5. Working method
It is envisioned that 6-8 face-to-face meetings over a period of 12-16 months will be needed to facilitate the discussion needed to complete these tasks. Telecons and electronic correspondence will be used to the maximum extent possible, in particular, between face-to face meetings to ensure that progress is maintained.
6. Preliminary schedule (How long?)
Recommendations to Transport Airplanes and Engines Subcommittee within 18 months of the initiation of work on these tasks.
7. Regulations/guidance affected
Regulations noted in Section 4 above.
8. Additional information
This is a very broad and far-reaching task. The currently available issue papers/special conditions have been written in response to very specific system implementations. In contrast, the stated intent of this task is to generate one single visionary requirement set which will ensure safety and at the same time accommodate all potential stability and/or command augmentation schemes. Within that intent, the task team will likely face the large challenge of generating a rational and defensible strategy for limiting the potential size of the pool of parameters and combinations of parameters under consideration. The current regulations address stability in terms of static stability (as stick force / speed), maneuvering stability (as stick force / g), directional stability (as force and deflection / sideslip), lateral stability (as force and deflection / sideslip). New and proposed stability and command augmentation schemes may necessitate, e.g. separate evaluations of disturbance rejection and command response, cross-axis coupling or de-coupling, or even different stability measures (e.g. stability with respect to angle of attack). These should be considered. Guidance for means of compliance will be very important to these topics, and should be given careful consideration.

One important reason for conventional stability has been to provide tactile feedback of flight condition (e.g. deviation from trim). For this reason, this task is closely related to the task considering flight envelope limiting. These two tasks may well be worked at the same time.

Attachment 6B Proposed Regulatory Material, Stability

Note: in this text, changes are tracked for visibility.
Original text is in black
Colored strikethroughs indicate deletions from the original text
Colored underlined text indicate additions to the original text

Proposal	Comments
§25.171 General. The airplane must have longitudinal, lateral~~be longitudinally, directionally~~, and directional stability characteristics~~laterally stable~~ in accordance with the provisions of §§25.173 through 25.181~~177~~. In addition, both suitable stability and suitable control feel are~~(static stability) is~~ required in any condition normally encountered in service.~~, if flight tests show it is necessary for safe operation.~~	Removed the wording, “must be … stable” to reflect the addition and changes in 25.176 and 25.177 that allow neutral stability. Changed order of categories “longitudinal, lateral and directional” to match the order of the regulation titles. Clarified wording to ensure “stability” and “control feel” are recognized as separate characteristics. The previous wording has been misread as the feel of “stability and control”. Deleted “(static stability)” because 25.176 allows neutral speed stability. Therefore control feel is still important and must be evaluated even with static stability is zero. Removed “if flight tests show it is necessary for safe operation” because suitable characteristics need to be present even in conditions not seen in flight test. This change is important because EFCS implementations allow the possibility of characteristics changing due to a change in control law schedule that can be triggered by flight phase, airplane configuration or some other means. Therefore, testing in several sample conditions, as in 25.175, does not provide information about untested conditions to the same degree it does with a mechanical flight control system. As a result, the requirements must be clear that 25.171 applies to “any condition normally encountered in service” regardless of whether “flight test show[s] it is necessary.” Removing the words “if flight tests show” does not imply a change to the Method of Compliance to 25.171 such as a reduction of flight testing.
§25.173 Static longitudinal stability. In each flight phase, the airplane must comply with §25.176 or §25.173(a) through (d): Under the conditions specified in §25.175, the characteristics of the elevator control forces (including friction) must be as follows: (a) A pull must be required to obtain and maintain speeds below the	Added a branching statement to allow alternate requirements of 25.176. Each flight phases must meet one set of requirement or the other. Even though 25.175 calls for demonstration of only some flap/gear combinations within a given flight phase, all the flap/gear combinations for a given flight phase must have the same longitudinal stability characteristics as distinguished by 25.173/175 or 25.176.

specified trim speed, and a push must be required to obtain and maintain speeds above the specified trim speed. This must be shown at any speed that can be obtained except speeds higher than the landing gear or wing flap operating limit speeds or V_{FC}/M_{FC}, whichever is appropriate, or lower than the minimum speed for steady unstalled flight.	
(b) The airspeed must return to within 10 percent of the original trim speed for the climb, approach, and landing conditions specified in §25.175 (a), (c), and (d), and must return to within 7.5 percent of the original trim speed for the cruising condition specified in §25.175(b), when the control force is slowly released from any speed within the range specified in paragraph (a) of this section.	
(c) The average gradient of the stable slope of the stick force versus speed curve may not be less than 1 pound for each 6 knots.	
(d) Within the free return speed range specified in paragraph (b) of this section, it is permissible for the airplane, without control forces, to stabilize on speeds above or below the desired trim speeds if exceptional attention on the part of the pilot is not required to return to and maintain the desired trim speed and altitude.	
§25.175 Demonstration of static longitudinal stability. In each flight phase, the airplane must comply with §25.176 or the applicable paragraph of §25.175(a) through (d): Static longitudinal stability must be shown as follows: (a) *Climb.* The stick force curve must have a stable slope at speeds between 85 and 115 percent of the speed at which the airplane— (1) Is trimmed, with— (i) Wing flaps retracted; (ii) Landing gear retracted; (iii) Maximum takeoff weight; and (iv) 75 percent of maximum continuous power for reciprocating engines or the maximum power or thrust selected by the applicant as an operating limitation for use during climb for turbine engines; and (2) Is trimmed at the speed for best rate-of-climb except that the speed need not be less than 1.3 V_{SR1}.	Added a branching statement to allow alternate requirements of 25.176. See additional comment for 25.173.
(b) *Cruise.* Static longitudinal stability must be shown in the cruise condition as follows: (1) With the landing gear retracted at high speed, the stick force curve must have a stable slope at all speeds within a range which is the greater of 15 percent of the trim speed plus the resulting free return speed range, or 50 knots plus the resulting free return speed range, above and below the trim speed (except that the speed range need not include speeds less than 1.3 V_{SR1}, nor speeds greater	

than $V_{FC}/M_{FC,}$ nor speeds that require a stick force of more than 50 pounds), with— (i) The wing flaps retracted; (ii) The center of gravity in the most adverse position (see §25.27); (iii) The most critical weight between the maximum takeoff and maximum landing weights; (iv) 75 percent of maximum continuous power for reciprocating engines or for turbine engines, the maximum cruising power selected by the applicant as an operating limitation (see §25.1521), except that the power need not exceed that required at V_{MO}/M_{MO}; and (v) The airplane trimmed for level flight with the power required in paragraph (b)(1)(iv) of this section. (2) With the landing gear retracted at low speed, the stick force curve must have a stable slope at all speeds within a range which is the greater of 15 percent of the trim speed plus the resulting free return speed range, or 50 knots plus the resulting free return speed range, above and below the trim speed (except that the speed range need not include speeds less than 1.3 V_{SR1}, nor speeds greater than the minimum speed of the applicable speed range prescribed in paragraph (b)(1), nor speeds that require a stick force of more than 50 pounds), with— (i) Wing flaps, center of gravity position, and weight as specified in paragraph (b)(1) of this section; (ii) Power required for level flight at a speed equal to (V_{MO} + 1.3 V_{SR1})/2; and (iii) The airplane trimmed for level flight with the power required in paragraph (b)(2)(ii) of this section. (3) With the landing gear extended, the stick force curve must have a stable slope at all speeds within a range which is the greater of 15 percent of the trim speed plus the resulting free return speed range, or 50 knots plus the resulting free return speed range, above and below the trim speed (except that the speed range need not include speeds less than 1.3 V_{SR1}, nor speeds greater than $V_{LE,}$ nor speeds that require a stick force of more than 50 pounds), with— (i) Wing flap, center of gravity position, and weight as specified in paragraph (b)(1) of this section; (ii) 75 percent of maximum continuous power for reciprocating engines or, for turbine engines, the maximum cruising power selected by the applicant as an operating limitation, except that the power need not exceed that required for level flight at V_{LE}; and	

(iii) The aircraft trimmed for level flight with the power required in paragraph (b)(3)(ii) of this section.	
(c) *Approach*. The stick force curve must have a stable slope at speeds between V_{SW} and 1.7 V_{SR1}, with— (1) Wing flaps in the approach position; (2) Landing gear retracted; (3) Maximum landing weight; and (4) The airplane trimmed at 1.3 V_{SR1} with enough power to maintain level flight at this speed.	
(d) *Landing*. The stick force curve must have a stable slope, and the stick force may not exceed 80 pounds, at speeds between V_{SW} and 1.7 V_{SR0} with— (1) Wing flaps in the landing position; (2) Landing gear extended; (3) Maximum landing weight; (4) The airplane trimmed at 1.3 V_{SR0} with— (i) Power or thrust off, and (ii) Power or thrust for level flight. ~~(5) The airplane trimmed at 1.3 V_{SR0} with power or thrust off.~~	Item (5) is deleted to fix an error introduced in Amdt 25-115.
§25.176 Static Longitudinal Stability- Alternate. In each flight phase, the airplane must comply with 25.173 and 25.175 or 25.176(a) through (c): a) Strong positive static longitudinal stability must be present which provides adequate cueing to the crew that the speed is above Vmo/Mmo or below the minimum speed for hands-free stabilized flight. Static longitudinal characteristics must be shown to be suitable based on the airplane handling qualities, including an evaluation of pilot workload and pilot compensation including the effects of atmospheric turbulence. These characteristics must be shown for appropriate combinations of configuration and thrust for climb, cruise, approach, landing and go-around. 1) Release of the controller at speeds above Vmo/Mmo or below the minimum speed for hands-free stabilized flight, must produce a prompt recovery towards normal operating speeds without resulting in a hazardous condition. 2) There must be no means by which a pilot can retrim the	The branching statement allows alternate requirements to 25.173/175. See additional comment for 25.173. 25.176 implements requirements that are derived from various Special Conditions for airplanes that did not comply with 25.173/175. The intent of 25.176 is that all airplanes that have certified with those Special Conditions would also be compliant with 25.176. Some requirements in 26.176 are not mentioned in these previous Special Conditions but these additions describe characteristics that were deemed to be a necessary part of the implementations covered by the Special Conditions. The additions to the Special Conditions are 176(a)(1), (a)(2), and (b)(2) In 176(a), the flight phases "climb, cruise, approach

controller forces resulting from this stability. b) Acceptable characteristics must include (b)(1) through (b)(4): 1) Adequate control of speed and flight path without creating excessive pilot workload. 2) Ability to acquire and maintain small changes in speed and altitude without exceptional attention on the part of the pilot. 3) Acceptable envelope protection with regard to airspeed or Mach. 4) Adequate cues to the pilot of significant speed excursions beyond the normal flight envelope. c) The airplane must provide adequate alerting to the pilot, in accordance with 25.1322, of a low energy (low speed/low thrust/low height) state to alert the crew of unsafe operating conditions and to enable them to take appropriate corrective action. 1) Low energy alerting must be active at appropriate altitudes and in appropriate configurations (e.g., at low altitude, in the approach and landing configurations). 2) Low energy alerting must not be activated during normal operation, including conditions specified in 25.143(h), and operation in moderate turbulence. 3) The pilot must not be able to cancel the low energy alert until the airplane has achieved a higher energy state. 4) Evaluation of low energy alerting must ensure that low energy cues are not a nuisance in all take-off and landing altitude ranges for which certification is requested. These evaluations must include all relevant combinations of weight, center of gravity position, configuration, airbrakes position, and available thrust, including reduced and derated take-off thrust operations and engine failure cases. The evaluation must assess the level of energy alerting and the effects of energy management errors.	and landing" are cited because they correspond to the flight phases in 25.175 for showing compliance to 25.173. Other flight phases are covered by 25.171 and are expected to have very similar characteristics as those specifically mentioned. High altitude airspeed excursions below normal operating speeds have resulted in high altitude stalls/upsets in the transport category fleet. This requirement specifies "low energy alerting", which may not provide pilot alerting for low airspeed excursions in the cruise phase. This is consistent with current EASA CRIs for neutral static stability airplanes. The FTHWG does not consider it necessary to include a "low airspeed alerting" requirement in the cruise phase provided; (1) that 25.176(b)(3) and associated guidance states that High AOA Limiting is required for airplanes with neutral speed stability; and (2) Topic 1 – Envelope Protections proposal includes slow decelerations to the HALF AOA limit for altitudes up to the maximum expected in operation in accordance with 25.21(c). If the HALF is shown to prevent stall up to the maximum altitude expected in operation (up to the approved ceiling), then the potential for high altitude stalls for neutral speed stability airplanes is sufficiently mitigated.
§25.177 Static lateral-directional stability. (a) The static directional stability (as shown by the tendency to recover from a skid with the directional controls~~rudder~~ free) must be positive for any landing gear and flap position and symmetric power condition, at speeds from 1.13 V_{SR1}, up to V_{FE}, V_{LE}, or V_{FC}/M_{FC} (as appropriate for the airplane configuration).	

(b) The static lateral stability (as shown by the tendency to raise the low wing in a sideslip with the lateral~~aileron~~ controls free) for any landing gear and flap position and symmetric power condition, may not be negative at any airspeed (except that speeds higher than V_{FE} need not be considered for flaps extended configurations nor speeds higher than V_{LE} for landing gear extended configurations) in the following airspeed ranges: (1) From 1.13 V_{SR1} to V_{MO}/M_{MO}. (2) From V_{MO}/M_{MO} to V_{FC}/M_{FC}, unless the divergence is— (i) Gradual; (ii) Easily recognizable by the pilot; and (iii) Easily controllable by the pilot.	The Special Conditions for EFCS airplanes with neutral lateral stability were issued prior to Amdt 135 (12/1/2011) when requirements (a) and (b) were reinstated. However, there is nothing in these requirements that conflict with EFCS implementations with neutral lateral stability. Therefore, no modifications are made.
(c) The following requirement must be met for the configurations and speed specified in paragraph (a) of this section. In straight, steady sideslips over the range of sideslip angles appropriate to the operation of the airplane, the directional~~aileron and rudder~~ control movements and forces must be substantially proportional to the angle of sideslip in a stable sense. The~~This~~ factor of proportionality must lie between limits found necessary for safe operation. During these straight, steady sideslips, necessary lateral control movements and forces must not be in the unstable sense with the exception of speeds above Vmo/Mmo per 25.177(b)(2). The range of sideslip angles evaluated must include those sideslip angles resulting from the lesser of: (1) One-half of the available directional (pedal)~~rudder~~ control input; and (2) A directional (pedal)~~rudder~~ control force of 180 pounds.	The intent of this change is to allow neutral static lateral stability. The text of applicable Special Conditions say that neutral stability will not meet “substantially proportional to the angle of sideslip” as required by the regulation. This is resolved by removing the lateral axis from the requirements concerning proportionality. A sentence is added to specifically address stability of lateral control movements and forces. The majority of the FTHWG found this resolution preferable.
(d) For sideslip angles greater than those prescribed by paragraph (c) of this section, up to the angle at which full directional (pedal)~~rudder~~ control is used or a directional (pedal)~~rudder~~ control force of 180 pounds is obtained, the directional~~rudder~~ control forces may not reverse, and increased directional control~~rudder~~ deflection must be needed for increased angles of sideslip. Compliance with this requirement must be shown using straight, steady sideslips. However, if~~, unless~~ full lateral control input is achieved before reaching either full directional~~rudder~~ control input or a directional~~rudder~~ control force of 180 pounds,~~;~~ a straight, steady sideslip need not be maintained~~ after achieving full lateral control input~~. This requirement must be met at all approved landing gear and flap positions for the range of operating speeds and power conditions appropriate to each landing gear and flap position with all engines operating.	Replaced the word “unless” because it was not clear whether it referred to “Compliance with this requirement” or “using straight, steady sideslips.”
§25.181 Dynamic stability.	The group discussed whether dynamic modes created by EFCS would drive any change to 25.181. The

(a) Any short period oscillation, not including combined lateral-directional oscillations, occurring between 1.13 V_{SR} and maximum allowable speed appropriate to the configuration of the airplane must be heavily damped with the primary controls— (1) Free; and (2) In a fixed position. (b) Any combined lateral-directional oscillations ("Dutch roll") occurring between 1.13 V_{SR} and maximum allowable speed appropriate to the configuration of the airplane must be positively damped with controls free, and must be controllable with normal use of the primary controls without requiring exceptional pilot skill.	result is that no change is needed because the existing 25.181 language covers "any short period oscillation" and "any combined lateral-directional oscillations" regardless of their source or characteristics. Although other dynamic modes are not covered here, such as roll, spiral, and phugoid modes, other requirements have provided sufficient coverage.

Attachment 6C Proposed Guidance Material, Stability

AC 25-7C and AC 25-25A

Note: in this text, changes are tracked for visibility.
Original text is in black
Colored strikethroughs indicate deletions from the original text
Colored underlined text indicate additions to the original text

25. General - § 25.171. ~~[Reserved]~~

a. Explanation. Section 25.171 requires the airplane to exhibit suitable stability characteristics around all three axes and through all parts of the flight envelope. While there are specific flight and loading conditions called out for compliance to specific stability requirements, 25.171 requires the airplane to exhibit suitable characteristics throughout the flight envelope, and that the stability characteristics allow normal piloting tasks without requiring exceptional pilot strength, skill or attention.

(1) Section 25.171 requires that the stability and the control feel be suitable in any condition normally encountered in service including those not specified in 25.173 through 25.177. Section 25.171 refers to both longitudinal and lateral/directional characteristics and both static and dynamic conditions including those not included in 25.181 (e.g. phugoid motions) and including those resulting from control systems operation.

(2) The stability (e.g. disturbance rejection) characteristics must be suitable in both hands off flight and during maneuvering.

b. Procedures. The general stability and the control feel of the airplane should be evaluated continuously in the course of flying the airplane for certification. Provided that there are no marginal compliance aspects, no specific test conditions are required for 25.171 beyond those already specified for compliance to other 14 CFR 25 requirements.

26. Static Longitudinal Stability and Demonstration of Static Longitudinal Stability - §§ 25.173, ~~and~~ 25.175 and 25.176.

a. Explanation. The regulation accommodates flight phases which provide classical longitudinal static (speed) stability and those which do not. This is done via a "branching" construct in the regulation which specifies that airplanes must meet either 25.173 and 175 or 25.176. This compliance branching is available on a flight phase-by-flight phase basis as long as the other requirements (e.g. smooth transitions between configurations, 25.143) are also demonstrated.

~~a. Explanation.~~

(1) Section 25.173 - Static Longitudinal Stability.

(a) Compliance with the general requirements of § 25.173 is determined from a demonstration of static longitudinal stability under the conditions specified in § 25.175.

(b) The requirement is to have a pull force to obtain and maintain speeds lower than trim speed, and a push force to obtain and maintain speeds higher than trim speed. There may be no force reversal at any speed that can be obtained, except lower than the minimum for steady, unstalled flight or, higher than the landing gear or wing flap operating limit speed or V_{FC}/M_{FC}, whichever is appropriate for the test configuration. The required trim speeds are specified in § 25.175.

(c) When the control force is slowly released from any speed within the required test speed range, the airspeed must return to within 10 percent of the original trim speed in the climb, approach, and landing conditions, and return to within 7.5 percent of the trim speed in the cruising condition specified in § 25.175 (free return).

(d) The average gradient of the stick force versus speed curves for each test configuration may not be less than one pound for each 6 knots for the appropriate speed ranges specified in § 25.175. Therefore, after each curve is drawn, draw a straight line from the intersection of the curve and the required maximum speed to the trim point. Then draw a straight line from the intersection of the curve and the required minimum speed to the trim point. The slope of these lines must be at least one pound for each 6 knots. The local slope of the curve must remain stable for this range.

(2) Section 25.175, Demonstration of Static Longitudinal Stability, specifically defines the flight conditions, airplane configurations, trim speed, test speed ranges, and power or thrust settings to be used in demonstrating compliance with the longitudinal stability requirements.

(3) Section 25.176 - Static Longitudinal Stability - Alternate.

(a) With the implementation of certain flight control laws, it has been found that airplane configurations which do not exhibit classical speed stability as demonstrated in § 25.173 can be acceptable. In order to appropriately compensate for the lack of conventional speed stability, § 25.176 requires these airplanes to exhibit a number of additional features. These features are considered to be a package, all of which are required to compensate for the lack of conventional stability. Since compliance to 25.176 depends on these control laws and features, compliance with §§25.671 and 25.672 is required per § 25.21(e).

(b) The demonstration of classical stability using the requirements of § 25.173 and § 25.175 ensures that other characteristics are also acceptable including: pitch attitude and flight path dynamics, workload during maneuvering, controller friction, command resolution, awareness of airspeed changes, stability during unattended operation and disturbance rejection. In the absence of classical stability, § 25.176 ensures that these elements are provided through other means.

(c) When control laws are used to replace unaugmented stability with the desired augmented stability, evaluation of the augmentation in the presence of gusts and turbulence is important for several reasons: the response to pilot commands may have different characteristics than the response to disturbances, the disturbance could saturate the rate or authority capability of the augmentation and the cueing and protection systems must be effective for disturbances. Therefore, § 25.176 requires an evaluation of characteristics in turbulence.

(d) Section 25.176(a) specifies requirements on longitudinal characteristics beyond the low and high speeds boundaries of the normal flight envelope. A small margin in speed between Vmo/Mmo and the start of strong stability is acceptable but this stability must begin before Vfc/Mfc. In the speed range for strong stability, control forces must not be allowed to be trimmed so that the speed awareness is not removed and the airplane will promptly recover towards normal operating speeds when the controller is released.

(e) Section 25.176(b) lists four specific characteristics which must be present to provide suitable static longitudinal characteristics although these may not be the only characteristics needed. General evaluations of handling qualities, pilot workload and pilot compensation must be made.

(f) Section 25.176(c) requires that the airplane provide adequate alerting to the pilot of a low energy (low speed/low thrust/low height) state. "Adequate alerting" means alerting information must be provided to alert the crew of unsafe operating conditions and to enable them to take appropriate corrective action.

b. Procedures.

(1) Stabilized Method for § 25.173 and § 25.175.

(a) For the demonstration of static longitudinal stability, the airplane should be trimmed in smooth air at the conditions required by the regulation. Aft c.g. loadings are generally most critical. After stabilizing at the trim speed, apply a light pull force and stabilize at a slower speed. Continue this process in increments, the size of the speed increment being dependent on the speed spread being investigated, until reaching the minimum speed for steady, unstalled flight or the minimum speed appropriate for the configuration. A continuous pull force should be used from the trim speed on each series of test points to eliminate hysteresis effects. At the end of the required speed range, the force should be gradually relaxed to allow the airplane to return slowly toward the trim speed and zero stick force. Depending on the amount of friction in the control system, the eventual speed at which the airplane stabilizes will normally be less than the original trim speed. The new speed, called the free return speed, must meet the requirements of § 25.173.

(b) Starting again at the trim speed, and with the airplane in trim, push forces should be gradually applied and gradually relaxed in the same manner as described in paragraph (a), above.

(c) The above techniques result in several problems in practice. One effect of changing airspeed is a change of altitude, with a corresponding change in Mach number and power or thrust output. Consequently, a reasonably small altitude band, limited to ±3,000 ft., should be used for the complete maneuver. If this altitude band is exceeded, regain the original trim altitude by changing the power or thrust setting and flap and gear position as necessary, but without changing the trim setting. Then continue the push or pull maneuver in the original configuration. Testing somewhat beyond the required speed limits in each direction assures that the resulting data covers at least the required speed ranges. It will also be noted in testing that while holding force constant at each data point, the airspeed and instantaneous vertical speed vary in a cyclic manner. This is due to the long period (phugoid) oscillation. Care should be exercised in defining and evaluating the data point, since it may be biased by this phugoid oscillation. Averaging these oscillating speeds at each data point is an acceptable method of eliminating this effect. Extremely smooth air improves the quality of the test data. In-bay and cross-bay wing fuel shift is another issue experienced in some airplanes. In-bay fuel shift occurs rapidly with pitch angle; therefore, consideration should be given to testing with fuel loadings that provide the maximum shift since it is generally destabilizing. Slower, cross-bay fuel shift, or burn from an aft tank, can influence the measured stability but usually only because of the time required to obtain the data points. This testing induced instability should be removed from the data before evaluating the slope of the stick force versus speed.

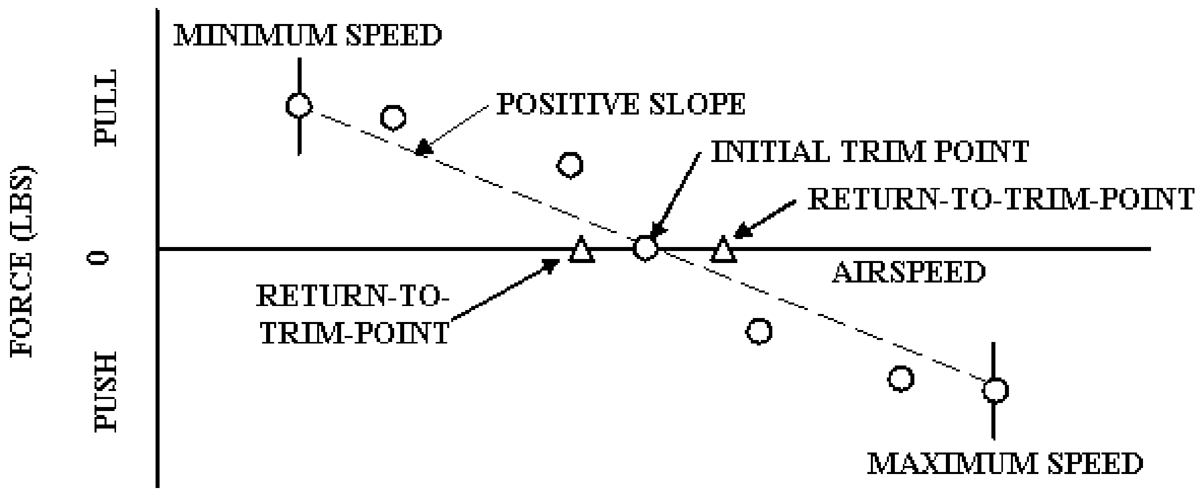
(2) Acceleration-Deceleration Method for § 25.173 and § 25.175.

(a) Trim at the desired airspeed and note the power or thrust setting. Without changing pitch trim, increase power or thrust to accelerate the airplane to the extreme speed of the desired data band. Using elevator control as needed, maintain approximately a constant altitude. Then, without changing pitch trim, quickly reset the power or thrust to the original power setting and allow the airplane to decelerate at a constant altitude back to the original trim speed. Obtain longitudinal static stability data during the deceleration to trim speed with the power and the pitch trim position the same as the original trim data point.

(b) Obtain data below the trim speed in a similar manner, by reducing power or thrust to decelerate the airplane to the lowest speed in the data band. Using elevator control as needed without changing pitch trim, maintain approximately a constant altitude. Then, without changing pitch trim, quickly reset the power to the original power setting, and record the data during the level flight acceleration back to trim speed. If, because of thrust/drag relationships, the airplane has difficulty returning to the trim conditions, small altitude changes within ± 2,000 feet can also be used to coax an airplane back to trim speed. Level flight is preferred, if possible. Obtain speed and elevator stick force data approximately every 10 knots of speed change.

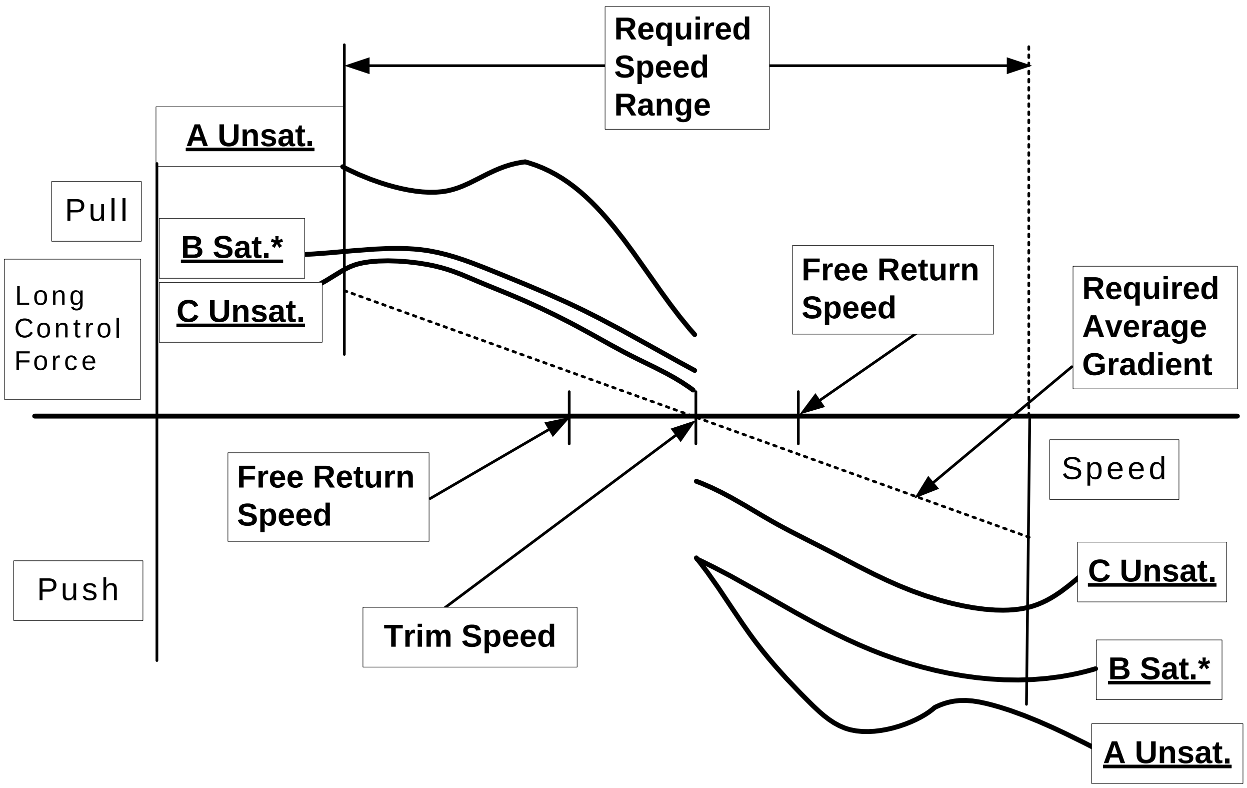
(3) The resulting pilot longitudinal force test points should be plotted versus airspeed to show the positive stable gradient of static longitudinal stability and that there are no "local" reversals in the stick force vs. airspeed relationship over the range of airspeeds tested. This plot should also show the initial trim point and the two return-to-trim points to evaluate the return-to-trim characteristics (see Figure 26-1).

Figure 26-1. Longitudinal Static Stability



(4) Examples of "local reversals" are given in Figure 26-2. Curves A and C depict a local gradient reversal within the required speed range. Even though it might be argued that the "average gradient" meets the one pound in six knots criterion, the gradient reversals would render these characteristics unacceptable. Curve B depicts a situation in which the gradient reverses, but only outside the required speed range. In addition, Curve B demonstrates a situation in which the local gradient does not always meet the required one pound in six knots, even though the average gradient does.

Figure 26-2. Local Reversal



* zero slope at end of speed range

(5) Static Longitudinal Stability – Alternate, § 25.176. Effects of external disturbances on the stability of the airplane should be assessed. For this purpose, it has been found acceptable to perform continuous qualitative evaluations throughout the flight test campaign. Since the airplane will likely be exposed to different levels of atmospheric disturbance during the course of a flight test program, attention should be given in each flight to the aspects of pilot workload, pilot compensation, control feel and the overall suitability of the static longitudinal characteristics of the airplane. This continuous evaluation should be complemented by dedicated flight tests, analysis or simulation whenever a marginal characteristic is found.

(6) Strong Static Longitudinal Stability at Envelope Boundaries, § 25.176(a). Experience has shown that strong positive static longitudinal stability is provided by at least 1 pound/6 knots stick force for a side stick controller. Comparable force gradient for a conventional wheel/column is 1 pound/4 knots. A higher force gradient is needed where speed is limited by Mmo/Md. These slopes are measured in the speed range where the applicable envelope protection or cueing functions are engaged.

(7) Static Longitudinal Characteristics, § 25.176(b).

(a) Precise control of speed and flight path should be accessed. For this purpose, it has been found acceptable to perform a continuous qualitative evaluation throughout the course of the flight test program, with attention to pilot workload while acquiring or maintaining small changes in speed, altitude or flight path. Especially relevant to this matter are AEO and OEI takeoff tests, approach and landing and go-around tests, flight level changes, configuration changes and the steady state trim required before or after a variety of flight test maneuvers in different combinations of weight, CG and power setting. It is not the intent of this regulation to require dedicated flight tests. However, this continuous evaluation should be complemented by dedicated flight tests, analysis or simulation whenever a marginal characteristic is found.

(b) Envelope protection: High Angle of Attack Limiting Function (HALF) that complies with 25.202 and 25.204 is an acceptable envelope protection. The high speed protection should include the strong positive stability described in 25.176(a) in both the altitude range limited by Vmo as well as Mmo. Evaluation of envelope protection functions include the requirements of 25.144.

(8) Low Energy Awareness, § 25.176(c)

[Contents for this section have not been sufficiently reviewed by the FTHWG.]

27. Static Directional and Lateral Stability - § 25.177.

a. Explanation.

(l) Static Directional Stability. Positive static directional stability is defined as the tendency to recover from a skid with the directional control~~rudder~~ free. This requirement returned at Amendment 25-135. Prior to Amendment 25-72, a separate demonstration of positive static directional stability was required by § 25.177(a) for any landing gear and flap position and symmetrical power or thrust condition at speeds from 1.13 V_{SR1} up to V_{FE}, V_{LE}, or V_{FC}/M_{FC}, as appropriate for the airplane configuration.

(2) Static Lateral Stability. Positive static lateral stability is defined as the tendency to raise the low wing in a sideslip with hands off the roll controls. This requirement returned at Amendment 25-135. Prior to Amendment 25-72, a separate demonstration was required by § 25.177(b) to show that static lateral stability was not negative in any landing gear and flap position and symmetrical power or thrust condition at speeds from 1.13 V_{SR1} to V_{FE}, V_{LE}, or V_{MO}/M_{MO}, as appropriate for the airplane configuration. At speeds from V_{MO}/M_{MO} to V_{FC}/M_{FC}, negative static lateral stability was permitted by § 25.177(b), if the divergence is:

(a) Gradual;

(b) Easily recognizable by the pilot; and

(c) Easily controllable by the pilot.

(3) Steady Straight Sideslips.

(a) Section 25.177(c) requires, in steady, straight sideslips throughout the range of sideslip angles appropriate to the operation of the airplane, that the directional~~aileron and rudder~~ control movements and forces be substantially proportional to the angle of sideslip. Also, the factor of proportionality must lie between limits found necessary for safe operation. The factor of proportionality is the slope of control movements and forces with respect to the angle of sideslip. During these straight, steady sideslips, necessary lateral control movements and forces must not be in the unstable sense with the exception of speeds above Vmo/Mmo per § 25.177(b)(2). Section 25.177(c) also states that that the range of sideslip angles evaluated must include those sideslip angles resulting from the lesser of: (1) one-half of the available directional~~rudder~~ control input; and (2) a directional~~rudder~~ control force of 180 pounds. This means that if using one-half of the available directional~~rudder~~ control input takes less than 180 pounds of force, then compliance must be based on using one-half of the available directional~~rudder~~ control input. If application of 180 pounds of directional~~rudder~~ control force results in using less than one-half of the available directional~~rudder~~ control input, then compliance must be based on applying 180 pounds of directional~~rudder~~ control force. By cross-reference to § 25.177(a), § 25.177(c) requires that these steady, straight sideslip criteria must be met for all landing gear and flap positions and symmetrical power or thrust conditions at speeds from 1.13 V_{SR1} to V_{FE}, V_{LE}, or V_{FC}/M_{FC}, as appropriate for the configuration.

(b) Experience has shown that an acceptable method for determining the appropriate sideslip angle for the operation of a transport category airplane is provided by the following equation:

$$ß = \arcsin(30/V)$$

where ß = Sideslip angle, and
V = Airspeed (KTAS)

Recognizing that smaller sideslip angles are appropriate as speed is increased, this equation provides sideslip angle as a function of airspeed. The equation is based on the theoretical sideslip value for a 30-knot crosswind, but has been shown to conservatively represent (i.e., exceed) the sideslip angles achieved in maximum crosswind takeoffs and landings and minimum static and dynamic control speed testing for a variety of transport category airplanes. Experience has also shown that a maximum sideslip angle of 15 degrees is generally appropriate for most transport category airplanes even though the equation above may provide a higher sideslip angle. However, limiting the maximum sideslip angle to 15 degrees may not be appropriate for airplanes with low approach speeds or high crosswind capability.

(c) A lower sideslip angle than that provided in paragraph 27a(3)(b) may be used if it is substantiated that the lower value conservatively covers all crosswind conditions, engine failure scenarios, and other conditions where sideslip may be experienced within the approved operating envelope. Conversely, a higher value should be used for airplanes where test evidence indicates that a higher value would be appropriate to the operation of the airplane.

(d) For the purpose of showing compliance with the requirement out to sideslip angles associated with the lesser of: (1) one-half of the available directional~~rudder~~ control input; and (2) a directional~~rudder~~ control force of 180 pounds, there is no need to consider a directional~~rudder~~ control input beyond that corresponding to full available rudder surface travel. Some directional~~rudder~~ control system designs may limit the available rudder surface deflection such that full deflection for the particular flight condition, or the maximum commanded sideslip angle for the flight condition, is reached before the directional~~rudder~~ control reaches one-half of its available travel. In such cases, further directional~~rudder~~ control input is unnecessary as it would not result in a higher sideslip angle, and therefore would not affect compliance with the rule.

(4) Full Directional Control~~Rudder~~ Sideslips.

(a) At sideslip angles greater than those appropriate for normal operation of the airplane, up to the sideslip angle at which full directional~~rudder~~ control input is used or a directional~~rudder~~ control force of 180 pounds is obtained, § 25.177(d) requires that the directional (~~rudder~~ pedal) control forces may not reverse and increased rudder deflection must be needed for increased angles of sideslip. The goals of this higher-than-normal sideslip angle test are to show that at full directional~~rudder~~ control input, or at maximum expected pilot effort: (1) the directional~~rudder~~ control force does not reverse, and (2) increased rudder deflection must be needed for increased angles of sideslip, thus demonstrating freedom from rudder lock or fin stall, and adequate directional stability for maneuvers involving large rudder inputs.

(b) Compliance with this requirement should be shown using straight, steady sideslips. However, if full lateral control input is reached before full directional~~rudder~~ control travel or a directional~~rudder~~ control force of 180 pounds is reached, the maneuver may be continued in a non-steady heading (i.e., rolling and yawing) maneuver. Care should be taken to prevent excessive bank angles that may occur during this maneuver.

(c) Section 25.177(d) states that the criteria listed in paragraph 27a(4)(a) must be met at all approved landing gear and flap positions for the range of operating speeds and power conditions appropriate to each landing gear and flap position with all engines operating. The range of operating speeds and power conditions appropriate to each landing gear and flap position with all engines operating should be consistent with the following:

1 For takeoff configurations, speeds from V_2+xx (airspeed approved for all-engines-operating initial climb) to V_{FE} or V_{LE}, as appropriate, and takeoff power/thrust;

2 For flaps up configurations, speeds from 1.23 V_{SR} to V_{LE} or V_{MO}/M_{MO}, as appropriate, and power from idle to maximum continuous power/thrust;

3 For approach configurations, speeds from 1.23 V_{SR} to V_{FE} or V_{LE}, as appropriate, and power from idle to go-around power/thrust; and

4 For landing configurations, speeds from V_{REF}-5 knots to V_{FE} or V_{LE}, as appropriate, with power from idle to go-around power/thrust at speeds from V_{REF} to V_{FE}/V_{LE}, and idle power at V_{REF}-5 knots (to cover the landing flare).

b. Procedures. The test conditions should include each flap and landing gear configuration as described in paragraphs 27a(1) through 27a(4) at an altitude appropriate to each configuration.

(1) Basic Tests for Static Directional and Lateral Stability.

(a) Static Directional Stability. To check static directional stability with the airplane in the desired configuration and stabilized at the trim speed, the airplane is slowly yawed in both directions while maintaining the wings level with the lateral~~roll~~ controls. When the directional control~~rudder~~ is released, the airplane should tend to return to straight flight.

(b) Static Lateral Stability. To check lateral stability with a particular configuration and trim speed, conduct steady, straight sideslips at the trim speed by maintaining the airplane heading with directional control~~rudder~~ and banking with the lateral~~roll~~ controls. When the lateral~~roll~~ controls are released, with the directional control~~rudder~~ held fixed, and the low wing tends~~should tend~~ to return to level. Initial bank angle should be appropriate to type; however, it is recommended that it should not be less than 10 degrees or that necessary to maintain the steady, straight sideslip with one-half directional control~~rudder~~ deflection, whichever occurs first. If lateral control deflection is needed during the straight, steady sideslip, lateral ~~Roll~~ control centering by the pilot should not be permitted during this evaluation (only a control release).~~.~~ The intent of this testing is to evaluate the short-term response of the airplane; therefore long-term effects, such as those due to spanwise fuel movement, need not be taken into account.

(2) Steady, Straight Sideslips. Steady, straight sideslips should be conducted in each direction to show that the directional~~aileron and rudder~~ control movements and forces are substantially proportional to the angle of sideslip in a stable sense, and that the factor of proportionality is within the limits found necessary for safe operation. Also, the necessary lateral control movements and forces must not be in the unstable sense with the exception of speeds above Vmo/Mmo per § 25.177(b)(2).These tests should be conducted at progressively greater sideslip angles up to the sideslip angle appropriate to the operation of the airplane (see paragraph 27a(3)(b)) or the sideslip angle associated with one-half of the available directional~~rudder~~ control input (as limited by a directional~~rudder~~ control force of 180 pounds), whichever is greater.

(a) When determining the lateral~~rudder~~ and directional~~aileron~~ control forces, the controls should be relaxed at each point to find the minimum force needed to maintain the control surface deflection. If excessive friction is present, the resulting low forces will indicate the airplane does not have acceptable stability or proportionality characteristics.

(b) In lieu of conducting each of the separate qualitative tests described in paragraph 27b(1), the applicant may use recorded quantitative data showing lateral~~aileron~~ and directional~~rudder~~ control force and position versus sideslip (left and right) to the appropriate limits in the steady heading sideslips conducted to show compliance with § 25.177(c). If the control force and position versus sideslip indicates appropriate lateral stability~~positive dihedral effect~~ and positive directional stability, compliance with § 25.177(a) and (b) will have been successfully demonstrated.

(3) Full Directional Control~~Rudder~~ Sideslips.

(a) Rudder lock is that condition where the rudder over-balances aerodynamically and either deflects fully with no additional pilot input or does not tend to return to neutral when the pilot input is released. It is indicated by a reversal in the directional~~rudder~~ control force as sideslip angle is increased. Full directional control~~rudder~~ sideslips are conducted to determine the directional~~rudder~~ control forces and deflections out to sideslip angles associated with full directional~~rudder~~ control input (or as limited by a directional~~rudder~~ control force of 180 pounds) to investigate the potential for rudder lock and lack of directional stability.

(b) To check for positive directional stability and for the absence of rudder lock, conduct steady heading sideslips at increasing sideslip angles until obtaining full directional~~rudder~~ control input or a directional~~rudder~~ control force of 180 pounds. If full lateral control is reached before reaching the directionalrudder control limit or 180 pounds of directionalrudder control force, continue the test to the directional controlrudder limiting condition in a non-steady heading sideslip maneuver.

(4) Control Limits. The control limits approved for the airplane should not be exceeded when conducting the flight tests required by § 25.177.

(5) Flight Test Safety Concerns. In planning for and conducting the full directional controlrudder sideslips, items relevant to flight test safety should be considered, including:

(a) Inadvertent stalls,

(b) Effects of sideslip on stall protection systems,

(c) Actuation of stick pusher, including the effects of sideslip on angle-of-attack sensor vanes,

(d) Heavy buffet,

(e) Exceeding flap loads or other structural limits,

(f) Extreme bank angles,

(g) Propulsion system behavior (e.g., propeller stress, fuel and oil supply, and inlet stability),

(h) Minimum altitude for recovery,

(i) Resulting roll rates when the sideslip at the lateral controlaileron limit is exceeded, and

(j) Position errors and effects on electronic or augmented flight control systems, especially when using the airplane's production airspeed system.

(k) Rudder loads, particularly those that may occur with dynamic rudder inputs.
(l) Cross-axis control system considerations.

28. Dynamic Stability - § 25.181.

a. Explanation. While the purpose of 25.173-177 are to ensure that the airplane exhibits satisfactory static stability and control feel characteristics, the purpose of 25.181 is to ensure that the dynamics of any motion resulting from control input or from external disturbances is satisfactory, such that the motion does not impede the pilot's ability to achieve precise attitude control. Therefore, 25.181 requires that longitudinal short period dynamics be heavily damped and the lateral-directional dynamics be positively damped and controllable without exceptional strength or skill. Evaluation of dynamic stability characteristics should include the response to turbulence and gusts. Nonlinear effects should also be considered such as authority or rate limits and EFCS mode transitions or nonlinear feedback.

a. Explanation.

(1) The dynamic stability tests described in this section should be conducted over the speed range of 1.13 V_{SR} to V_{FE}, V_{LE} or V_{FC}/M_{FC}, as appropriate.

(2) Dynamic Longitudinal Stability.

(a) The classic short period oscillation is the first oscillation the pilot sees after disturbing the airplane from its trim condition with the pitch control (as opposed to the long period (phugoid)). Care should be taken that the control movement used to excite the motion is not too abrupt.

(b) Heavily damped means that the oscillation has decreased to 1/10 the initial amplitude within approximately two cycles after completion of the control input.

(c) Short period oscillations must be heavily damped, both with controls free and controls fixed.

(3) Dynamic Lateral-Directional Stability. The evaluation of the dynamic lateral-directional stability should include any combined lateral-directional oscillation (classically "(“Dutch roll") occurring over the speed range appropriate to the airplane configuration. This oscillation must be positively damped with controls free and must be controllable with normal use of the primary controls without requiring exceptional piloting skill.

(4) EFCS and SAS Characteristics. The use of a closed-loop EFCS or SAS has the potential to introduce additional dynamic modes, whose character may be distinct from or a modification of the classical short period or "Dutch roll" oscillatory modes. Any dynamic motion, whether stemming from the aerodynamic short period or Dutch roll modes or generated by closed loop systems interactions should be evaluated under 25.181 for adequate stability characteristics. The frequency range of interest for these modes of motion is one in which dynamic modes affect the pilot's control of the airplane.

b. Procedures.

(1) Dynamic Longitudinal Stability.

(a) The test for longitudinal dynamic stability is accomplished by a rapid movement or pulse of the longitudinal control in a nose up and nose down direction at a rate and degree necessary to obtain a short period pitch response from the airplane. The best way to excite a particular mode of motion is via a doublet input at the target frequency. Appropriate frequencies for excitation should be selected after reviewing the frequencies of the augmented and unaugmented airplane, and its control system.

(b) Dynamic longitudinal stability should be checked at a sufficient number of points in each configuration to assure compliance at all operational speeds.

(2) Dynamic Lateral~~-~~-Directional Stability.

(a) A typical test for lateral-directional dynamic stability is accomplished by a directional control~~rudder~~ doublet or triplet input at a rate and amplitude that will excite the lateral-directional response (i.e., Dutch roll). The control input should be in phase with the airplane's oscillatory response.

(b) Dynamic lateral~~-~~-directional stability should be checked under all conditions and configurations. If critical, special emphasis should be placed on adverse wing fuel loading conditions.

(3) Airplanes Equipped with a Closed Loop EFCS or Stability Augmentation Systems (SAS). In the event a closed loop control system ~~SAS~~ is operating while demonstrating~~required for the airplane to show~~ compliance with § 25.181(a) or (b), it must also meet the requirements of §§ 25.671 and 25.672. The potential for additional dynamic modes of motion should be considered and investigated in their axes and at their critical frequencies with the systems operating normally. Additionally:

(a) If a single failure of the EFCS/SAS can degrade dynamic stability characteristics, such as for an airplane ~~airplane is~~ equipped with only one SAS (i.e., a single strand system), in accordance with § 25.672, compliance with the dynamic stability requirements of § 25.181(a) or (b), as applicable, must be shown throughout the normal operating flight envelope to be certificated with the EFCS/SAS operating normally, and in a reduced, practical operating flight envelope that will permit continued safe flight and landing with the single EFCS/SAS failure~~inoperative~~.

(b) If the airplane is equipped with more than one SAS, the resulting effects of SAS failure should be considered when determining whether or not the primary and any redundant SAS should be operating simultaneously for showing compliance with the dynamic stability requirements of § 25.181(a) or (b). If the primary and redundant SAS are dissimilar, the functional capability (i.e., control authority) of the redundant SAS should be considered with regard to restricting the operating envelope after failure of the primary SAS. At the applicant's option, however, compliance with § 25.181(a) or (b) may still be demonstrated to a reduced flight envelope with no SAS operating as described in paragraph 28b(3)(a), above.

(c) Regardless of the EFCS/SAS redundancy, following any single failure or combination of failures not shown to be extremely improbable, the airplane should be safely controllable at the point of system failure or malfunction anywhere in the approved operating flight envelope of the airplane. Accordingly, it should be demonstrated that the airplane remains controllable during transition from the operating SAS to any redundant SAS, and during transition from anywhere in the normal operating envelope to the reduced practical operating envelope of § 25.672(c), if applicable. Airplane controllability should be demonstrated to meet the following levels as defined by the FAA HQRM. (The FAA HQRM is described in Appendix 5 of this AC.)

1 In the normal operating flight envelope with the SAS operating, the handling qualities should be "satisfactory" (SAT) as defined by the FAA HQRM.

2 At the point of SAS failure in the normal operating envelope, the airplane should be "controllable" (CON), as defined by the FAA HQRM, during the short term transitory period required to attain a speed and configuration that will permit compliance with paragraph 3, below.

3 During transition from the primary SAS to a redundant SAS, or from the normal operating envelope to a reduced, practical operating envelope (where applicable), the handling qualities should be “adequate” (ADQ) as defined by the HQRM.

4 In the reduced, practical operating flight envelope that will permit continued safe flight and landing, the handling qualities should be “satisfactory” (SAT) as defined by the HQRM.

AC 25-25A

4.14 **Demonstration of Static Longitudinal Stability, § 25.175 and § 25.176.**
4.14.1 To show compliance with § 25.175, … [unchanged]
4.14.2 Acceptable Test Program, § 25.175. [remainder unchanged]
4.14.3 Static Longitudinal Stability- Alternate, § 25.176
To show compliance with this requirement, the applicant should combine qualitative evaluations with the other testing. Each change in airplane or control system behavior due to icing that has a significant effect on the characteristics relative to the requirement of 25.176 should be specifically investigated.

Appendix 4 Topic 7 Side Stick Controllers

FAA Aviation Rulemaking Advisory Committee

FTHWG Topic 7

Side Stick Controls

Recommendation Report

January, 2017

Table of Contents

Executive Summary

Current FAA Part 25 regulations and guidance pertaining to pilot strength and controllability are intended for conventional control column and wheel designs. These regulations are not directly applicable to side stick controllers and Issue Paper special conditions have been necessary for any design incorporating a side stick controller to address controllability, maneuverability and stability requirements. These special conditions have specified qualitatively “suitable” control forces during required testing, in lieu of the existing quantitative maximum and minimum control force criteria for conventional control wheels, and add other requirements for suitable pilot-in-the-loop characteristics. Other special conditions have specified limit pilot forces and torques for structural design of side stick controller components, in lieu of existing pilot applied force and torque requirements for conventional controller design loads.

EASA have implemented requirements similar to the FAA Issue Paper special conditions into regulation at Amendment 13 of CS25. Other airworthiness authorities have yet to make regulatory or guidance changes to address side stick controllers. The objective of this tasking is to develop a harmonized standard applicable to side stick controllers to be implemented by the FAA and EASA at a future amendment.

It was the position of the FTHWG chairpersons, supported by the FAA representatives, that the qualitative criteria currently in the FAA special conditions and EASA CS 25.143(k) were to be avoided in the recommended harmonized regulations for side sticks. The proposed regulatory changes and associated guidance material for Subpart B provide quantitative maximum and minimum pilot control forces for side sticks where such criteria currently exist for conventional control wheels. Also included are requirements for pilot-in-the-loop handling characteristics evaluations that are considered appropriate for all controller types but are specifically intended to identify any unsafe behavior especially in airplane designs incorporating augmented or closed-loop control systems and/or low-force, small displacement side stick controllers.

The side stick control system design loads and other side stick control system design requirements related to controller coupling, dual pilot control input awareness and failure annunciations are not included in the proposed regulatory and guidance changes. These areas are recommended to be addressed by the Flight Controls Harmonization Working Group whose participants have the expertise to address the associated regulations in Subparts C, D and F, with participation from the FTHWG.

Background

Aircraft equipped with side stick controllers instead of conventional column and wheel control inceptors are designed for one-hand operation. Some current pilot control force limits are based upon two-handed effort and therefore are not appropriate for aircraft type designs utilizing side stick controllers. In addition, given the difference in pilot arm and wrist positions and the associated difference in force and leverage capabilities with side stick controllers, the single-handed force requirements were also to be reviewed for potential revisions. Previous aircraft models with side stick controllers, such as the Airbus A320, A330, A340, A350 & A380, Bombardier BD 500, Dassault Falcon 7X and Embraer EMB 545, & 550, have utilized Issue Papers and CRIs to address these unique requirements. As the use of side stick controllers has become more commonplace in modern Transport Category airplanes designs, continued use of Issue Papers and CRIs to address the unique considerations for such designs has become a significant burden to applicants and airworthiness authorities.

Details of the task have been defined at the working level in the work plan (Topic 7, Side Stick Controls) resulting from the Phase 1 FTHWG Transport Airplane Performance and Handling Characteristics – New Task Recommendation Report (Revision A, January 30, 2014), included as Attachment 7A.

The applicable rules and guidance materials associated with pilot-applied pitch and roll force limits were reviewed and revisions are proposed for 14 CFR Part 25 Subpart B that provide a harmonized standard addressing the use of side stick controllers.

A. What is the underlying safety issue addressed by the JAR/FAR? Or alternatively (use the alternative in our appendices)

As described in FAA AC 25-7C, the maximum and minimum pilot control force criteria specified in §25.143(d) and contained in other maneuver-specific regulations are intended to permit a pilot to smoothly and safely control and maneuver the airplane without exceptional skill or strength and without risk of over-stressing the airframe or encountering characteristics that would interfere with normal maneuvering. Existing FAA Part 25 regulations pertaining to pilot strength and controllability are intended for conventional control wheel designs and are not directly applicable to side stick controllers.

B. What is the task?

Review current rules and guidance within 14 CFR Part 25 Subpart B pertaining to pilot-applied pitch and roll force limits and special conditions used for approval of side stick controllers on previous model certification programs. Based on this review, develop harmonized standards for temporary and maximum prolonged pilot-applied force levels for side stick controllers to be incorporated into a future revision of associated FAA rules and guidance. It was identified in Phase 1 of the tasking that at least the following requirements would need to be addressed:

a) Pilot Short & Long Term Forces in §25.143(d) for pitch and roll
b) Pilot force gradient guidance in AC 25-7 for §25.143(g)
c) Pilot Short Term one-handed force requirement in §25.145(b)
d) Maximum Pilot force in the landing configuration for accelerating from trim to 1.7V_{SR} and decelerating to V_{SW} in 25.175(d)
e) Maximum pilot stick forces that limit stability demonstrations prescribed in §25.175(b)(1)-(3)
f) Maximum Pilot force to recover to 1G flight when speed brakes are extended in §25.253(a)(5)
g) Pilot pitch forces for out-of-trim recovery in§ 25.255(f)

In addition to force limit requirements, certain aspects of pilot interactions for use of side stick controllers were also to be evaluated. It was expected that at least the following characteristics would need to be addressed:

h) Side stick controller coupling design
i) Pilot-in-the-loop (PIL) characteristics, including operation in turbulence
j) Pitch and roll control force and displacement sensitivity

It was also expected that this task would include recommendations for further review and revision of regulations and guidance beyond Subpart B that may need to be addressed (e.g., §25.397).

It should be noted that this task was to focus on pilot-applied input force requirements and the pilot and system interface characteristics noted above. While industry experience to date has been with passive side stick controllers, consideration was also to be given to emerging active side stick controller technologies.

This task was not to address lateral/directional/longitudinal stability requirements that are applicable for advanced flight control system designs that augment the inherent airframe stability.

C. Why is this task needed?

Current FAA Part 25 regulations and guidance pertaining to pilot strength and controllability are intended for conventional control column and wheel designs. They are not directly applicable to side stick controllers and special conditions have been necessary for any design incorporating a side stick controller to address controllability and maneuverability requirements.

The applicable rules and guidance materials associated with pilot-applied pitch and roll force limits were to be reviewed and new regulations and guidance were to be proposed for Part 25 Subpart B that would provide a harmonized standard addressing the use of side stick controllers.

This review and proposed revisions to rules and guidance material were also to potentially address pilot interface and system characteristics pertaining to the following items currently contained in existing FAA Issue Paper special conditions for side sticks:

a) Pilot control authority to ensure the coupling design addresses corrective and /or overriding control inputs by either pilot. The coupling design should provide for reliable, unambiguous indications (e.g., aural, visual and/or tactile) indicating the side stick that is in command, not in command, and when combined inputs are being applied (if simultaneous inputs are allowed by the design).
b) Pilot control such that the side stick controllers do not produce unsuitable pilot-in-the-loop control characteristics when considering precision path control / tasks and turbulence
c) Pitch and roll control force and displacement sensitivity compatibility to insure normal inputs on one control axis will not cause significant unintentional inputs on the other.

These control harmony characteristics should also insure that precision control tasks are accomplished without exceptional piloting skill or alertness.

This review was also expected to result in recommendations for future revisions to any rules and guidance materials within 14 CFR Part 25 outside of Subpart B that pertain to pilot applied control force limits or side stick controller system design and interaction characteristics such as 14 CFR 25.397(c) and CS 25.777(i).

D. Who has worked the task?

The Flight Test Harmonization Working Group has worked this task during Phase 2 activities. Participants in this FTHWG task included:

Airframe Manufacturers:
Boeing, Airbus, Gulfstream, Bombardier, Dassault, Textron Aviation, Embraer

Airworthiness Authorities:
FAA, EASA, TCCA (CAAI and JCAB as observers)

Operators:
American Airlines, Delta Airlines

Labor Union:
ALPA

E. Any relation with other topics?

The Envelope Protection – Topic 1 is related to this topic by 1) a recommended allowance for airplanes equipped with a load factor limiting function to meet §25.143(g) without satisfying the specified minimum pitch control forces to avoid easily overstressing the airplane inadvertently; and 2) proposed modifications to the same regulations and guidance paragraphs recommended for this topic – §§ 25.145(b) and 25.175(d), and associated guidance paragraphs. Proposed changes to incorporate side stick pitch force criteria should be integrated with the recommended changes from Topic 1.

The Adaptation for Flight in Icing – Topic 2 is related to this topic by proposed modifications to the guidance paragraphs associated with § 25.145(i)(2). Proposed changes to incorporate side stick pitch force criteria in the AC25-25A guidance paragraph should be integrated with the recommended changes from Topic 2.

The Lateral/Directional/Longitudinal Stability – Topic 6 is related to this topic due to the minimum permissible static longitudinal stability gradient for stick force versus airspeed specified in §25.173(c) and the associated guidance, as well as the maximum longitudinal stick force criteria specified in §25.175(b)&(d) and the associated guidance. Proposed regulatory and guidance changes to incorporate side stick pitch force criteria should be integrated with the recommended changes from Topic 6.

The Out-of-Trim Characteristics – Topic 13 is related to this topic due to specified pitch control force criteria in §25.255(f) and associated guidance for pitch control forces when showing compliance with §25.255(a)&(f). Proposed regulatory and guidance changes to incorporate side stick pitch force criteria should be integrated with the recommended changes from Topic 13.

Pilot Induced Oscillation/Airplane Pilot Coupling (PIO/APC) – Topic 15 and Handling Qualities Rating Method (HQRM) – Topic 16 planned for Phase 3 of the FTHWG tasking are also related to this topic. PIO/APC evaluations and existing guidance material are generally associated with §25.143. This proposal introduces §25.143(k) to 14 CFR and modifies CS25.143(k) to include pilot-in-the-loop handling characteristics evaluations intended to identify any unsafe behavior, especially in airplane designs incorporating augmented or closed-loop control systems and/or low-force, small displacement side stick controllers. Precision path control tasks used to assess PIO/APC susceptibility are defined in FAA AC25-7C (and as modified by FAA Issue Papers) and the HQRM of AC25-7C has been used to determine acceptability of the airplane handling qualities during these pilot evaluations. It is expected that the PIO/APC and HQRM guidance currently in FAA AC25-7C will be revised during Phase 3 of the FTHWG tasking and that the proposed §25.143(k) will be refined further, if necessary.

Failure Assessment Methodology and Classification (HQ + Perf) – Topic 17 planned for Phase 3 of the FTHWG tasking is also related to this topic. Although the maximum and minimum control forces established in §25.143(d) are to be applied for the testing required by §25.143(a) through (c), which includes any "probable operating condition" in §25.143(b) and the noted engine failure conditions, existing guidance in AC 25-7C paragraph 20.a(2)(b) suggests that the long-term force requirements of 25.143(d) would be applicable for failure conditions that affect the ability to trim out or eliminate sustained control forces. Further, recent proposed ARAC recommended rulemaking related to §25.671(c), and guidance related to §§ 25.933(a), 25.1309, 25.1329 make reference to the maximum short and long-term control forces of § 25.143(d). It is expected that the contents of the Topic 17 tasking will review the existing guidance related to application of the § 25.143(d) control forces for failure conditions during Phase 3 of the FTHWG tasking and recommend any necessary changes.

Historical Information

A. What are the current regulatory and guidance material in CS 25 and FAR 25?

The current FAA and EASA regulations applicable to this topic are those that currently define a quantitative maximum or minimum pitch or roll control force requirement, or specify a qualitative pitch or roll control force requirement with associated guidance material where quantitative criteria are established as an acceptable means of compliance. The included list of affected regulations exceeds those initially identified in the work plan included as Attachment 7A. The amendment levels of the regulations referenced below include through 14 CFR Part 25 Amdt 143 and CS 25 Amdt 18.

Current 14.CFR Part 25 Subpart B – Flight regulations at Amendment 25-143:

Controllability and Maneuverability

§25.143 General.

(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

(g) When maneuvering at a constant airspeed or Mach number (up to V_{FC}/M_{FC}), the stick forces and the gradient of the stick force 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 in maintaining control of the airplane, and local gradients must not be so low as to result in a danger of overcontrolling.

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

(1) Controllability must be demonstrated with the most critical of the ice accretion(s) for the particular flight phase as defined in Appendices C and O of this part, as applicable, in accordance with §25.21(g);

(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

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-42, 43 FR 2321, Jan. 16, 1978; Amdt. 25-84, 60 FR 30749, June 9, 1995; Amdt. 25-108, 67 FR 70826, Nov. 26, 2002; Amdt. 25-121, 72 FR 44667, Aug. 8, 2007; Amdt. 25-129, 74 FR 38339, Aug. 3, 2009; Amdt. 25-140, 79 FR 65525, Nov. 4, 2014]

§25.145 Longitudinal control.

(b) With the landing gear extended, no change in trim control, or exertion of more than 50 pounds control force (representative of the maximum short term force that can be applied readily by one hand) may be required for the following maneuvers:

(1) With power off, flaps retracted, and the airplane trimmed at 1.3 V_{SR1}, extend the flaps as rapidly as possible while maintaining the airspeed at approximately 30 percent above the reference stall speed existing at each instant throughout the maneuver.

(2) Repeat paragraph (b)(1) except initially extend the flaps and then retract them as rapidly as possible.

(3) Repeat paragraph (b)(2), except at the go-around power or thrust setting.

(4) With power off, flaps retracted, and the airplane trimmed at 1.3 V_{SR1}, rapidly set go-around power or thrust while maintaining the same airspeed.

(5) Repeat paragraph (b)(4) except with flaps extended.

(6) With power off, flaps extended, and the airplane trimmed at 1.3 V_{SR1}, obtain and maintain airspeeds between V_{SW} and either 1.6 V_{SR1} or V_{FE}, whichever is lower.

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-23, 35 FR 5671, Apr. 8, 1970; Amdt. 25-72, 55 FR 29774, July 20, 1990; Amdt. 25-84, 60 FR 30749, June 9, 1995; Amdt. 25-98, 64 FR 6164, Feb. 8, 1999; 64 FR 10740, Mar. 5, 1999; Amdt. 25-108, 67 FR 70827, Nov. 26, 2002]

§25.173 Static longitudinal stability.

Under the conditions specified in §25.175, the characteristics of the elevator control forces (including friction) must be as follows:

(c) The average gradient of the stable slope of the stick force versus speed curve may not be less than 1 pound for each 6 knots.

[Amdt. 25-7, 30 FR 13117, Oct. 15, 1965]

§25.175 Demonstration of static longitudinal stability.

Static longitudinal stability must be shown as follows:

(b) *Cruise*. Static longitudinal stability must be shown in the cruise condition as follows:

(1) With the landing gear retracted at high speed, the stick force curve must have a stable slope at all speeds within a range which is the greater of 15 percent of the trim speed plus the resulting free return speed range, or 50 knots plus the resulting free return speed range, above and below the trim speed (except that the speed range need not include speeds less than 1.3 V_{SR1}, nor speeds greater than V_{FC}/M_{FC}, nor speeds that require a stick force of more than 50 pounds), with—

(i) The wing flaps retracted;

(ii) The center of gravity in the most adverse position (see §25.27);

(iii) The most critical weight between the maximum takeoff and maximum landing weights;

(iv) 75 percent of maximum continuous power for reciprocating engines or for turbine engines, the maximum cruising power selected by the applicant as an operating limitation (see §25.1521), except that the power need not exceed that required at V_{MO}/M_{MO}; and

(v) The airplane trimmed for level flight with the power required in paragraph (b)(1)(iv) of this section.

(2) With the landing gear retracted at low speed, the stick force curve must have a stable slope at all speeds within a range which is the greater of 15 percent of the trim speed plus the resulting free return speed range, or 50 knots plus the resulting free return speed range, above and below the trim speed (except that the speed range need not include speeds less than 1.3 V_{SR1}, nor speeds greater than the minimum speed of the applicable speed range prescribed in paragraph (b)(1), nor speeds that require a stick force of more than 50 pounds), with—

(i) Wing flaps, center of gravity position, and weight as specified in paragraph (b)(1) of this section;

(ii) Power required for level flight at a speed equal to $(V_{MO} + 1.3\ V_{SR1})/2$; and

(iii) The airplane trimmed for level flight with the power required in paragraph (b)(2)(ii) of this section.

(3) With the landing gear extended, the stick force curve must have a stable slope at all speeds within a range which is the greater of 15 percent of the trim speed plus the resulting free return speed range, or 50 knots plus the resulting free return speed range, above and below the trim speed (except that the speed range need not include speeds less than 1.3 V_{SR1}, nor speeds greater than V_{LE}, nor speeds that require a stick force of more than 50 pounds), with—

(i) Wing flap, center of gravity position, and weight as specified in paragraph (b)(1) of this section;

(ii) 75 percent of maximum continuous power for reciprocating engines or, for turbine engines, the maximum cruising power selected by the applicant as an operating limitation, except that the power need not exceed that required for level flight at V_{LE}; and

(iii) The aircraft trimmed for level flight with the power required in paragraph (b)(3)(ii) of this section.

(d) *Landing.* The stick force curve must have a stable slope, and the stick force may not exceed 80 pounds, at speeds between V_{SW} and 1.7 V_{SR0} with—

(1) Wing flaps in the landing position;

(2) Landing gear extended;

(3) Maximum landing weight;

(4) The airplane trimmed at 1.3 V_{SR0} with—
(i) Power or thrust off, and
(ii) Power or thrust for level flight.

(5) The airplane trimmed at 1.3 V_{SR0} with power or thrust off.

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-7, 30 FR 13117, Oct. 15, 1965; Amdt. 25-108, 67 FR 70827, Nov. 26, 2002; Amdt. 25-115, 69 FR 40527, July 2, 2004]

§25.253 High-speed characteristics.

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

(5) With the airplane trimmed at V_{MO}/M_{MO}, extension of the speedbrakes over the available range of movements of the pilot's control, at all speeds above V_{MO}/M_{MO}, but not so high that V_{DF}/M_{DF} would be exceeded during the maneuver, must not result in:
(i) An excessive positive load factor when the pilot does not take action to counteract the effects of extension;
(ii) Buffeting that would impair the pilot's ability to read the instruments or control the airplane for recovery; or
(iii) A nose down pitching moment, unless it is small.

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-23, 35 FR 5671, Apr. 8, 1970; Amdt. 25-54, 45 FR 60172, Sept. 11, 1980; Amdt. 25-72, 55 FR 29775, July 20, 1990; Amdt. 25-84, 60 FR 30750, June 9, 1995; Amdt. 25-121, 72 FR 44668, Aug. 8, 2007; Amdt. 25-135, 76 FR 74654, Dec. 1, 2011; Amdt. 25-140,79 FR 65525, Nov. 4, 2014]

§25.255 Out-of-trim characteristics.

(a) From an initial condition with the airplane trimmed at cruise speeds up to V_{MO}/M_{MO}, the airplane must have satisfactory maneuvering stability and controllability with the degree of out-of-trim in both the airplane nose-up and nose-down directions, which results from the greater of—

(1) A three-second movement of the longitudinal trim system at its normal rate for the particular flight condition with no aerodynamic load (or an equivalent degree of trim for airplanes that do not have a power-operated trim system), except as limited by stops in the trim system, including those required by §25.655(b) for adjustable stabilizers; or

(2) The maximum mistrim that can be sustained by the autopilot while maintaining level flight in the high speed cruising condition.

(f) In the out-of-trim condition specified in paragraph (a) of this section, it must be possible from an overspeed condition at V_{DF}/M_{DF} to produce at least 1.5 g for recovery by applying not more than 125 pounds of longitudinal control force using either the primary longitudinal control alone or the primary longitudinal control and the longitudinal trim system. If the longitudinal trim is used to assist in producing the required load factor, it must be shown at V_{DF}/M_{DF} that the longitudinal trim can be actuated in the airplane nose-up direction with the primary surface loaded to correspond to the least of the following airplane nose-up control forces:

(1) The maximum control forces expected in service as specified in §§25.301 and 25.397.

(2) The control force required to produce 1.5 g.

(3) The control force corresponding to buffeting or other phenomena of such intensity that it is a strong deterrent to further application of primary longitudinal control force.

[Amdt. 25-42, 43 FR 2322, Jan. 16, 1978]

<u>Current CS 25 Subpart B – Flight regulations at Amendment 18:</u>
(Only included where differences exist)

CONTROLLABILITY AND MANOEUVRABILITY

CS 25.143 General.

(k) Side Stick Controllers

In lieu of the maximum control forces provided in CS 25.143(d) for pitch and roll, and in lieu of specific pitch force requirements of CS 25.145(b) and CS 25.175(d), it must be shown that the temporary and maximum prolonged force levels for side stick controllers are suitable for all expected operating conditions and configurations, whether normal or non-normal.

It must be shown by flight tests that turbulence does not produce unsuitable pilot-in-the-loop control problems when considering precision path control/tasks.

[Amdt No: 25/3, 7, 13, 15, 16, 18]

CS 25.175 Demonstration of static longitudinal stability

{Sub-paragraph (d)(5) of 14 CFR 25.175 is not included. The specified thrust condition is covered by 14 CFR/CS 25.175(d)(4)(i) and should be removed from 14 CFR Part 25.}

Current FAA Guidance Material
FAA guidance material for 14 CFR §§25.143, 25.145, 25.173, 25.175, 25.253 and 25.255 is contained in Chapter 2, Sections 3, 5 and 8 of AC25-7C, 'Flight Test Guide for Certification of Transport Category Airplanes'. Recommended modification to the existing guidance content of the existing AC is shown with mark-ups in Attachment 7C.

For icing conditions, FAA guidance is provided in AC25-25A for 14 CFR 25.143(i). Recommended modification to the existing guidance content of the existing AC is shown with mark-ups in Attachment 7C.

Current CS25 Guidance Material
EASA guidance for CS 25 is provided via Acceptable Means of Compliance (AMC) material presented in Book 2. In general, FAA AC 25-7C provides more extensive guidance for compliance with the listed regulations than does CS 25 Book 2. Specific advisory material related to this recommendation is currently provided as AMC 25.143(d), AMC No 1 to CS25.143(g), AMC No 2 to CS 25.143(g), AMC 25.173(c), AMC 25.253(a)(5), and AMC 25.255.

No EASA guidance is provided for CS 25.143(a)(b)(k) related to control force or displacement sensitivity and demonstration that Pilot-Induced-Oscillations/Airplane-Pilot-Coupling tendencies are not encountered. Also, no specific guidance is provided for CS 25.145(b) or CS 25.175 maximum control forces.

B. What, if any, are the differences in the existing regulatory and guidance material CS 25 and FAR 25?

There are no substantive differences between CS 25 and 14 CFR Part 25 paragraphs applicable to this topic, except for the following:

1) CS 25 includes CS 25.143(k) as shown above in paragraph A. It specifically exempts the maximum control force requirements of §§ 25.143(d), 25.143(b) and 25.175(d) and replaces them with subjective criteria. In addition, it includes a requirement for side stick controllers to show by flight tests that conducting precision path control tasks in turbulence does not result in pilot-in-the-loop control problems.
2) CS 25 does not include § 25.175(d)(5) as is included in 14 CFR Part 25. The specified thrust condition is covered by 14 CFR/CS 25.175(d)(4)(i) and should be removed from 14 CFR Part 25.
3) CS 25 includes § 25.397(d) for limit pilot forces related to control system component structural design limits for side sticks. 14 CFR Part 25 does not include this subparagraph but the FAA has applied similar criteria to airplanes with side stick controllers through Issue Paper special conditions.
4) CS 25 includes § 25.777(i) which adds a requirement for pitch and roll cockpit controls related to control forces and displacement sensitivity and assurance that normal inputs on one control axis will not cause significant unintentional inputs on the other. CS 25.777(i)

is not specific to side stick controllers but the FAA has applied similar criteria to airplanes with side stick controllers through Issue Paper special conditions.

There is substantial difference between the advisory materials for acceptable means of compliance in FAA AC25-7C when compared to EASA CS25 Book 2 AMC content. In general, FAA AC 25-7C provides more extensive guidance for compliance with the regulations related to this proposal than does CS 25 Book 2. AC 25-7C provides detailed guidance for §§25.143, 25.145, 25.173, 25.175, 25.253 and 25.255 while CS 25 Book 2 limits AMC material to CS §§ 25.143(a)(b)(d)(g), 25.173(c), 25.253(a)(4)(5), and 25.255.

Where CS 25 AMC guidance is provided, it is not in conflict with FAA AC25-7C guidance, except for AMC25.255 paragraph 3 for compliance with out-of-trim maneuver force characteristics required by §25.255(b)(2) for conditions between V_{FC}/M_{FC} and V_{DF}/M_{DF}. AMC 25.255 imposes a more stringent criteria for out-of-trim maneuvering characteristics where a push force at 1g (with an airplane nose-up mistrim) can relax to zero force in a positive g condition provided that the stick force versus g curve has a positive slope at that point and cannot return to zero force at any higher Nz up to the maximum to be demonstrated. AC25-7C interprets the same requirement of §25.255(b)(2) to mean that the longitudinal control force for load factors greater than 1g may not be less than that used to obtain the initial 1g condition with the mistrim. This guidance difference is not related to side stick controllers and it is recommended that it be addressed as part of Topic 13 of this FTHWG tasking.

No EASA guidance is provided for CS 25.143(a)(b)(k) related to control force or displacement sensitivity and demonstration that no Pilot-Induced-Oscillations/Airplane-Pilot-Coupling tendencies are encountered. Also, no specific guidance is provided for CS 25.145(b) or CS 25.175(b)(d) maximum control forces.

C. What are the existing CRIs/IPs (SC and MoC)?

The FAA has applied Issue Papers to airplanes to be certified with side stick controllers, including:

1) F-X, *Side Stick Controllers – Controllability and Maneuverability*, with special conditions for subjectively suitable side stick pitch and roll control forces for expected operating conditions in lieu of §§ 25.143(d), 25.143(i)(2), 25.145(b), 25.173(c) and 25.175(b)(d); provisions for overriding control inputs by either pilot without unsafe characteristics, along with appropriate annunciation of controller status; and that use of the side stick doesn't result in unsuitable pilot-in-the-loop characteristics during precision path control tasks and turbulence and that pitch and roll control force and displacement sensitivity must be compatible such that inputs on one control axis will not cause significant unintentional inputs on the other. Some aspects of this Issue Paper are considered outside of Subpart B and thus outside the scope of this topic, but should be considered for future tasking of the Flight Controls Harmonization Working Group.
2) A-X, *Limit Pilot Forces for Side Stick Control*, with special conditions for limit pilot forces and torques for structural design of side stick control components in lieu of §25.397(c). This Issue Paper is considered outside of Subpart B and thus outside the

scope of this topic, but should be considered for future tasking of the Flight Controls Harmonization Working Group.

3) S-X, *Active Control Side Stick – Characteristics and Requirements*, with alternate means of compliance for §§ 25.671, 25.672, 25.685, 25.771, 25.777, 25.779, 25.1301, 25.1309, 25.1322 and 25.1523 for active control side sticks with reference to SAE ARP 5764 standards for active pilot inceptors. This also identifies demonstrations of crew awareness and deterrence of dual pilot inputs. This Issue Paper is considered outside of Subpart B and thus outside the scope of this Topic, but should be considered for future tasking of the Flight Controls Harmonization Working Group.

EASA has implemented many aspects of the FAA Issue Papers F-X and A-X into regulations in recent CS 25 amendments with similar content in CS 25.143(k), 25.397(d) and 25.777(i). There are no EASA CRIs issued to airplane designs including side stick controls with a certification basis of CS 25 at Amendment 18.

D. What, if any, are the differences in the Special Conditions (CRIs/IPs) (SC and MoC) and what do these differences result in?

EASA has implemented many aspects of the FAA Issue Papers F-X and A-X into regulations in recent CS 25 amendments with similar content in CS 25.143(k), 25.397(d) and 25.777(i). A special condition included in the FAA Issue Paper F-X related to the electronic side stick controller design providing for corrective and/or overriding control inputs by either pilot without unsafe characteristics and annunciations of controller status has not been included in CS 25 nor included in recent CRIs. EASA also has not applied a CRI for active control side sticks similar to FAA IP S-X. These aspects of side stick controllers are considered to be outside the scope of this topic, but should be considered for future tasking of the Flight Controls Harmonization Working whose participants have the expertise to address the associated regulations and guidance.

Although EASA has implemented some side stick specific regulations, the content is aligned with similar special conditions in FAA Issue Papers. However, the Subpart B related criteria are qualitative and can lead to different conclusions about the acceptability of minimum and maximum side stick forces, depending on the certification authority.

Consensus

It was not possible to achieve a full consensus of the FTHWG participants on the need for quantitative side stick force requirements or their values. A majority position was established that aligns with the guidelines provided for FAA rulemaking activities provided by the FTHWG chairpersons and the FAA, as discussed below in the Recommendation section. The proposed changes to existing regulations and guidance in the Recommendation below reflect the FTHWG majority position with the following dissenting opinions that could not be resolved in the time available:

Dissenting Opinions	FTHWG Response
1) Embraer does not see the need for	As noted in the Recommendation section, the counsel

specific force criteria rather than maintaining the qualitative criteria of the existing IP and CS 25.143(k), as many other current regulations are equally qualitative in nature. Embraer believes that even with the presence of the quantitative force requirements, a qualitative criterion is still necessary to guarantee safe operation of the airplane.	from the FTHWG co-chairs, supported by FAA input, was that subjectively suitable control forces as required by the current Issue Paper special conditions and EASA CS 25.143(k) would not be acceptable as US federal regulations. Although it is agreed that many existing regulations include qualitative criteria, the existing regulations related to minimum and maximum control forces permitted for conventional control wheels and rudder pedals include quantitative requirements. This proposal only includes quantitative requirements for side stick control forces where such requirements currently exist for conventional control wheels. The existing requirements of 25.143(a)(b)(c) and the associated guidance in AC25-7C paragraph 20b(1), specify the qualitative nature of the control forces and airplane handling qualities under any probable operating condition, in icing and non-icing. The noted existing guidance also clearly states that compliance is primarily a qualitative pilot assessment throughout the flight test program.
2) Boeing, Embraer and TCCA consider there to be insufficient data to support the maximum and minimum side stick control force values included in the proposal.	As noted in the Recommendation section, the selected short term maximum side stick control forces were based upon available military and industry studies for pilot strength capability, including validated human strength models, with the selected maximum values conservatively below what the 25th percentile female can apply. The minimum permissible pitch forces for static (speed) stability and maneuvering stability are based upon the existing control column minimum forces, and the ratio between the established maximum permissible side stick pitch forces and the existing maximums for conventional control wheels. Each OEM member with side stick control designs has assessed these minimum stability gradient levels (speed stability only where included in normal operation, and maneuver stability only when not accompanied by load factor limiting) and have agreed that the minimum pitch forces are consistent with approved designs. Also, as noted in the Recommendation section, the FAA is conducting a pilot strength study to be completed by the end of 2017 to cover today's pilot population. This study is expected to address side stick controllers, as well

	as conventional control wheels, and the results of that study are intended to be incorporated into a future revision of the regulations and guidance included in this report. Until that time, the side stick control force values presented in the report represent the best data available and are considered reasonable and appropriate by the majority of the FTHWG members.
3) Boeing considers the proposal to be incomplete. It should include additional requirements and guidance related to side stick controller force and displacement sensitivity, dual pilot input, handedness and ambidexterity, biodynamic coupling and handling qualities evaluations.	Although the FTHWG agrees that the noted aspects are important considerations, especially for pitch and roll controllers with small displacement and light control forces typical of some side stick designs, the existing §25.143(a)(b) and the proposed addition of §25.143(k) are considered to adequately address this concern. The added §25.143(k) paragraph includes requirements that unsuitable pilot-in-the-loop control characteristics not be encountered during precision path control tasks, including while in expected levels of turbulence, and pitch and roll control force sensitivity and displacement sensitivity must be compatible. The contents of this proposed regulation include the handling qualities related criteria from the FAA Special Conditions and EASA regulations applied to side stick controls for several decades, and the majority of FTHWG members, including airworthiness authorities, do not agree that additional requirements are needed within Subpart B. The existing general requirements for controllability and maneuverability in §25.143(a)(b) and the related guidance in AC25-7C are applicable to all controller types and address the noted concerns regarding control sensitivity, pilot-in-loop handling qualities issues and potential for PIO. The proposed guidance refers to the additional criteria of §25.143(k) and pilot assessments of the controller characteristics during the handling qualities testing already included in AC25-7C for showing compliance with §25.143(a)(b). In addition, the tasking for Phase 3 of the FTHWG includes Topic 15 - PIO/APC and Topic 16 – Handling Qualities Rating Method (HQRM) where the requirements of §25.143 and associated guidance are expected to be reviewed and revised. This task should assure any remaining concerns about adequate pilot-in-the-loop assessments are included in the guidance, regardless of the controller type, including addressing issues for handedness/ambidexterity.

	The side stick control system design requirements related to controller coupling, dual pilot control input awareness and failure annunciations, and requirements related to design loads, are not included in the proposed regulatory and guidance changes for Subpart B. These aspects of side stick design approval/certification are considered more appropriate for regulations outside of Subpart B and are recommended to be addressed by the Flight Controls Harmonization Working Group whose participants have the expertise to address the associated regulations in Subparts C, D and F, with participation from the FTHWG.

Recommendation

The counsel from the FTHWG co-chairs, supported by FAA input, was that subjectively suitable control forces as required by the current Issue Paper special conditions and EASA CS 25.143(k) would not be acceptable as US federal regulations. Specific control force levels (maximum and minimum) for airplane designs incorporating side stick controllers were developed that would be approximately equivalent to the current control force requirements for conventional control wheels. At the time of this effort by the FTHWG, it was understood that the FAA was conducting a pilot strength study for today's pilot population to be completed by the end of 2017, with the intent to revise the pilot control force standards currently in the regulations and guidance, where appropriate. The FTHWG believes the data from these future studies (which likely will include new pilot force levels for control wheel as well as side stick controls) can and should be incorporated into a future amendment of the regulations included in this report. Until that time, available pilot strength studies from military and industry and a validated human strength model were used to develop the proposed side stick control force standards which are believed to be reasonable and appropriate based on the current state-of-the art for existing Part 25 side stick implementations, including active control side sticks. The force levels chosen for side sticks during the FTHWG effort in some cases are based upon available data for "stick" (thought to be, at least in some cases, center-stick) controllers. This is noted as appropriate by some Air Force studies and the data presented in MIL-STD-1797A, though the linkage between the available "stick" data and side sticks was questioned by the FAA member.

Existing FAA special conditions related to side stick control system design loads and other side stick control system design requirements related to controller coupling and deterrence of dual pilot inputs (provisions for overriding control inputs by either pilot or dual pilot control input awareness), standards for active control side sticks and failure annunciations are not included in the recommended regulatory and guidance changes. These areas are considered more appropriate for the Flight Controls Harmonization Working Group whose participants have the expertise to address the associated regulations in Subparts C, D and F (14 CFR 25.397(c), 25.671, 25.672, 25.685, 25.771, 25.777, 25.779, 25.1301, 25.1309, 25.1322 and CS25.397(d). It is recommended that harmonization and implementation of special conditions for these aspects of side stick controllersbe considered for future tasking for the Flight Controls Harmonization Working Group, with participation from members of the FTHWG.

A. Rulemaking

1. What is the proposed action?

It is recommended that modifications to the FAA and EASA Part 25 Subpart B regulations be made as contained in Attachment 7B. In addition, it is recommended that CS 25.777(i) be deleted because it is considered by the FTHWG to pertain to airplane handling characteristics and its content is included in the proposed §25.143(k).

Further, the FAA should liaise with other airworthiness authorities to ensure consistent implementation in their associated regulations and guidance material.

2. What should the harmonized standard be?

See Attachment 7B for the recommended changes to current FAA and EASA Part 25 regulations.

3. How does this proposed standard address the underlying safety issue?

This proposal establishes quantitative maximum and minimum side stick control forces permissible during required controllability, maneuvering and stability testing that are intended to provide an equivalent level of safety achieved by the current regulations applicable to conventional control wheel designs. In addition, it includes requirements for pilot-in-the-loop handling characteristics evaluations to identify any unsafe behavior that could occur, especially in airplane designs incorporating augmented or closed-loop control systems and/or low-force, small displacement side stick controllers.

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

The proposed regulatory changes include content from existing FAA Issue Paper special conditions and existing CS 25 (Amdt 18) regulations to achieve a harmonized standard. More significantly, the qualitative criteria of the existing Issue Paper special conditions and CS 25.143(k) for side stick controller forces are replaced with quantitative maximum and minimum forces permissible during the required controllability, maneuverability and stability testing. These side stick force levels are intended to be approximately equivalent to the control forces specified for conventional control wheel designs. As such, it is considered that the proposed standard will maintain the current level of safety for airplanes with side stick controllers.

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

Manufacturers of transport category airplanes with side stick controllers have typically also included irreversible flight control systems with closed-loop control in the pitch and roll axis. As such, the control forces for the side stick are provided by artificial means (fixed spring gradient or active stick force gradient scheduling by flight condition) to provide nominal control force vs displacement gradients. These typical designs do not include side stick control forces that approach the recommended maximum forces standards. The minimum proposed maneuver stability (stick force vs g) and speed stability (stick force vs speed) requirements for side stick designs have in most current designs been met through alternate criteria in lieu of minimum control force gradients (i.e., load factor envelope protections, neutral speed stability special conditions, etc.). Current side stick designs incorporating speed stability are designed to have a minimum stick force vs speed that is above the minimum specified in the proposal, and current side stick designs without load factor limiting are designed to have a minimum stick force at limit maneuvering load factor that is above the minimum specified in the proposal. As such, it is considered that the proposed standard will maintain the current level of safety for airplanes with side stick controllers relative to current industry practice.

6. Who would be affected by the proposed change?

Manufacturers developing new or derivative transport category airplanes that include side stick controllers (passive or active) would be required to meet the new quantitative control force standards for Subpart B. In addition, §25.143(k) would be applicable to all new or derivative transport category airplanes (regardless of pitch/roll controller design) and includes requirements for pilot-in-the-loop handling characteristics evaluations and pitch and roll control force and displacement compatibility.

7. Does the proposed standard affect other HWG's and what is the result of any consultation with other HWGs?

The side stick control system design loads and other side stick control system design requirements related to controller coupling and deterrence of dual pilot inputs (provisions for overriding control inputs by either pilot or dual pilot control input awareness), standards for active control side sticks and failure annunciations are not included in the recommended regulatory and guidance changes. These areas are considered more appropriate for the Flight Controls Harmonization Working Group whose participants have the expertise to address the associated regulations in Subparts C, D and F (14 CFR 25.397(c), 25.671, 25.672, 25.685, 25.771, 25.777, 25.779, 25.1301, 25.1309, 25.1322 and CS25.397(d).

In addition, it is recommended that EASA delete CS 25.777(i) as the FTHWG considers it to pertain to airplane handling characteristics and its content has been included in the proposed §25.143(k). This should be referred to the FCHWG for concurrence.

There was no consultation with the FCHWG during the development of this proposal. It was understood that the FCHWG was inactive at the time.

B. Advisory Material

1. Is existing FAA advisory material adequate? If not, what advisory material should be adopted?

The current FAA and EASA advisory material is not adequate. The recommended changes to the regulations, including the addition of maximum and minimum control forces for side stick controllers necessitates advisory material changes to FAA AC 25-7C. Proposed changes to FAA AC25-7C are included in Attachment 7C.

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

FAA AC 25-7C Paragraph 20. General - § 25.143, Paragraph 21. Longitudinal Control – § 25.145, Paragraph 26. Static Longitudinal Stability and Demonstration of Static Longitudinal Stability – §§ 25.173 and 25.175, Paragraph 32. High Speed Characteristics – § 25.253, Paragraph 33. Out-of-Trim Characteristics – § 25.255 and Paragraph 228. Design and Function of Artificial Stall Warning and Identification Systems.

FAA AC 25-25A Chapter 4. Acceptable Means of Compliance – Flight Test Program paragraph 4.9.4.1.1.

EASA CS 25 Book 2 AMC 25.143(d) Controllability and Manoeuvrability, AMC No 1 to CS25.143(g) Controllability and Manoeuvrability, AMC No 2 to CS 25.143(g) Controllability and Manoeuvrability, AMC 25.173(c) Static Longitudinal Stability, AMC 25.253(a)(5) High Speed Characteristics, and AMC 25.255 Out-of-Trim Characteristics.

Economics

A. What is the cost impact of complying with the proposed standard (it may be necessary to get FAA Economist support to answer this one)?

There is no expected increase in cost to manufacturers or operators. There is expected to be a small reduction in new airplane certification costs by eliminating the administrative burden of coordination and compliance with Issue Paper special conditions currently associated with side stick control forces. It is not expected that additional flight testing or compliance activity is required relative to what is traditionally done for conventional control wheel designs or relative to compliance with the existing Issue Paper special conditions.

The second part of the new 25.143(k) paragraph for FAA 14 CFR incorporates the content of CS 25.777(i), which is currently required for new airplane certifications regardless of pitch/roll controller design. The first part of the proposed §25.143(k) is similar to CS25.143(k) and FAA Issue Paper special conditions applied to side stick controllers. In this proposal, the requirements are not limited to side stick controllers and thus would apply to conventional control wheel designs. Although this establishes a new requirement for control wheel designs, the requirement for suitable pilot-in-the-loop characteristics during precision path control tasks and turbulence is traditionally considered to be required under §25.143(a)(b) general controllability requirements and any associated PIO/APC susceptibility evaluations for compliance with those paragraphs. As such, no significant additional burden to applicants is expected to show compliance with the proposed §25.143(k) than is currently necessary to comply with §25.143(a)(b).

Also, the proposed AC 25-7C guidance retains the current wording for acceptable means of compliance for §25.143(a)-(g) and adds §25.143(k) – "*Compliance with § 25.143 (a) through (g) and (k) is primarily a qualitative determination by the pilot during the course of the flight test program.*" Unless the airplane exhibits marginal closed loop characteristics or excessive control forces, or the airplanes of similar design have shown susceptibility for PIO/APC, no further testing should be required beyond what is currently done for compliance with §25.143.

B. Does the HWG want to review the draft NPRM prior to publication in the Federal Register?

Yes.

ICAO Standards
How does the proposed standard compare to the current ICAO standard?

ICAO Annex 8 for Airworthiness of Aircraft, Part III for Large Aeroplanes includes Flight standards for in Chapter 2, including flying qualities standards in Section 2.3. These ICAO standards are qualitative in nature, and while they do include criteria that the stability of the airplane allow the for maneuvering and speed changes without excessive demands on the pilot's strength, they do not specifically address different pitch and roll controller designs or include specific maximum and minimum permissible controller forces. The proposed regulatory changes associated with this task are not considered to be in conflict with the ICAO standard.

Attachment 7A: Phase 1 Final Report: Work Plan – Side Stick Controls

1. What is the task?

Review current rules and guidance within 14 CFR Part 25 Subpart B pertaining to pilot-applied pitch and roll force limits and special conditions used for approval of side stick controllers on previous model certification programs. Based on this review, develop harmonized standards for temporary and maximum prolonged pilot-applied force levels for side stick controllers to be incorporated into a future revision of associated FAA rules and guidance. It is expected that at least the following requirements will need to be addressed:

a) Pilot Short & Long Term Forces in 25.143(d) for pitch and roll
b) Pilot force gradient guidance in AC 25-7 for 25.143(g)
c) Pilot Short Term one-handed force requirement in 25.145(b)
d) Maximum Pilot force in the landing configuration for accelerating from trim to 1.7Vsr and decelerating to V_{SW} in 25.175(d)
e) Maximum pilot stick forces that limit stability demonstrations prescribed in 25.175(b)(1)-(3)
f) Maximum Pilot force to recover to 1G flight when speed brakes are extended in 25.253(a)(5)
g) Pilot pitch forces for out-of-trim recovery in 25.255(f)

In addition to force limit requirements, certain aspects of pilot interactions for use of side stick controllers will also need to be evaluated. It is expected that at least the following characteristics will need to be addressed:

h) Side stick controller coupling design
i) Pilot-in-the-loop (PIL) characteristics, including operation in turbulence
j) Pitch and roll control force and displacement sensitivity

It is also expected that this task will include recommendations for further review and revision of regulations and guidance beyond Subpart B that may need to be addressed (ie., 25.397).

It should be noted that this task will focus on pilot-applied input force requirements and the pilot and system interface characteristics noted above. While industry experience to date has been with passive side stick controllers, consideration should also be given to emerging active side stick controller technologies.

This task will not address lateral/directional/longitudinal stability requirements that are applicable for advanced flight control system designs that augment the inherent airframe stability.

2. Who will work the task?

The Flight Test Harmonization Working Group (FTHWG) will have primary responsibility for this task. The group should be supported as necessary by the FCHWG, or appropriate flight controls subject matter experts within the FTHWG, for clarification on Flight control system design aspects. Coordination within the FTHWG is expected with other subteams working “Stability” and “Envelope Protection” topics within this overall tasking.

3. Why is this task needed? (Background information)

Aircraft equipped with side stick controllers instead of conventional column and wheel control inceptors are designed for one-hand operation. The current pilot control force limits are based on two-handed effort and therefore are not adequate for aircraft type designs utilizing side stick controllers. In addition, given the difference in pilot arm and wrist positions and the associated difference in force and leverage capabilities with side stick controllers, the single-handed force requirements should also be reviewed for any potential revisions. Previous aircraft models with side stick controllers, such as the Airbus A320, A330, A340 & A380, Bombardier BD 500, Dassault Falcon 7X and Embraer EMB 550, have utilized Special Conditions and CRIs to address these unique requirements.

The applicable rules and guidance materials associated with pilot-applied pitch and roll force limits need to be reviewed and revisions proposed for 14 CFR Part 25 Subpart B that provide a harmonized standard addressing the use of side stick controllers.

This review and proposed revisions to rules and guidance material should also address pilot interface and system characteristics pertaining to the following items:

a) Pilot control authority to insure the coupling design addresses corrective and /or overriding control inputs by either pilot. The coupling design should provide for reliable, unambiguous indications (e.g., aural, visual and/or tactile) indicating the side stick that is in command, not in command, and when combined inputs are being applied (if simultaneous inputs are allowed by the design).
b) Pilot control such that the side stick controllers do not produce unsuitable PIL control characteristics when considering precision path control / tasks and turbulence
c) Pitch and roll control force and displacement sensitivity compatibility to insure normal inputs on one control axis will not cause significant unintentional inputs on the other. These control harmony characteristics should also insure that precision control tasks are accomplished without exceptional piloting skill or alertness.

This review is also expected to provide recommendations for future revisions to any rules and guidance materials within CFR Part 25 outside of Subpart B that pertain to pilot applied control force limits or side stick controller system design and interaction characteristics such as 14 CFR 25.397(c) and CS-25A-13 25.777(i).

4. References (existing regulatory and guidance material, including special conditions, CRIs, etc.)

FAA 14 CFR Part25 Subpart B:

a) Controllability & Maneuverability: 25.143(d), 25.143(g) and 25.145(b)
b) Stability: 25.175(d)
c) Miscellaneous Flight Requirements: 25.253(a)(5), 25.255(f)
d) Control System Limit Pilot Forces and Torques: 25.397(c)

EASA CS-25 A-13:

a) Controllability & Maneuverability: 25.143(k) and 25.145(b)
b) Stability: 25.175(d)
c) Miscellaneous Flight Requirements: 25.253(a)(5), 25.255(f)
d) Control System Limit Pilot Forces and Torques: 25.397(d)
e) Cockpit Control Force and Displacement: 25.777(i)

FAA Special Conditions

a) FAA Final SC No. 25-316-SC Airbus A380-800

b) FAA Final SC No 25-477-SC Bombardier Aerospace Model BD-500-1A10 & 1A11 Airplanes: Side stick Controllers
c) FAA Final SC No. 25-479-SC Embraer S.A., Model EMB-550 Airplane, Limit Pilot Forces for stick shaker control
d) FAA Final SC No. 25-498-SC Embraer S.A., Model EMB-550 Airplanes; Side stick Controllers

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5. Working method
It is envisioned that 3-4 face-to-face meeting days will be needed to facilitate the discussion needed to complete these tasks. Telecons and electronic correspondence will be used to the maximum extent possible.
6. Preliminary schedule (How long?)
Provide recommendations to the ARAC Transport Airplanes and Engines Subcommittee within 18 months of the initiation of work on these tasks.
7. Regulations/guidance affected
Regulations noted in Section 4 above
8. Additional information

Attachment 7B: Recommended Rulemaking Text

Proposal – Rev -

§25.143 General.

(a)-(c) [No change]

(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**~~

Force, in pounds, applied to the relevant control	**Pitch**	**Roll**	**Yaw**
(1) For short term application:			
Control wheel (two hands available for control)	**75**	**50**	
Control wheel (one hand available for control)	**50**	**25**	
Side stick	**35**	**15/11[1]**	
Rudder pedal			**150**
(2) For long term application:			
Control wheel	**10**	**5**	
Side stick	**7**	**3**	
Rudder pedal			**20**

[1]15 lb inward, 11 lb outward

(e)-(h) [No Change]

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

(1) Controllability must be demonstrated with the most critical of the ice accretion(s) for the particular flight phase as defined in Appendices C and O of this part, as applicable, in accordance with § 25.21(g);

(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

Rationale

Although the word "conventional" is removed here, the proposed guidance includes statements indicating that these short and long term force limits are appropriate for "conventional control wheel and side stick installations".

This table has been modified to more closely match the comparable table from Part 23 where different pitch and roll controllers are addressed.

The FTHWG determined that covering center stick controllers is not needed at this time. This task is specifically to address side stick controllers which have become a common design choice by industry. Proposed guidance has been included to say forces may not be applicable for center sticks or other non-conventional controllers. In these cases, special conditions may be necessary to establish alternate criteria for other controller types or non-conventional installations.

The proposed short term side stick control force maximums are based upon available pilot strength studies from military and industry and a validated human strength model which are believed to be reasonable based on the current state-of-the art for existing Part 25 side stick implementations, including active side sticks. The long term side stick control force maximums apply the same 1-hand ratios as established for the short term forces, whereas Part 23 long term forces apply the same maximums regardless of controller type. Lower forces are considered more conservative and appropriate for side sticks compared to a conventional control wheel.

Throughout this proposal, the permissible pitch control forces for side sticks are based upon the ratio of 35/75 for conditions that are traditionally considered 2-hand maneuvers for control wheels, and 35/50 for conditions that are considered 1-hand maneuvers for

from the maneuver without exceeding a pull control force of 50 pounds **for a control wheel or 35 pounds for a side stick**; 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) [No change] **(k) It must be shown that unsuitable pilot-in-the-loop control characteristics are not encountered when considering precision path control tasks and turbulence. In addition, pitch and roll control force sensitivity and displacement sensitivity must be compatible, so that normal inputs on one control axis will not cause significant unintentional inputs on the other.** ~~**(k) [CS] Side stick controllers**~~ ~~**In lieu of the maximum control forces provided in CS 25.143(d) for pitch and roll, and in lieu of specific pitch force requirements of CS 25.145(b) and CS 25.175(d), it must be shown that the temporary and maximum prolonged force levels for side stick controllers are suitable for all expected operating conditions and configurations, whether normal or nonnormal.**~~ ~~**It must be shown by flight tests that turbulence does not produce unsuitable pilot-in-the-loop control problems when considering precision path control/tasks.**~~	control wheels. The second part of the proposed 25.143(k) is included from the existing CS 25.777(i). The FTHWG consensus position is that this is better placed in Subpart B because it relates to handling qualities. The second part of the existing CS 25.143(k) is retained with some modifications aligning closer with the FAA IP Special Condition wording. It is recommended that EASA delete CS 25.777(i) when this proposal is implemented.
§25.145 General. (a) [No change] (b) With the landing gear extended, no change in trim control, or exertion of more than 50 pounds control force **for a control wheel** (representative of the maximum short term force that can be applied readily by one hand) **or 35 pounds for a side stick** may be required for the following maneuvers: (1) With power off, flaps retracted, and the airplane trimmed at 1.3 V_{SR1}, extend the flaps as rapidly as possible while maintaining the airspeed at approximately 30 percent above the reference stall speed existing at	

each instant throughout the maneuver. (2) Repeat paragraph (b)(1) except initially extend the flaps and then retract them as rapidly as possible. (3) Repeat paragraph (b)(2), except at the go-around power or thrust setting. (4) With power off, flaps retracted, and the airplane trimmed at 1.3 V_{SR1}, rapidly set go-around power or thrust while maintaining the same airspeed. (5) Repeat paragraph (b)(4) except with flaps extended. (6) With power off, flaps extended, and the airplane trimmed at 1.3 V_{SR1}, obtain and maintain airspeeds between V_{SW} and either 1.6 V_{SR1} or V_{FE}, whichever is lower. (c)-(d) [No Change]	
§25.173 Static longitudinal stability. Under the conditions specified in §25.175, the characteristics of the elevator control forces (including friction) must be as follows: (a)-(b) [No Change] (c) The average gradient of the stable slope of the stick force versus speed curve may not be less than 1 pound for each 6 knots **for a control wheel, or 1 pound for each 9 knots for a side stick**. (d) [No Change]	For side sticks, this is 0.167 lb/kt*(35/50)=.117 lb/kt or 1 lb per 9 kts, based on 1lb/6kt is considered 1-hand criteria for control wheels.
§25.175 Demonstration of static longitudinal stability. Static longitudinal stability must be shown as follows: (a) [No Change] (b) Cruise. Static longitudinal stability must be shown in the cruise condition as follows: (1) With the landing gear retracted at high speed, the stick force curve must have a stable slope at all speeds within a range which is the greater of 15 percent of the trim speed plus the resulting free return speed range, or 50 knots plus the resulting free return speed range, above and below the trim speed (except that the speed range need not include speeds less than 1.3 V_{SR1}, nor speeds greater than V_{FC}/M_{FC}, nor speeds that require a stick force of more than 50 pounds **for a**	

control wheel or 35 pounds for a side stick), with— (i) The wing flaps retracted; (ii) The center of gravity in the most adverse position (see §25.27); (iii) The most critical weight between the maximum takeoff and maximum landing weights; (iv) 75 percent of maximum continuous power for reciprocating engines or for turbine engines, the maximum cruising power selected by the applicant as an operating limitation (see §25.1521), except that the power need not exceed that required at V_{MO}/M_{MO}; and (v) The airplane trimmed for level flight with the power required in paragraph (b)(1)(iv) of this section. (2) With the landing gear retracted at low speed, the stick force curve must have a stable slope at all speeds within a range which is the greater of 15 percent of the trim speed plus the resulting free return speed range, or 50 knots plus the resulting free return speed range, above and below the trim speed (except that the speed range need not include speeds less than 1.3 V_{SR1}, nor speeds greater than the minimum speed of the applicable speed range prescribed in paragraph (b)(1), nor speeds that require a stick force of more than 50 pounds **for a control wheel or 35 pounds for a side stick**), with— (i) Wing flaps, center of gravity position, and weight as specified in paragraph (b)(1) of this section; (ii) Power required for level flight at a speed equal to (V_{MO} + 1.3 V_{SR1})/2; and (iii) The airplane trimmed for level flight with the power required in paragraph (b)(2)(ii) of this section. (3) With the landing gear extended, the stick force curve must have a stable slope at all speeds within a range which is the greater of 15 percent of the trim speed plus the resulting free return speed range, or 50 knots plus the resulting free return speed range, above and below the trim speed (except that the speed range need not include speeds less than 1.3 V_{SR1}, nor speeds greater than V_{LE}, nor speeds that require a stick force of more than 50 pounds **for a control wheel or 35 pounds for a side stick**), with— (i) Wing flap, center of gravity position, and weight as specified in paragraph (b)(1) of this section; (ii) 75 percent of maximum continuous power for reciprocating engines or, for turbine engines, the maximum cruising power	

selected by the applicant as an operating limitation, except that the power need not exceed that required for level flight at V_{LE}; and (iii) The aircraft trimmed for level flight with the power required in paragraph (b)(3)(ii) of this section. (c) Approach. [No Change] (d) Landing. The stick force curve must have a stable slope, and the stick force may not exceed 80 pounds **<u>for a control wheel or 40 pounds for a side stick</u>**, at speeds between V_{SW} and 1.7 V_{SR0} with— (1) Wing flaps in the landing position; (2) Landing gear extended; (3) Maximum landing weight; (4) The airplane trimmed at 1.3 V_{SR0} with— (i) Power or thrust off, and (ii) Power or thrust for level flight. ~~**(5) The airplane trimmed at 1.3 V_{SR0} with power or thrust off.**~~	(5) should have been deleted when (4) was revised with 14 CFR Amdt 25-115. It's content is redundant with (4)(i).
§25.253 High-speed characteristics. (a) Speed increase and recovery characteristics. The following speed increase and recovery characteristics must be met: (1)–(4) [No Change] (5) With the airplane trimmed at V_{MO}/M_{MO}, extension of the speedbrakes over the available range of movements of the pilot's control, at all speeds above V_{MO}/M_{MO}, but not so high that V_{DF}/M_{DF} would be exceeded during the maneuver, must not result in: (i) An excessive positive load factor when the pilot does not take action to counteract the effects of extension; (ii) Buffeting that would impair the pilot's ability to read the instruments or control the airplane for recovery; or (iii) A nose down pitching moment, unless it is small.	No change is proposed to 25.253, but subparagh (5) is included as reference for the related guidance change proposal.
§25.255 Out-of-trim characteristics. (a)-(e) [No Change] (f) In the out-of-trim condition specified in paragraph (a) of this section, it must be possible from an overspeed condition at V_{DF}/M_{DF} to produce at least 1.5 g for recovery by applying not more than 125 pounds of longitudinal control force **<u>for a control wheel or 50 pounds for a side</u>**	50 lb for side stick is 8 lb lower (more conservative) than the

<u>stick</u>, using either the primary longitudinal control alone or the primary longitudinal control and the longitudinal trim system. If the longitudinal trim is used to assist in producing the required load factor, it must be shown at V_{DF}/M_{DF} that the longitudinal trim can be actuated in the airplane nose-up direction with the primary surface loaded to correspond to the least of the following airplane nose-up control forces: (1) The maximum control forces expected in service as specified in §§25.301 and 25.397. (2) The control force required to produce 1.5 g. (3) The control force corresponding to buffeting or other phenomena of such intensity that it is a strong deterrent to further application of primary longitudinal control force.	standard ratio of 35/75*125 lb, but aligns with current TCCA special conditions applied to recent side stick projects.

Attachment 7C: Recommended Guidance Material

<u>AC 25-7C Proposed Changes</u>

20. General - § 25.143.

a. <u>Explanation</u>. The purpose of § 25.143 is to verify that any operational maneuvers conducted within the operational envelope can be accomplished smoothly with average piloting skill and without encountering a stall warning or other characteristics that might interfere with normal maneuvering, or without exceeding any airplane structural limits. Control forces should not be so high that the pilot cannot safely maneuver the airplane. Also, the forces should not be so light that it would take exceptional skill to maneuver the airplane without over-stressing it or losing control. The airplane response to any control input should be predictable to the pilot **<u>and pitch and roll control force sensitivity and displacement sensitivity must be compatible, so that normal inputs on one control axis will not cause significant unintentional inputs on the other.</u>**

(1) The maximum forces given in the table in § 25.143(d) for pitch and roll control for short term application are applicable to maneuvers in which the control force is only needed for a short period. **<u>For conventional control wheels,</u>** ~~W~~**<u>w</u>**here the maneuver is such that the pilot will need to use one hand to operate other controls (such as during the landing flare or a go-around, or during changes of configuration or power/thrust resulting in a change of control force that needs to be trimmed out) the single-handed maximum control forces will be applicable. In other cases (such as takeoff rotation, or maneuvering during en route flight), the two-handed maximum forces will apply.

<u>The maximum short term and long term forces in the table in § 25.143(d) are based upon conventional control wheel and side stick installations (with adjustable arm/elbow rest), where their location relative to the pilot Design Eye Point (DEP) and range of motion are consistent with the standard design practice for flight deck ergonomics that accommodate the full pilot population range specified by § 25.777(c). Where non-conventional control wheel or side stick installations or other controller types (e.g., center-sticks) are used, the short and long term forces in the § 25.143(d) table and the maximum and minimum control forces specified in Subpart B and this AC may not be appropriate.</u>

(2) Short-term and long-term forces should be interpreted as follows:

(a) Short-term forces are the initial stabilized control forces that result from maintaining the intended flight path following configuration changes and normal transitions from one flight condition to another, or from regaining control following a failure. It is assumed that the pilot will take immediate action to reduce or eliminate such forces by re-trimming or changing configuration or flight conditions, and consequently short-term forces are not considered to exist for any significant duration. They do not include transient force peaks that may occur during the configuration change, change of flight conditions, or recovery of control following a failure.

(b) Long-term forces are those control forces that result from normal or failure conditions that cannot readily be trimmed out or eliminated.

(3) In conducting the controllability and maneuverability tests to show compliance with § 25.143 at speeds between V_{MO}/M_{MO} and V_{FC}/M_{FC}, the airplane should be trimmed at V_{MO}/M_{MO}.

(4) Modern wing designs can exhibit a significant reduction in maximum lift capability with increasing Mach number. The magnitude of this Mach number effect depends on the design characteristics of the particular wing. For wing designs with a large Mach number effect, the maximum bank angle that can be achieved

while retaining an acceptable stall margin can be significantly reduced. Because the effect of Mach number can be significant, and because it can also vary greatly for different wing designs, the multiplying factors applied to V_{SR} may be insufficient to ensure that adequate maneuvering capability exists at the minimum operating speeds. To address this issue, § 25.143(h) was added by Amendment 25-108 to require a minimum bank angle capability in a coordinated turn without encountering stall warning or any other characteristic (including the envelope protection features of fly-by-wire flight control systems or automatic power or thrust increases) that might interfere with normal maneuvering. The maneuvering requirements consist of the minimum bank angle capability the FAA deems adequate for the specified regimes of flight combined with additional bank angle capability to provide a safety margin for various operational factors. These operational factors include both potential environmental conditions (e.g., turbulence, wind gusts) and an allowance for piloting imprecision (e.g., inadvertent overshoots). The FAA considers the automatic application of power or thrust by an envelope protection feature to be a feature that might interfere with normal maneuvering because it will result in a speed increase and flight path deviation, as well as potentially increasing crew workload due to the unexpected power or thrust increase.

b. General Test Requirements.

(1) Compliance with § 25.143 (a) through (g) **and (k)** is primarily a qualitative determination by the pilot during the course of the flight test program. The control forces required and airplane response should be evaluated during changes from one flight condition to another and during maneuvering flight. The forces required should be appropriate to the flight condition being evaluated. For example, during an approach for landing, the forces should be light and the airplane responsive in order that adjustments in the flight path can be accomplished with a minimum of workload. In cruise flight, forces and airplane response should be such that inadvertent control input does not result in exceeding limits or in undesirable maneuvers. Longitudinal control forces should be evaluated during accelerated flight to ensure a positive stick force with increasing normal acceleration. Forces should be heavy enough at the limit load factor to prevent inadvertent excursions beyond the design limit. Sudden engine failures should be investigated during any flight condition or in any configuration considered critical, if not covered by another section of part 25. Control forces considered excessive should be measured to verify compliance with the maximum control force limits specified in § 25.143(d). Allowance should be made for delays in the initiation of recovery action appropriate to the situation.

(2)-(3) [No Change]

c. Controllability Following Engine Failure.

[No Change]

d. Pilot Induced Oscillations (PIO).

(1) Explanation.

(a) Section 25.143(a) and (b) require that the airplane be safely controllable and maneuverable without exceptional piloting skill and without danger of exceeding the airplane limiting load factor under any probable operating conditions**. In addition, Section 25.143(k) requires that unsuitable pilot-in-the-loop control characteristics not be encountered during precision path control tasks, including while in expected levels of turbulence.** Service history events have indicated that modern transport category airplanes can be susceptible to airplane-pilot coupling under certain operating conditions and would not meet the intent of this requirement.

(b)-(c) [No Change]

(d) This service experience has shown that compliance with only the quantitative, open-loop (pilot-out-of the loop) requirements does not guarantee that the required levels of flying qualities are achieved. Therefore, in order to ensure that the airplane has achieved the flying qualities required by § 25.143(a)**(b)** and (~~b~~**k**), the airplane should be evaluated by test pilots conducting high-gain (wide-bandwidth), closed loop tasks to determine that the potential of encountering adverse PIO tendencies is minimal.

e. Maneuvering Characteristics - § 25.143(g).

(1) General. An acceptable means of compliance with the requirement that stick forces may not be excessive when maneuvering the airplane is to demonstrate that, in a turn for 0.5g incremental normal acceleration (0.3g above 20,000 feet) at speeds up to V_{FC}/M_{FC}, the average stick force gradient does not exceed 120 pounds per g **for a control conventional wheel or 55 pounds per g for a side stick. This gradient should be evaluated in flight conditions where it is possible to achieve the specified load factor without engagement of stall warning or envelope protections (e.g., high angle of attack limiting).**

(2) Interpretive Material.

(a) The objective of § 25.143(g) is to ensure that the limit strength of any critical component on the airplane would not be exceeded in maneuvering flight. In much of the structure, the load sustained in maneuvering flight can be assumed to be directly proportional to the load factor applied. However, this may not be the case for some parts of the structure (e.g., the tail and rear fuselage). Nevertheless, it is accepted that the airplane load factor will be a sufficient guide to the possibility of exceeding limit strength on any critical component if a structural investigation is undertaken whenever the design positive limit maneuvering load factor is closely approached. If flight testing indicates that the positive design limit maneuvering load factor could be exceeded in steady maneuvering flight with a 50 pound ~~stick~~ force **for a conventional control wheel or 25 pounds for a side stick**, the airplane structure should be evaluated for the anticipated load at ~~a 50 pound stick force~~ **this pitch control force level**. The airplane will be considered to have been overstressed if limit strength has been exceeded in any critical component. For the purposes of this evaluation, limit strength is defined as the lesser of either the limit design loads envelope increased by the available margins of safety, or the ultimate static test strength divided by 1.5.

(b) Minimum Stick Force to Reach Limit Strength.

1 A stick force of at least 50 pounds **for a conventional control wheel or 25 pounds for a side stick** to reach limit strength in steady maneuvers or wind-up turns is considered acceptable to demonstrate adequate minimum force at limit strength in the absence of deterrent buffeting. If heavy buffeting occurs before the limit strength condition is reached, a somewhat lower stick force at limit strength may be acceptable. The acceptability of ~~a stick force of less than 50 pounds~~ **the lower stick force** at the limit strength condition will depend upon the intensity of the buffet, the adequacy of the warning margin (i.e., the load factor increment between the heavy buffet and the limit strength condition), and the stick force characteristics. In determining the limit strength condition for each critical component, the contribution of buffet loads to the overall maneuvering loads should be taken into account.

2 This minimum stick force applies in the en route configuration with the airplane trimmed for straight flight, at all speeds above the minimum speed at which the limit strength condition can be achieved without stalling. No minimum stick force is specified for other configurations, but the requirements of § 25.143(g) are applicable in these conditions.

(c) Stick Force Characteristics.

1 At all points within the buffet onset boundary determined in accordance with § 25.251(e), but not including speeds above V_{FC}/M_{FC}, the stick force should increase progressively with increasing load factor. Any reduction in stick force gradient with change of load factor should not be so large or abrupt as to impair significantly the ability of the pilot to maintain control over the load factor and pitch attitude of the airplane.

2 Beyond the buffet onset boundary, hazardous stick force characteristics should not be encountered within the permitted maneuvering envelope as limited by paragraph 20e(2)(c)3. It should be possible, by use of the primary longitudinal control alone, to rapidly pitch the airplane nose down so as to regain the initial trimmed conditions. The stick force characteristics demonstrated should comply with the following:

(aa) For normal acceleration increments of up to 0.3g beyond buffet onset, where these can be achieved, local reversal of the stick force gradient may be acceptable, provided that any tendency to pitch up is mild and easily controllable.

(bb) For normal acceleration increments of more than 0.3g beyond buffet onset, where these can be achieved, more marked reversals of the stick force gradient may be acceptable. It should be possible to contain any pitch-up tendency of the airplane within the allowable maneuvering limits, without applying push forces to the control column and without making a large and rapid forward movement of the control column.

3 In flight tests to satisfy paragraphs 20e(2)(c)(1) and (2), the load factor should be increased until either:

(aa) The level of buffet becomes sufficient to provide a strong and effective deterrent to any further increase of the load factor; or

(bb) Further increase of the load factor requires a stick force in excess of 150 pounds **for a conventional control wheel or 70 pounds for a side stick** (or in excess of 100 **or 45** pounds**, respectively,** when beyond the buffet onset boundary) or is impossible because of the limitations of the control system; or

(cc) The positive limit maneuvering load factor established in compliance with § 25.337(b) is achieved.

(d) Negative Load Factors. It is not intended that a detailed flight test assessment of the maneuvering characteristics under negative load factors should necessarily be made throughout the specified range of conditions. An assessment of the characteristics in the normal flight envelope involving normal accelerations from 1g to zero g will normally be sufficient. Stick forces should also be assessed during other required flight testing involving negative load factors. Where these assessments reveal stick force gradients that are unusually low, or that are subject to significant variation, a more detailed assessment, in the most critical of the specified conditions, will be required. This may be based on calculations, provided they are supported by adequate flight test or wind tunnel data.

f. Thrust or Power Setting for Maneuver Capability Demonstrations.

[No change]

21. Longitudinal Control - § 25.145.

a. Explanation.

(1) Section 25.145(a)

[No Change]

(2) Section 25.145(b) requires changes to be made in flap position, power or thrust, and speed without undue effort when re-trimming is impractical. The purpose is to ensure that any of these changes are possible assuming that the pilot finds it necessary to devote at least one hand to the initiation of the desired operation without being overpowered by the primary airplane controls. The objective is to show that an excessive change in trim does not result from the application or removal of power or thrust or the extension or retraction of wing flaps. The presence of gated positions on the flap control does not affect the requirement to demonstrate full flap extensions and retractions without changing the trim control. Compliance with § 25.145(b) also requires that the relation of control force to speed be such that reasonable changes in speed may be made without encountering very high control forces.

(3) Section 25.145(c)

[No Change]

(4) Section 25.145(d)

[No Change]

b. Procedures. The following test procedures outline an acceptable means for demonstrating compliance with § 25.145. These tests may be conducted at an optional altitude in accordance with § 25.21(c). Where applicable, the conditions should be maintained on the engines throughout the maneuver.

(l) Longitudinal control recovery, § 25.145(a).

[No Change]

(2) Longitudinal control, flap extension, § 25.145(b)(1).

(a) Configuration:

1 Maximum landing weight or a lighter weight if considered more critical.

2 Critical c.g. position.

3 Wing flaps retracted.

4 Landing gear extended.

5 Engine power or thrust at flight idle.

(b) Test procedure: The airplane must be trimmed at a speed of 1.3 V_{SR}. The flaps must be extended to the maximum landing position as rapidly as possible while maintaining approximately 1.3 V_{SR} for the flap position existing at each instant throughout the maneuver. The control forces must not exceed 50 ~~lbs.~~**pounds** (the maximum force for short term application that can be applied readily by one hand) **for a**

conventional control wheel or 35 pounds for a side stick controller throughout the maneuver without changing the trim control.

(3) Longitudinal control, flap retraction, § 25.145(b)(2) & (3).

(a) Configuration:

1 Maximum landing weight or a lighter weight if considered more critical.

2 Critical c.g. position.

3 Wing flaps extended to the maximum landing position.

4 Landing gear extended.

5 Engine power or thrust at flight idle and the go-around power or thrust setting.

(b) Test procedure: With the airplane trimmed at 1.3 V_{SR}, the flaps must be retracted to the full up position while maintaining approximately 1.3 V_{SR} for the flap position existing at each instant throughout the maneuver. The longitudinal control force must not exceed 50 ~~lbs.~~ **pounds for a conventional control wheel or 35 pounds for a side stick controller** throughout the maneuver without changing the trim control.

(4) Longitudinal control, power or thrust application, § 25.145(b)(4) & (5).

(a) Configuration:

1 Maximum landing weight or a lighter weight if considered more critical.

2 Critical c.g. position.

3 Wing flaps retracted and extended to the maximum landing position.

4 Landing gear extended.

5 Engine power or thrust at flight idle.

(b) Test procedure: The airplane must be trimmed at a speed of 1.3 V_{SR}. Quickly set go-around power or thrust while maintaining the speed of 1.3 V_{SR}. The longitudinal control force must not exceed 50 pounds **for a conventional control wheel or 35 pounds for a side stick controller** throughout the maneuver without changing the trim control.

(5) Longitudinal control, airspeed variation, § 25.145(b)(6).

(a) Configuration:

1 Maximum landing weight or a lighter weight if considered more critical.

2 Most forward c.g. position.

3 Wing flaps extended to the maximum landing position.

4 Landing gear extended.

5 Engine power or thrust at flight idle.

(b) Test Procedure: The airplane must be trimmed at a speed of 1.3 V_{SR}. The speed should then be reduced to V_{SW} and then increased to 1.6 V_{SR}, or the maximum flap extended speed, V_{FE}, whichever is lower. The longitudinal control force must not be greater than 50 ~~**lbs**~~ **pounds for a conventional control wheel or 35 pounds for a side stick controller**. Data from the static longitudinal stability tests in the landing configuration at forward c.g., § 25.175(d), may be used to show compliance with this requirement.

(6) Longitudinal control, flap retraction and power or thrust application, § 25.145(c).
[No Change]

(7) Longitudinal control, out-of-trim takeoff conditions, §§ 25.107(e)(4) and 25.143(a)(1). See paragraphs 10b(9)(c)3 and 4.

26. Static Longitudinal Stability and Demonstration of Static Longitudinal Stability - §§ 25.173 and 25.175.

a. Explanation.

(1) Section 25.173 - Static Longitudinal Stability.

(a) Compliance with the general requirements of § 25.173 is determined from a demonstration of static longitudinal stability under the conditions specified in § 25.175.

(b) The requirement is to have a pull force to obtain and maintain speeds lower than trim speed, and a push force to obtain and maintain speeds higher than trim speed. There may be no force reversal at any speed that can be obtained, except lower than the minimum for steady, unstalled flight or, higher than the landing gear or wing flap operating limit speed or V_{FC}/M_{FC}, whichever is appropriate for the test configuration. The required trim speeds are specified in § 25.175.

(c) When the control force is slowly released from any speed within the required test speed range, the airspeed must return to within 10 percent of the original trim speed in the climb, approach, and landing conditions, and return to within 7.5 percent of the trim speed in the cruising condition specified in § 25.175 (free return).

(d) The average gradient of the stick force versus speed curves for each test configuration may not be less than one pound for each 6 knots **for a conventional control wheel, or one pound for each 9 knots for a side stick controller,** for the appropriate speed ranges specified in § 25.175. Therefore, after each curve is drawn, draw a straight line from the intersection of the curve and the required maximum speed to the trim point. Then draw a straight line from the intersection of the curve and the required minimum speed to the trim point. The slope of these lines must be at least ~~**one pound for each 6 knots**~~ **the minimum value specified for the type of pitch controller**. The local slope of the curve must remain stable for this range.

(2) Section 25.175, Demonstration of Static Longitudinal Stability, specifically defines the flight conditions, airplane configurations, trim speed, test speed ranges, and power or thrust settings to be used in demonstrating compliance with the longitudinal stability requirements.

b. Procedures.

(1) Stabilized Method.

[No Change]

(2) Acceleration-Deceleration Method.

[No Change]

(3) The resulting pilot longitudinal force

[No Change]

(4) Examples of "local reversals" are given in Figure 26-2. Curves A and C depict a local gradient reversal within the required speed range. Even though it might be argued that the "average gradient" meets the ~~**one pound in six knots**~~ **minimum** criterion, the gradient reversals would render these characteristics unacceptable. Curve B depicts a situation in which the gradient reverses, but only outside the required speed range. In addition, Curve B demonstrates a situation in which the local gradient does not always meet the ~~**required one pound in six knots**~~ **minimum criterion**, even though the average gradient does.

[No Change to Figure 26-2]

32. High Speed Characteristics - § 25.253.

a. Explanation.

[No Change]

b. Regulations Affected.

[No Change]

c. Procedures.

[No Change]

(1)-(6) Roll Capability, § 25.253(a)(4).

[No Change]

(7) Extension of Speedbrakes. The following guidance is provided to clarify the meaning of the words "the available range of movements of the pilot's control" in § 25.253(a)(5) and to provide guidance for demonstrating compliance with this requirement. Normally, the available range of movements of the pilot's control includes the full physical range of movements of the speedbrake control (i.e., from stop to stop). Under some circumstances, however, the available range of the pilot's control may be restricted to a lesser range associated with in-flight use of the speedbrakes. A means to limit the available range of movement to an in-flight range may be acceptable if it provides an unmistakable tactile cue to the pilot when the control reaches the maximum allowable in-flight position and compliance with § 25.697(b) is shown for positions beyond the in-flight range. Additionally, the applicant's recommended procedures and training must be consistent with the intent to limit the in-flight range of movements of the speedbrake control.

(a) [No Change]

(b) The effect of extension of speedbrakes may be evaluated during other high speed testing (for example, paragraphs 31b(2) and 32c(1) through (5) of this AC) and during the development of emergency descent procedures. It may be possible to infer compliance with § 25.253(a)(5) by means of this testing. To aid in determining compliance with the qualitative requirements of this rule, the following quantitative values may be used as a generally acceptable means of compliance. A positive load factor should be regarded as excessive if it exceeds 2 g. A nose-down pitching moment may be regarded as small if it necessitates an incremental force of less than 20 pounds **for a conventional control wheel or 15 pounds for a side stick controller** to maintain 1 g flight. These values may not be appropriate for all airplanes, and will depend on the characteristics of the particular airplane design in high speed flight. Other means of compliance may be acceptable, provided that compliance has been shown to the qualitative requirements specified in § 25.253(a)(5).

33. Out-Of-Trim Characteristics - § 25.255.

a. Explanation.

[No Change]

b. Reference Regulation. Section 25.255.

c. Discussion of the Regulation.

(1) Section 25.255(a) is the general statement of purpose. Maneuvering stability may be shown by a plot of applied control force versus normal acceleration at the airplane c.g.. Mistrim must be set to the greater of the following:

(a) Section 25.255(a)(l). A 3-second movement of the longitudinal trim system at its normal rate for the particular flight condition with no aerodynamic load. Since many modern trim systems are variable rate systems, this subsection requires that the maneuver condition be defined and that the no-load trim rate for that condition be used to set the degree of mistrim required. For airplanes that do not have power-operated trim systems, experience has shown a suitable amount of longitudinal mistrim to be applied is that necessary to produce a 30 pound control force **for a conventional control wheel or 20 pounds for a side stick controller**, or reach the trim limit, whichever occurs first.

(b) Section 25.255(a)(2).

[No Change]

(2)-(6) Sections 25.255(b)-(e)

[No Change]

(7) Section 25.255(f) requires that in the out-of-trim condition specified in § 25.255(a), it must be possible to produce at least 1.5 g during recovery from the overspeed condition of V_{DF}/M_{DF} **by applying not more than 125 pounds of longitudinal control force for a conventional control wheel or 50 pounds for a side stick controller**. If adverse flight characteristics preclude the attainment of this load factor at the highest altitude reasonably expected for recovery to be initiated at V_{DF}/M_{DF} following an upset at high altitude, the flight envelope (c.g., V_{DF}/M_{DF}, altitude, etc.) of the airplane should be restricted to a value where 1.5 g is attainable. If trim must be used for the purpose of obtaining 1.5 g, it must be shown to operate with the primary control surface loaded to the least of three specified values.

(a) The **control** ~~force~~ **input** resulting from application of the pilot limit loads of § 25.397 ~~**(300 lbs.)**~~.

(b) The control ~~**force**~~ **input** required to produce 1.5 g ~~**(between 125 and 300 lbs.)**~~.

(c) The control ~~**force**~~ **input** corresponding to buffeting or other phenomena of such intensity that it is a strong deterrent to further application of primary longitudinal control force.

d. Procedures.

[No Change – See 25.255 Out-of-Trim Proposal for Topic 13]

Chapter 8 - Airworthiness: Miscellaneous Items

228. Design and Function Of Artificial Stall Warning and Identification Systems.

a.- e. [No Change]

f. System Functional Requirements.

(1) Operation of the stall identification system should reduce the airplane's angle-of-attack far enough below the point for its activation that inadvertent return to the stall angle-of-attack is unlikely.

(2) The characteristics of stall identification systems, which by design are intended to apply an abrupt nose-down control input (e.g., a stick pusher), should make it unlikely that a flightcrew member will prevent or delay its operation. The required stick force, rate of application, and stick travel will depend on the airplane's stall and stick force characteristics, but a force of 50 to 80 pounds **for a conventional control wheel** applied virtually instantaneously has previously been accepted as providing this characteristic. **Stick pusher force levels for a side stick controller should be evaluated on a case-by-case basis, but should not be less than 35 pounds.**

(3) Normal operation of the stall identification system should not result in the total normal acceleration of the airplane becoming negative.

(4) The longitudinal maneuvering capability of an airplane equipped with stall identification systems, at all speeds likely to be encountered in normal operations, should be substantially the same as would be expected for an airplane with acceptable aerodynamic stall characteristics.

g. System Tolerances.

[No Change]

<u>AC 25-25A Proposed Changes</u>

CHAPTER 4. ACCEPTABLE MEANS OF COMPLIANCE—FLIGHT TEST PROGRAM

4.9.4 <u>Low g Maneuvers and Sideslips</u>.

The maneuvers in paragraph 4.9.4.3 of this AC represent an example of an acceptable test program for showing compliance with controllability requirements in low g maneuvers and in sideslips to evaluate susceptibility to ice-contaminated tailplane stall.

4.9.4.1 Section 25.143(i)(2).

4.9.4.1.1 The regulation states: "It must be shown that a push force is required throughout a pushover maneuver down to a zero g load factor, or to 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 **<u>for a conventional control wheel or 35 pounds for a side stick</u>**…."

4.9.4.1.1 [No Change]

4.9.4.2 [No Change]

4.9.4.3 [No Change]

Appendix 5 Topic 9 Wet Runway Stopping Performance Interim Report

FAA Aviation Rulemaking Advisory Committee
FTHWG Topic 9
Wet Runway Stopping Performance
Interim Report

Recommendation Report

January 14, 2017

Table of Contents

Executive Summary

The Flight Test Harmonization Working Group was tasked to look at issues that have arisen concerning landing operations on a wet runway. The three specific tasks are:

1) In light of recent runway overrun accidents and incidents after landing on wet runways, recommend steps that should be taken to address this safety issue;

   - There are 5 recommended steps identified and one informational industry regulatory activity.

2) Recommend a harmonized means of determining wet runway landing performance for grooved and porous friction coarse runways, which, at the type certificate holder's option, can be provided in the Airplane Flight Manual for airplane operators' use in showing compliance with landing distance requirements set forth in the applicable operating rules; and

   - Work is starting on this item. Before addressing this item it was felt it was best to come to a consensus on task 3.

3) Consider whether to add a type certification standard in §/CS 25.125 requiring determination of wet runway landing distances for smooth, and at the option of the applicant, grooved/porous friction course runways.

   - The consensus of the group is there should be a §/CS 25.125 requirement to determine wet runway landing distances.

This interim report primarily addresses Task 1 and provides an update on the status of Task 2 and 3 which will be part of the final report committed for July 1, 2017.

Background

A. What is the underlying safety issue addressed by the EASA CS/FAA CFR?

Several accidents and incidents have raised questions regarding landing performance on wet runways. There has been evidence that airplanes could not obtain the expected wheel braking performance during these accidents and incidents as defined by CFR 25.109. Furthermore when this reduced wet runway wheel braking (less than CS/CFR 25.109 level) is used in a computation of landing distance and is compared against the current combination of CFR 25 required landing distance and operating requirements for wet or slippery runways the distance may be longer than the current standards require.

It is also possible when the nominal wet runway wheel braking as defined in CS/CFR 25.109 is used for calculations looking at the entire airplane envelope that the landing distance may be very close to (minimal margin) or exceed the current standards for wet runway performance which are based on a dry runway CFR 25 landing distance calculation multiplied by operating factors. The Takeoff and Landing Performance Assessment (TALPA) aviation rulemaking activity of the late 00's recognized there were areas of the operational envelope where this could occur when considering a safety margin of 15% on the assumed calculation time of arrival wet runway (braking action good).

Other items which affect this situation are:

- Significant variation in certification methods when determining the CS/CFR 25.125 landing distance during airplane type certification and AFM expansion.
- Manufacturers recommending operating guidelines that may not be consistent with the certification demonstrations
- Varying operational factors used for different type of operations.
- Wet runway wheel braking characteristics which significantly vary from dry runway wheel braking characteristics
- Wet runway wheel braking characteristics which are reduced from the FAA wet runway wheel braking definition in CFR 25.109
- Enactment of ICAO State Letter 2015 05 29 - sl - 030e
- EASA NPA 2016-11
- Implementation of TALPA ARC recommendations by FAA via advisory material

- Wet runway wheel braking level as documented in CS/CFR 25.109 brought into question by original organization that defined the method used to create CFR 25.109.

The original tasking document in attachment 9A contains specific examples of the observed wet runway wheel braking.

Note: TCCA and ANAC have similar requirements to CS/CFR 25.125. Their operational factors are comparable to either the FAA factors or EASA factors.

Definition:

In this report the phrase **"reflects the physics of stopping an airplane on a wet runway"** or similar phraseology such as **"physics-based wet runway rule"** is used.

This phrase is being used to differentiate between the current requirements for landing distance accounting for a wet or slippery runway which are based on a CFR 25.125 dry runway distance increased by factors defined in operating regulations and what an airplane experiences when performing a maximum effort stop on a wet runway based on a model of wet runway wheel braking accepted and used in CFR 25.109, the wet runway accel-stop regulation.

The primary items that are different are:

- Dry runway wheel braking has a low variation with ground speed and is generally accepted to have a low variation to different surfaces such as asphalt, concrete, grooves, PFC and construction items such as surface texture and cross slope while wet runway wheel braking has a significant reduction with increasing speed. Wet runway wheel braking is also more sensitive to the type of surface on which the stop is being performed.
- Higher temperatures and altitudes may exacerbate the difference between dry and wet runway wheel braking due to higher airspeeds and therefore higher ground speeds. CFR 25.125 does not require an applicant to account for temperature variation (although some applicants do).
- Some manufacturers recommend always flying higher approach speeds than the CFR 25.125 dry landing distance is based. At higher speeds, a greater difference in wheel braking may exist between dry and wet runway surfaces.
- Other items which may affect the difference between CFR 25.125 dry runway distance factored by operating requirements and what an airplane experiences when performing a maximum effort stop on a wet runway
    - Method of determining air distance used in computation of CFR 25.125 dry runway distance
    - Runway slope
    - Dry runway torque capability of the wheel brake (wet runway wheel braking is seldom torque limited)

B. What is the task?

There were 3 tasks identified to address the issue of wet runway landing performance:

1) In light of recent runway overrun accidents and incidents after landing on wet runways, recommend steps that should be taken to address this safety issue;

2) Recommend a harmonized means of determining wet runway landing performance for grooved and porous friction coarse runways, which, at the type certificate holder's option, can be provided in the Airplane Flight Manual for airplane operators' use in showing compliance with landing distance requirements set forth in the applicable operating rules; and

3) Consider whether to add a type certification standard in CS/CFR 25.125 requiring determination of wet runway landing distances for smooth and at the option of the applicant, grooved/porous friction course runways.

C. Why is this task needed?

Task 1: Even though there has been significant work accomplished and changes to the industry to address causal factors in overruns such as runway contamination, unstable approaches and high speed landings there has not been a discussion as to the factors affecting the ability of the airplane to create wet runway wheel braking due to the tire ground interaction nor whether the combination of the CFR 25 methods and operating requirements could be improved. Part of the improvement could possibly be providing flight crew and operators with better performance training so they truly understand the issues with landing on wet runways, providing a calculation for the wet runway landing distance that reflects the physics of stopping an airplane on a wet runway, improving identification of when a runway has the potential to adversely affect the airplanes stopping distance plus other considerations.

Task 2: Currently there are two approved methods of obtaining improved landing distance performance for runways that are well maintained grooved or Porous Friction Coarse (PFC). The two methods result in different but similar performance standards with each potentially being more limiting than the other. One standard should be adequate.

Task 3: Because of the reasons stated above it has been highlighted that the existing method of using a dry runway certified landing distance and then factoring it by operating rule for a condition of a wet/slippery dispatch distance does not represent the physics involved and may in some cases be inadequate to ensure operating margins when the airplane arrives at the destination airport.

D. Who has worked the task?

This task has been worked by a sub-team of specialists on landing certification, flight test performance, and flight operations from the entities involved. The primary individuals and organizations working this issue are:

<u>Members from the FTHWG polling organizations</u>

Regulators: FAA, EASA, TCCA

Manufacturers: Airbus, Boeing, Bombardier, Dassault, Embraer, Gulfstream, Textron Aviation

Other: American Airlines, ALPA

Other observers and contributors: Delta Airlines, JCAB, NJASP, NTSB, ESDU

E. Any relation with other topics?

Topic 10 - Runway Excursion Hazard Classification
Future phase 3 related topic – Return to Land

Historical Information

A. What are the current regulatory and guidance material in CS 25 and CFR 25?

For airplane performance the pertinent regulations are CS/CFR 25.101 (d), (e), (f) and (g), CS/CFR 25.125, CS/CFR 25.1587 (b)(3), (b)(4) and (b)(7). Advisory circulars are AC 25-7C, AC 25-32, AC 121.195 (d)-1.

Not directly applicable but related is CS/CFR 25.109 where the wet runway wheel braking assumed for RTO performance is defined for both wet and wet grooved/PFC runways.

Not directly applicable but related is AC 120-28C and 29A and the associated OPS Specs where the standard for landing distance for autoland is related to a 15% increase on the basic CFR dry operating runway length. This is equivalent to the current wet runway operating standard of the 60% increased by 1.15.

Also involved are operating regulations which call out the factors that are applied to the current CS/CFR 25.125 dry runway landing distances. Following is a list of factors:

60% rule:
91.1037 (b) Large Transport: Turbine Engine
121.185 Reciprocating engines
121.195 (b) Transport: Turbine Engine
121.197 Transport: Alternates Turbojet
121.203 Non-transport
135.375 Large Transport: reciprocating engines
135.385 Large Transport: turbine engines
135.387 Large Transport: Turbojet: alternates
135.393 Large non-transport: destination (note no turbo-propeller exception)

70% rule:

121.185 Reciprocating engines: alternate if destination can't meet 185(a)(2)
121.187 Reciprocating engines: alternates
121.195 (c) Transport: Turbo-propeller alternate if destination can't meet 195(b)(2)
121.197 Transport: Turbo-propeller: alternate
121.205 Non-transport: alternate
135.375 Reciprocating engines: alternate if destination can't meet 375(a)(2)
135.377 Reciprocating engines: alternates
135.385 (c) Transport: Turbo-propeller alternate if destination can't meet 385 (b)(2)
135.387 Large Transport: Turbo-propeller: alternates
135.395 Large non-transport: alternate (note appears to apply to both turbojet and turbo prop)

80% rule
91.1037 (c)(d) Destinations in accordance with approved Destination Airport Analysis, & alternates (for wet, 91.1037(e) explicitly allows 1.15 * 80% distance)
135.385(f) Eligible on Demand-some interpret this as available for wet runway basis
135.387(b) Eligible on Demand alternate-some interpret this as available for wet runway basis

EASA, ANAC and Transport Canada have operating standards on wet runway that are equivalent to CFR 121/135 standards however currently do not have the equivalent of the 80% rule that is in CFR 91 and 135 however EASA does have an NPA out for comment which would incorporate an 80% rule.

Related to some of the operating regulations above is a follow on requirement "no person may takeoff a turbojet powered airplane when the appropriate weather reports and forecasts, or a combination thereof, indicate that the runways at the destination airport may be wet or slippery at the estimated time of arrival unless the effective runway length at the destination airport is at least 115 percent of the runway length required under paragraph xxx of this section."

Related but not specifically addressed are the regulatory landing requirements on contaminated runways which are included in EASA regulations. The 1.15 factor in the operating regulations noted in the previous paragraph is stated for wet or slippery runways where a slippery runway would presumably be a contaminated runway.

Also related are airport advisory circulars which discuss design and maintenance of a runway surface for good wet runway wheel braking both for smooth ungrooved surfaces and grooved runways plus equivalent ICAO airport design publications.

B. What, if any, are the differences in the existing regulatory and guidance material CS 25 and CFR 25?

There are no differences between CS 25 and CFR 25 however with operating standards there are differences in classification of airplanes/operations that are subject to specific factors. The basic operating standards are similar i.e. the 60% rule for a dry runway landing distance which is then increased by 15% for a wet runway landing distance. However as noted above there are other cases where they differ. TCCA and ANAC have similar requirements to CS/CFR 25.125.

At the end of the 3rd quarter in 2016 EASA published a NPA which includes using a time of arrival wet runway landing distance as a baseline for reduced required landing distance operations (equivalent to FAA Eligible on Demand/Fractional Ownership in US operating regulations). During this rulemaking task the EASA team contemplated recommending a physics-based wet runway rule for CS25. There was a decision to not recommend this at this time because the FTHWG activity on wet runway was on-going and it was felt that was a more appropriate group to consider this regulatory change.

C. What are the existing CRIs/IPs (SC and MoC)?

The CRI/IP's fall into two categories; the first is creating performance data addressing shorter braking distances that may be used on wet grooved/PFC runway surfaces. The second category is CRI/IP allowing physics-based wet runway performance in the AFM for airplanes which are operated such that they are not required to apply specific operating factors to the dry runway AFM performance for a wet runway dispatch calculation.

<u>Typical titles of CRI/IP</u>
Landing Distance on Smooth Wet Runways (EASA CRI, FAA IP)

For the wet grooved/PFC improved performance there are currently two methods that have been used: FAA method based on AC 121.195(d)-1A (TCCA method similar but based on TALPA principles) and an EASA method which adjusts the wet runway braking distance for improved grooved/PFC braking. Task 2 of the topic is to look at these two methods and determine if there can be harmonization to one method.

<u>Typical titles of CRI/IP/TCCA CM</u>
Landing Distance on Grooved Wet Runway Surfaces (FAA IP, TCCA CM)
Landing Distances on Wet Porous Friction Course/Grooved Runways (EASA CRI)

In addition to the above there has also been an FAA IP for an airplane with no thrust reversers where the landing distance is based on CFR 121.195 (b) and (d) increased by another factor of 1.2 accounting for the lack of thrust reverser. The final required wet runway distance is: [(CFR 25.125 dry field length)/0.6]*1.15*1.20 = (CFR 25.125 dry field length)*2.3.

Currently the FAA and ANAC have accepted both the FAA and EASA methods.

D. What, if any, are the differences in the Special Conditions (SC and MoC) and what do these differences result in?

Not applicable

Consensus

At this time only recommendations for Task 1 is addressed in this report. Task 1 does not contain modifications to specific regulations but rather provides recommendations on activity that can be pursued to address issues associated with wet runway overruns. If the recommendations are accepted by the ARAC and the ARAC directs the FAA/others to work them, they may lead to new regulations and/or new guidance material.

There are six recommendations for Task 1 that the group agreed to forward to the ARAC. All voting members either accepted or abstained from the polling on these six items creating a consensus opinion with no dissents.

Although all members accepted these six items going forward that does not mean there were not differences of opinion as to components that may be part of the different recommendations. These differences of opinions are discussed at a high level in the ***Group Consensus*** part of the recommendations.

Recommendations for Task 1

This interim report provides recommendations addressing task 1. Task 1 requests recommendations for addressing the safety issue for the ARAC to consider for future recommendations. It does not include specific rulemaking items but rather opportunities for the FAA and industry to investigate ways forward as to the recognized reduced wet runway friction safety issue.

Because runway excursions have been a major safety focus in the industry for a number of years there have been numerous industry efforts to address the issues. In general these initiatives have not concentrated on wet runway issues specifically but rather have addressed the general topic of runway excursions. Following is a brief summary of recommendations/actions that have been taken by the industry addressing runway landing overruns and by connection addressing wet runway landing overruns. The following lists recommendations for the regulatory bodies to consider going forward by these industry efforts. Some of the recommendations for the regulatory bodies are similar to initiatives recommended as part of task 1.

- Major industry initiatives:
    - Commercial Aviation Safety Team – Safety Enhancements
        - SE215: Runway Excursion - Landing Distance Assessment
        - SE216: Runway Excursion - Flight Crew Landing Training
        - SE217: Runway Excursion - Takeoff Procedures and Training
        - SE218: Runway Excursion - Overrun Awareness and Alerting Systems
        - SE219: Runway Excursion - Policies, Procedures and Training to Prevent Runway Excursions
        - SE220: Runway Excursion - Runway Distance Remaining Signs
        - SE221: Runway Excursion - Policies and Procedures to Mitigate Consequences and Severity
        - SE222: Runway Excursion - Airplane-based Runway Friction Measurement and Reporting (R-D)
            - FAA research on this issue recently concluded on this subject
    - European Action Plan for Prevention of Runway Excursions
        - Recommendations in Section 3 for;
        - 3.1 General Principles and Local Runway Safety Teams;
        - 3.2 Aerodrome Operator;
        - 3.3 Air Navigation Service Provider;
        - 3.4 Aircraft Operator;
        - 3.5 Aircraft Manufacturers;
        - 3.6 Regulatory and Oversight Issues;
        - 3.7 EASA
    - Implementation of TALPA (Takeoff and Landing Performance Assessment) reporting practices for non-dry runway including the publication of FICONs when the arrival runway is wet or contaminated – implementations started on Oct. 1, 2016
        - Includes the reporting of a runway condition code of 5 for each third of the runway that is considered wet – optional during initial implementation year.
        - Includes concept of reporting "Slippery when Wet" if a runway is below the minimum wet runway friction standard as measured by Continuous Friction Measuring Equipment for more than 1000 feet.
            - Note: if this standard had been in place in April of 2011, an overrun of a SWA 737 at Chicago Midway may have been avoided.
        - Voluntary implementation of TALPA ARC recommendations as to airplane performance data by airplane operators and manufactures
    - ICAO State letter AN 4/1.1.55-15/30 which proposes implementation of TALPA ARC type runway reporting and performance data (including time of arrival wet runway) by November 2020 – this includes amendments to annexes 3, 6, 8, 14, and 15 plus PANS-ATM and PANS-Aerodromes. This also includes a new Airplane Performance Manual in support of Annex 6 and 8.
    - EASA NPA 2016-11 on implementation of TALPA ARC type recommendations into EASA operating and certification specifications as well as aerodromes.
    - SAFO 06012 - Landing Performance Assessments at Time of Arrival (Turbojets)
    - SAFO 15009 - Turbojet Braking Performance on Wet Runways

Task 1 - In light of recent runway overrun accidents and incidents after landing on wet runways, recommend steps that should be taken to address this safety issue;

The following recommendations from the Flight Test Harmonization Working Group:

A. Landing Safety Training Aid

It is recommended to convene a group of industry experts to produce a Landing Safety Training Aid (LSTA). This training aid would be a suggested comprehensive training program on the subject of landing procedures and performance data.
The group should include representatives from aircraft operators, airport operators, aircraft manufacturers, regulatory agencies, flight safety organizations, and pilot unions.

The goal is to minimize, to the greatest extent practical, the probability of a landing accident or incident due to mis-information or ignorance of landing performance.

This effort would be FAA and/or EASA sponsored and become the definitive source for airplane landing performance similar to what the Takeoff Safety Training Aid (TOSTA) has become for takeoff performance. Similar to the TOSTA, it would provide a vetted resource in many cases dispelling incorrect interpretations and myths as to landing performance.

The intended audience for the LSTA would be 14 CFR 121, 135, and 91K operators. However, many of the principles, concepts, and procedures would equally apply to other aircraft operators and would be recommended for use by those operators when applicable.

It is expected that a LSTA would reduce landing accidents and incidents in the same way that the Takeoff Safety Training Aid reduced takeoff accidents and incidents.

Group Consensus

- No dissenting opinions received.
- 1 abstained, 1 abstained due to lack of response

Recommended ARAC action: *if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the appropriate FAA/EASA/TCCA.*

See attachment 9B for complete discussion on this recommendation.

B. Codify TALPA ARC Recommendations

It is recommended that the TALPA ARC recommendations be codified.

In 2009, the Takeoff and Landing Performance Assessment Aviation Rulemaking Committee (TALPA ARC) provided a number of recommendations intended to address inadequacies in the regulations, guidance, and industry practices for conducting landing performance assessments at the time of arrival. The TALPA ARC ultimately recommended rule changes and guidance related to 14 CFR 23, 25, 26, 121, 135, and 139.

The recommendation discussed in this document, to be considered by the ARAC, is to codify the previously provided TALPA ARC recommendations for incorporation into regulations and guidance material.

This effort in concert with the ICAO and EASA efforts would bring harmonization to the greatest degree possible when it comes to worldwide operation on non-dry runways.

Group Consensus

- No dissenting opinions received.
- 1 considered abstained due to lack of response.

Not all parties accepted the recommendation to codify TALPA recommendations without comment as noted in attachment 9C . There is a realization that there has been industry activity since the time the TALPA recommendations were submitted to the FAA in 2009. There is also recognition that original recommendations have been modified by FAA during the voluntary implementation, that ICAO has created a state letter which deviates from the original TALPA recommendations, and EASA has created an NPA working towards codification of the TALPA recommendations as modified by the ICAO. What this means is if the recommendation is accepted there will be comment and discussions required on specific issues described above as the activity progresses through a harmonization process.

Also it should be recognized that if this recommendation is accepted and forwarded, the logical body for harmonizing the CFR 25 codifications would be the Flight Test Harmonization Working Group.

Recommended ARAC action*: if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the appropriate FAA/EASA/TCCA.*

See attachment 9C for complete discussion on this recommendation.

C. Identification of Poor Performing Wet Runways:

It is recommended airplane certification and operational performance organizations to work directly in a regulatory agency sponsored team with airport organizations on a method to quantitatively identify runway conditions leading to poor performing wheel braking on wet runways and using this information to identify poor performing wet runways.

If a runway cannot create adequate wet runway wheel braking performance, then a Field Condition report (FICON) should be published via NOTAM informing the operator that a reduced wheel braking performance can exist when the specific runway is wet, that can also affect maximum cross-wind recommendation.

This concept is consistent with a TALPA recommendation to use reduced assumed wheel braking for TOA landing distance determination on runways where measured friction is below the minimum friction level as defined by the FAA AC or other applicable standard.

The current standards are reliant on Continuous Friction Measuring Equipment (CFME) which is typically not available at the runways that have reduced wet wheel braking capability. Other techniques of recognizing poor wet runways need to be established that can be used at airports that do not have access to CFME equipment or that can be used in combination with CFME's. These techniques need to be specific and have meaning as to airplane stopping performance.

Group Consensus

- No dissenting opinions received.
- 1 abstained, 1 considered abstained due to lack of response

Recommended ARAC action: *if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the appropriate FAA personnel when considering proposed FAA future research programs and to the Tech Center Airport research team for discussion in their upcoming "Expert" panel meeting on future wet runway research. The first meeting of this "Expert" panel is planned for mid-February of 2017.*

See attachment 9D for complete discussion on this recommendation.

D. Create CFR 25 standard that reflects the physics of stopping an airplane on a wet runway.

It is recommended to create CFR 25 standard and operational factors that reflect the physics of stopping an airplane on a wet runway.

Currently the operating requirements at dispatch for landing at a destination or alternate on a wet runway are not tied to the physics associated with landing and stopping an airplane on a wet runway. Also depending on ACO/manufacturer may be made based on methods in AC 25-7C that may not be compatible with current regulation CFR 25.101(f) requiring the landing distance be determined "in accordance with procedures established by the applicant for operation in service". This second assertion is well known and has been accepted by the FAA for 40 years with typical arguments made in association with the "large" factor applied by the operating regulations, typically referring to the Part 121/135 60% rule which may or may not apply to any specific FAA operation.

The dry operationally factored landing distance is then increased by 15% to obtain a wet runway landing distance.

The result of these varying dry factors with the aggressive nature of dry runway Part 25 flight testing/certification and calculation of the CFR 25 dry runway distance has led to the current situation where:

- Significant margin variations exist from airplane to airplane when compared to a wet runway landing distance calculation based on a more representative physical model.
- Flight crews have limited knowledge of the actual landing distance margin on a wet runway surface and it is therefore difficult to evaluate whether actions should be taken on a degraded wet runway.
- There may be reduced margin for airplanes operating in ISA+ temperatures or at high altitudes.

Group Consensus

- No dissenting opinions received.
- 1 considered abstained due to lack of response.

As this recommendation documenting the rationale for continued work on task 3 towards physics based wet runway dispatch rule all acceptances are contingent on final proposal to be delivered in the final report. There is possible dissent with the final recommended rule depending on specifics.The state of the current proposal is discussed in the report section - Topic 9 Wet Runway Stopping Performance Task 2 and 3.

Recommended ARAC action: *if the ARAC concurs with the recommendation it is requested that no other action be taken and the FTHWG will continue forward with Task 2 and 3 as assigned in the original tasking.*

See attachment 9E for complete discussion on this recommendation.

E. Ground Spoiler not armed warning regulation/guidance

There has been a history of landing incidents/accidents with the ground spoilers not being armed, with the subsequent reduction in wheel braking effectiveness as well as drag reduction, which have been a significant contribution to runway overruns. One example incident cited as supporting material for Task 1 of Wet Runway Stopping Performance is the overrun by SWA Flight 1919, B737-700 in Chicago Midway Airport, IL on April 26, 2011. It is recommended to create a CFR 25 regulatory warning indicating an unarmed ground spoiler configuration when the airplane drops below an appropriate height above the runway, with enough flexibility to cope with potential different aircraft designs.

Group Consensus

- No dissenting opinions received.
- 1 abstained as their products do not require such a system. 1 considered abstained due to lack of response.
- 1 accepted but noted for new TC's only, 1 accepted but noted not required for airplanes with automatic speed brake deployment without the need to arm the system.

Recommended ARAC action: *if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the Transport Standards organizations of the FAA/EASA/TCCA.*

See attachment 9F for proposed rationale, requirement and advisory material.

F. Require of a ROPs/RSAT/Smart Landing type systems for CFR 25

This was a recommendation initially however we have been made aware that there is to be active rulemaking activity in EASA associated with this recommendation. As such the group feels it is appropriate to wait and see what the EASA proposal is and potentially comment on it at that time.

In 2013 EASA published an NPA 2013-09, Reduction of Runway Excursions that proposed a new rule:

SUBPART D — Design and Construction
CS 25.705 Runway Overrun Awareness and Avoidance System (ROAAS)
(See AMC 25.705)

A ROAAS must be installed.
The ROASS must be a real-time crew alerting system that makes energy based assessments of predicted stopping distance versus landing distance available, and meets the following requirements:

(a) The system must provide the crew with timely in-flight predictive alert of runway overrun risk; and
(b) The system must provide the crew with:
(1) on-ground predictive alert, or
(2) automated means for runway overrun protection during landing

This proposed rule was consistent with the NTSB safety recommendation A-11-28 to the FAA and with recommendations from the European Action Plan for Prevention of Runway Excursions to regulatory agencies. EASA received comments on this proposal that has caused them a delay in going forward. Also since that time EUROCAE has created working group WG-101 to create minimum operational performance specifications for such systems. It should also be noted that these type of system only provides in-flight information if you know the surface is degraded and appropriately plan for that eventuality.

Our understanding is that current EASA plans are to publish a revised NPA in the first quarter of 2017. The FAA's current position is a rule is not required as the industry is/has worked towards these products based on their merits and they are certifiable with existing regulations.

As this is an active rulemaking activity the group feels it is appropriate to wait and see what the EASA proposal is and potentially comment on it at that time.

Group Consensus

- 6 accepted this recommendation but in general have a wait and see towards EUROCAE committee report and any EASA re-proposals expected in early 2017
- 4 abstained but in general have a wait and see towards EUROCAE committee report and any EASA re-proposals expected in early 2017
- 1 simply agreed it is appropriate to wait and see like the accepted and abstained
- 1 considered abstained due to lack of response

Recommended ARAC action: *None at this time, however when/if EASA does propose a CS25 standard it is recommended the ARAC request the FTHWG review the EASA proposal for consideration by the FAA and TCCA working towards a harmonized standard.*

No attachment required for this item.

Topic 9 Wet Runway Stopping Performance Task 2 and 3

As noted in recommendation 4 for task 1, the FTHWG has found it reasonable to consider an improved physics-based wet runway standard for CS/CFR 25. Thus work is going forward on Task 3 including the following accomplishments:

- Reviewed validity of current CS/CFR 25.109 definition of wet runway stopping performance against manufacturer flight test results and revised standard from ESDU (Engineering Science and Data Unit, original basis for 25.109).
    - While it is true there have been incidents and accidents that showed lower than expected wheel braking, it has not been established that the existing standard is significantly out of line with the airplanes' reasonably expected stopping performance on reasonably built and maintained runway.
- Surveyed the group as to the principles that should be used when creating a CFR 25 wet runway standard. The survey has shown that there are varying opinions on any individual principle being considered however the consensus of the group is that there should be a CFR 25 wet runway standard that is based on physical model of what is expected for wet runway stopping performance.
- The survey also showed there are issues where it may be difficult to find consensus.
- Multiple proposals have been generated and discussed:
    - The majority of the group has settled on an outline of a proposal that results in a Part 25 guideline based on realistic operational parameters and 25.109 wet runway wheel braking.
    - There are concerns with this that still needs to be worked out
        - Does a check against reduced wet runway wheel braking need to be included
        - This may lead to a CFR 25 dry and wet distance based on different certification methods
        - What are appropriate operational factors to be applied?
- Have general agreement that the FTHWG should recommend operational factors to be applied at the time of dispatch. It is recognized this could be particularly difficult for the FAA as the FAA has more operating classifications than EASA or TCCA. It is recognized this is a CFR 25 based group discussing recommendations for the operational world however it has been recognized the factor applied in operations is directly related to how the CFR 25 distance is defined.
- Created a study to see what the current status is of using the CS/CFR 25.125 defined dry landing distances increased by the operating factors compared to an improved physics-based wet runway calculation.

Remaining work on Task 2/3

The remaining work for Task 3 is to finalize on a wet runway calculation method that can be accepted by consensus. Then finalize the recommended codification and recommended operating factors. In parallel to that effort is a requirement to look at Task 2 and determine if the best way to account for wet grooved runway is to simply do the recommended wet runway calculation only considering the grooved runway wet runway braking assumption similar to the FAA/TCCA method or rather apply a calculation basis similar to the EASA CRI's.

Attachment 9A - Work Plan – Wet Runway Stopping Performance

1. What is the task?
There are three tasks: 1) In light of recent runway overrun accidents and incidents after landing on wet runways, recommend steps that should be taken to address this safety issue; 2) Recommend a harmonized means of determining wet runway landing performance for grooved and porous friction coarse runways, which, at the type certificate holder's option, can be provided in the Airplane Flight Manual for airplane operators' use in showing compliance with landing distance requirements set forth in the applicable operating rules; and 3) Consider whether to add a <u>type certification standard</u> in §/CS 25.125 requiring determination of wet runway landing distances for smooth, and at the option of the applicant, grooved/porous friction course runways.
2. Who will work the task?
The Flight Test Harmonization Working Group (FTHWG) will have primary responsibility for this task. The group should be augmented as necessary with subject matter experts in the areas of runway pavement friction (including effects of surface texture, grooving, and drainage), brakes and anti-skid systems, operational data analysis as well as representatives from airplane operators.
3. Why is this task needed? (Background information)
<u>For task 1</u>: Several recent accidents have raised questions regarding wet runway stopping performance. A few examples include: East Coast Jet Flight 81, a Hawker Beechcraft 125-800 at Owatonna, MN on July 31, 2008 American Airlines Flight AA331, a Boeing 737-800 at Kingston, Jamaica on December 22, 2009 Southwest Airlines Flight 1919, a Boeing 737-700 at Chicago Midway Airport, IL on April 26, 2011 Analyses indicate that the braking coefficient of friction in each case was significantly lower than expected for a wet runway (i.e., lower than the level specified in §/CS 25.109). The runway excursion at Midway Airport was especially troubling because it occurred on a grooved runway. In connection with the landing overrun at Kingston, Jamaica identified above, Boeing analyzed data from other incidents, accidents, and from flight tests and normal operations. This analysis showed that a similar braking friction level, which was **about half** of the wet runway braking coefficient used in the §/CS 25.109 standard, had been experienced in a number of the previous accidents and incidents as well as during flight tests and normal operations. (Note: The reason that the friction level of the §/CS 25.109 standard is used for comparison is that it is thought to be an accurate representation of wet runway braking friction and is used not only for determining wet runway accelerate-stop distances, but also would be used in the landing data for time of arrival performance assessments as recommended by the Takeoff and Landing Performance Assessment Aviation Rulemaking Committee (TALPA ARC)). Runway texture measurements and water drainage evaluations at a few of the runways exhibiting this performance did not indicate any specific deficiencies. The investigations considered issues like rubber surface contamination or contaminated surface states (i.e., flooded or standing water), but concluded from the available evidence that these situations were not present. The investigations concluded these low friction values were not found to be caused by rubber contamination or water depths of 3mm or greater. The above information indicates that this may be an industry-wide issue, not limited to specific airplane types or locations. The root cause has not been identified, and nothing, other than airplane braking system failures, has been ruled out. The deficient performance may be due to airplane issues (e.g., anti-skid performance), runway issues, or issues with our understanding or modeling of wet runway airplane stopping performance (e.g., erroneous relationship between macro texture and braking friction, unknown effect of active rainfall, differences between pavement types, etc.), or a combination of reasons. It is envisioned for this task that experts in airplane stopping performance, airplane braking systems, wet runway friction, runway design, construction, and maintenance, and other stakeholders would share data and expertise to determine the cause of the observed performance shortfall and recommend actions to take, if any, to address the resulting safety concerns. Potential actions <u>may</u> include (but also are not limited to): further research, changes to airplane design standards (e.g., §/CS

25.109, AC 25-7C, braking or anti-system safety standards), runway design, construction, and/or maintenance standards, definitions of wet vs. contaminated runways, operating practices or procedures on wet runways, or other mitigations.

Note: The outcome of this task may influence the outcome of the other two tasks.

For task 2: FAA and EASA operating rules for certain types of operations require an additional 15% of landing distance when the runway is forecast to be wet on arrival. These operating rules also allow use of a shorter wet runway landing distance if, based on a showing of actual operational landing techniques on a wet runway, that shorter distance is approved and included in the airplane flight manual. This provision is typically used to allow the use of a shorter wet runway landing distance on grooved or porous friction course (PFC) runways.

FAA and EASA advisory material differs for determining wet runway operational landing distances for grooved or PFC runways. The methods are not equivalent and should be harmonized.

For task 3: Currently, the type certification rules of CFR 25 and CS-25 only require landing distances to be determined for dry runways. The effect of wet runways on landing performance is addressed in operating rules applicable to certain types of operations. For convenience, manufacturers of airplanes used primarily in those types of operations typically include in the airplane flight manual wet runway landing performance information that complies with the requirements of the associated operating rule.

Consideration should be given as to whether wet runway landing performance should be included in the CFR 25/CS-25 type certification requirements for two reasons: (1) As with takeoff performance, the effect of a wet runway on landing performance should be dependent on the type of airplane rather than the type of operation being conducted; and (2) It may be possible, if the TALPA ARC recommendations are implemented, for an airplane to legally take off for a destination where the runway is forecast to be wet on arrival, but be unable to land there if the runway actually is wet on arrival.

Reason #2 above is due to fundamental differences in the methods for determining airplane landing performance on a wet runway between the operating rules and the TALPA ARC proposal for time of arrival landing performance assessments. (Note: This disparity could potentially also be addressed by simply changing the operating rule. In any case, if a wet runway landing distance requirement is added to the certification requirements, the operating rules would probably need to be revised accordingly.

4. References (existing regulatory and guidance material, including special conditions, CRIs, etc.)
§ 25.109, § 25.125, AC 25-7C, CS-25, Owatonna Accident Report, Performance Study - 26 Apr 2011 737-700 Chicago Midway Overrun, JCAA News Release on AAL 737-800 Landing Overrun, AC 121.195(d)-1A, EASA smooth wet runway landing distance CRI, EASA grooved wet runway landing distance CRI, Draft Flight Working Paper on landing distances
5. Working method
It is envisioned that 8-10 face-to-face meetings will be needed to facilitate the discussion needed to complete these tasks. Telecons and electronic correspondence will be used to the maximum extent possible.
6. Preliminary schedule (How long?)
Recommendations to Transport Airplanes and Engines Subcommittee within 24 months of the initiation of work on these tasks.
7. Regulations/guidance affected
Potential effects on §/CS 25.109, §/CS 25.125, ACs 25-7C, 121.195(d)-1A, relevant airport runway design and maintenance standards, and TALPA ARC recommendations. Also, potential effects on §§ 91.1037(e), 121.195(d), 135.385(d), EU OPS 1.520(c).
8. Additional information

Attachment 9B – Recommendation - Landing Safety Training Aid

Executive Summary

The aviation industry has been plagued with accidents on landing. This was a similar story in the 1980s. But at that time, it involved overruns during aborted takeoffs. One highly effective solution was the development of the “Takeoff Safety Training Aid.” This recommendation, from the Flight Test Harmonization Working Group, is to develop a similar training aid for landing.

Introduction

In recent history, the issue of landing safety has been highlighted in various safety analyses following a number of incidents and accidents. Because of this, the Flight Test Harmonization Working Group (FTHWG) was tasked to address the issue.

This report documents and presents one the findings and recommendations of the working group.

Recommendation

It is recommended to convene a group of industry experts to produce a Landing Safety Training Aid (LSTA). This training aid would be a suggested comprehensive training program on the subject of landing procedures and performance data.

The group should include representatives from aircraft operators, airport operators, aircraft manufacturers, regulatory agencies, flight safety organizations, and pilot unions.

The goal is to minimize, to the greatest extent practical, the probability of a landing accident or incident. The important elements of the program would include:

- Stabilized approach
- Missed approach / go-around decision
- AFM climb limitations
- Missed approach obstacle clearance
- Landing minima based on go-around climb capability
- Dispatch regulations for runway length
- Assessment of runway length at time of landing
- Runway surface and reporting
- Touchdown point and flare technique
- Wind considerations, head / tail / cross
- Use of autobrakes
- Use of autoland
- Bounced landings
- Landing at a weight heavier than the max landing weight
- Use of reversers and other deceleration devices
- Failure cases

Much of this information is contained in advisory circular 91-79A. This recommendation is to expand on the advisory circular information and create a comprehensive training program.

The intended audience for the LSTA would be 14 CFR 121, 135, and 91K operators. However, many of the principles, concepts, and procedures would equally apply to other aircraft operators and would be recommended for use by those operators when applicable.

The format and organization of the LSTA could follow something similar to the highly successful Takeoff Safety Training Aid. The organization of the safety aid would consist of:

1. Landing Safety – Overview for Management
2. Pilot Guide to Landing Safety
3. Example Landing Safety Training Program
4. Landing Safety Background Data

Why

A study of aircraft accident data shows that, since 1959, runway excursions during landing was the third leading contributor to fatal accidents in the worldwide commercial jet fleet. More alarming is, of all of the contributors to fatal accidents, runway excursions are the only category showing an increase over time.

This same study breaks down the primary factors for landing excursions into three areas: touchdown point, touchdown speed, and deceleration after touchdown. All of these factors could be enhanced with flight crew training.

A similar recommendation is supported by the Commercial Aviation Safety Team (CAST). In their report on runway excursion, flight crew training on landing was cited as a recommended safety enhancement.

Also, following the report from the Takeoff and Landing Performance Assessment (TALPA) Aviation Rulemaking Committee (ARC), most air carriers have adopted the recommendations. Because full implementation of all of the recommendations involves participants other than just aircraft operators, a coordinated effort for implementation has taken time. The FAA has recently completed voluntary implementation in October 2016.

A LSTA would be an excellent opportunity for the industry to coordinate training of flight crews in the use these new procedures for determining runway surface conditions and assessing the required runway length for landing.

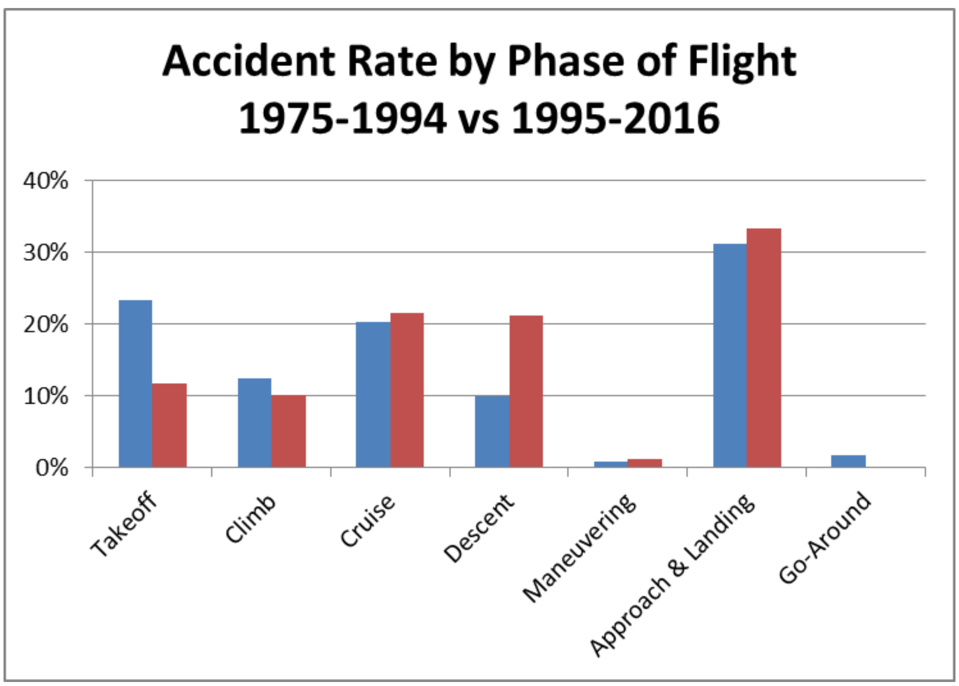
It is anticipated that a LSTA would become an authoritative source of landing performance issues. Historically, landing performance has been taught with inconsistent methods and often based on inaccurate information. This training has been based on CFR 25 certification methods and associated operating factors which do not necessarily give a good picture of what an airplane will do when flown in service using normal operational techniques. During the TALPA ARC, a significant amount of time was spent making sure all parties truly understood the aspects of certification airplane landing performance, operational landing performance, and what actual margins were built in the AFM data.

Benefits

It is expected that a LSTA would reduce landing accidents and incidents in the same way that the Takeoff Safety Training Aid reduced takeoff accidents and incidents.

The graph below was made from an analysis of the NTSB accident database for CFR 121 aircraft operations. The number non-ground related accidents were plotted as a percentage of the total accidents attributed to a phase of flight.

It shows a dramatic drop in the percentage of accidents attributed to takeoff, when comparing the twenty years before the Takeoff Safety Training Aid was released, to the twenty years following its release. By focusing a training program on landing, similar results should be achieved for landing safety.



Costs

Assuming the project would be handled similar to the Takeoff Safety Training Aid, a lead organization would be selected, presumably a manufacturer (Boeing led the Takeoff Safety Training Aid) which would be supported by representatives from other manufacturers and airlines. It would be approximately a one year project with the cost distributed over the organizations that where supporting the project. A very rough estimate of the cost would be the lead organization supplying 1 to 2 man-year of work and the supporting organization supplying ½ to 1 man-year of work. Plus printing, cost of a possible computer based training module and video shoots to support the CBT.

This estimate is significantly less than the Takeoff Safety Training Aid because of expected efficiency gain from 1990 to 2016 in computing, graphic, word processing tools and methods etc. also many of the resources necessary already exist in the industry, the project would bring them to one definitive source.

Group Consensus

- No dissenting opinions received.
- 1 abstained, 1 abstained due to lack of response

Recommended ARAC action: *if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the appropriate FAA/EASA/TCCA.*

Attachment 9C – Recommendation - Codify TALPA ARC Recommendations

Statement of Recommendation

In 2009, the Takeoff And Landing Performance Assessment Aviation Rulemaking Committee (TALPA ARC) provided a number of recommendations intended to address inadequacies in the regulations, guidance, and industry practices for conducting landing performance assessments at the time of arrival. The TALPA ARC ultimately recommended rule changes and guidance related to 14 CFR 23, 25, 26, 121, 135, and 139.
The recommendation discussed in this document, to be considered by the FTHWG, is to codify the previously provided TALPA ARC recommendations for incorporation into regulations and guidance material.

Why this recommendation is important
To date there is no FAA requirement that a manufacturer provide landing distance information for non-dry runways, although overrun events on non-dry runways continue to occur. The current operational requirements for dispatch to wet or slippery runways may not be adequate, particularly in worsening conditions and for warmer than standard temperatures and downhill runway gradients.

Benefit of implementing the recommendation
Codification of the TALPA ARC recommendations would mandate manufacturers of transport category aircraft and many CFR 23 aircraft either provide certified landing distance information on wet and contaminated runways, or prohibit operation on those surfaces for which no data is provided. This landing distance data would incorporate representative air distances and account for non-standard temperatures and runway gradients beyond -1%. Updates to the operational requirements of CFR 121 and 135 would dictate when this landing data was to be used in the course of making a landing assessment. Guidance provided to airport operators will address accurate reporting of actual runway conditions, allowing operators to make an assessment using appropriate data.
Implementing the TALPA ARC recommendations will yield multiple benefits, including:

- Definition and standardization of braking mu for wet and contaminated runway surfaces.
- Definition and standardization of impingement drag from spray-causing contaminants.
- Common modeling of runway condition effects between takeoff and landing.
- Full accounting of environmental conditions at time of arrival.
- Full accounting of environmental conditions for takeoff.
- Assessment of landing based on realistic performance, with a reasonable safety margin.
- Decreases reliance on antiquated dispatch rules that don't address all important considerations.
- A means to correlate runway condition or contaminant (type and depth) as well as braking action reports to manufacturer data based on either.
- Recommendations identify multiple areas that would benefit from specific additional training.

Ease/cost of implementing the recommendation

Because the TALPA ARC recommendations have been implemented voluntarily in the United States, officially as of October 1, 2016, much of the basis for regulatory material exists. The FAA has published AC 25-31 and -32 in response to the recommendations on computing contaminated runway takeoff and landing data. FAA Airports have modified their AC's covering winter operations, NOTAM reporting and wet runway maintenance. Flight Standards has published a revision to AC 91-79a and included in the FAA order 8900.1 best practices associated with TALPA implementation. Flight Standards plans to follow up this 8900.1 publication with an advisory circular. Also TALPA recommendations included specific language for CFR 25, 26, 121 and 135.

Many US airlines have implemented TALPA ARC consistent procedures and performance information minimizing incremental operating costs of implementing TALPA.

Because all this activity has been accomplished to date it is thought that much of the cost of implementing TALPA ARC recommendations is minimal to the FAA and CFR 121 operators.

However there are issues when considering implementation as to the business jet and general aviation. In an attempt to minimize issues during implementation the CFR 25 committee of the TALPA ARC and the FAA AC 25-32 stated that existing data (JAA/EASA) may be used (supplemented if necessary) and that manufacturers consider incrementing and/or factoring existing data to obtain TALPA consistent data. Generic factors were created for operators if the manufacturer does not provide appropriate data or guidance. The following was the timeline recommended by the ARC.

Timing – Requirement to have revised AFM or other acceptable data for operational use shall be available:
a. Two years after approval of the appropriate regulations for in-production airplanes
b. Four years after approval of the appropriate regulations for out-of-production airplanes.

The following tables were included in the TALPA ARC submittals. These tables show the best information available at the time (2009) as to the data available for JAR/EASA standards and data that could potentially be modified by increments or factors.

Retroactive application of contaminated runway takeoff/landing performance information

Category	Coverage	Data Requirements
1	Data 25X1591 or CS25.1591	a or b
2	Operational data available that can be adjusted to show compliance with the intent of 25.125(B)	a or c
3	No data available that can be adjusted to meet the intent of 25.125(b) – manufacturer supports airplane	Factors as documented in operating requirements.
4	Airplane not supported by manufacturer and compliant data not available.	Factors as documented in operating requirements.

Airplane Categorization

Category	Type Design Holder	Airplane Model
1	328 Support Services GmbH	Dornier 328?????
	ATR – GIE Avions de Transport Régional	ATR-42, ATR-72
	Airbus	A318, A 319, A320, A321, A330, A340, A350, A380
	Boeing	717, 737-6/7/8/900, 747-400/-8, 757-300, 767-400, 777, 787
	Bombardier	Regional Jet, Global Express, Dash 8, Challenger 604
	Cessna	500, 550, S550, Bravo, 560, Ultra, Encore, Encore+, 560XL, 560XLS, 650, 680, 750
	Dassault	Falcon 7X,900EX, 2000, 2000EX??????
	Embraer	EMB-135, 145, ERJ-170, 190
	Gulfstream Aerospace Corporation	G-IV/V/V-SP ??????
	Gulfstream Aerospace LP	1125 Westwind Astra/Astra SPX, G-100, G-150, G-200 (Galaxy) ?????
	Hawker Beechcraft	400A, 400XP, Hawker 750, Hawker 800/800XP/850XP/900XP, 4000
	Learjet	45, 55, 60, 85
	Saab	340, 2000 ??????

2	ATR – GIE Avions de Transport Régional	
	Airbus	A300, A300-600, A310
	BAE Systems	BAe/Avro 146, Jetstream 4101
	Boeing	DC-8, DC-9, MD-80/90, DC-10???, MD-11, 727, 737, 747
	Bombardier	Challenger
	Cessna	
	Dassault	Falcon 900 ???
	Embraer	EMB-120
	Fokker Services	F100, F27, F28 ????
	Gulfstream Aerospace Corporation	G-II, G-III???
	Gulfstream Aerospace LP	???
	Hawker Beechcraft	
	Israel Aircraft Industries	1124/1125???
	Learjet	????
3	Boeing	707
	Lockheed	L1011, Electra, 130
4	STC that effects performance	

Other considerations of codifying TALPA ARC recommendations

In September of 2016 EASA released an NPA that would codify TALPA ARC recommendations. The NPA contains the basic language of the TALPA CFR 25 AC's and the recommended operating practices in the FAA 8900 order and mandates a time of arrival assessment of the landing distance necessary based on the conditions that exist at the time of arrival.
In 2016 the ICAO released a state letter with Standards and Recommended Practices incorporating the TALPA ARC recommendations.

Neither the EASA nor ICAO is identical to the FAA TALPA implementation but they are based on the TALPA philosophies. Codifying the TALPA ARC recommendations would further harmonize EASA and FAA regulations.

Issues considered during discussions.

During discussion on this item no voting member rejected this recommendation however there were qualifications on this support from the manufacturers and one regulator. Issues raised were the following:

Issue 1 - Concern with TALPA dry runway landing distance data. The dry aspects of AC25-32 are not the same as 25.125 and would lead to 2 sets of DRY runway performance data computed on different assumptions. Having two sets of dry runway landing performance data increases cost, influences schedule, increases work with a supplier for database changes, verification and validation impacts to database as well as increases potential operator confusion.

Comment on issue 1: The rationale for a separate time-of-arrival data set for dry runway are based on concerns over items such as method of air distance calculation, lack of temperature, slope accountability in 25.125 data etc.:

- *Depending on method of certification used and parameters included in the AFM directly affects the appropriateness of using the dry runway data as computed to meet 25.125 and published in the manufacturers AFM.*
    - *If the AFM data based on CFR 25.125 is computed based on operationally achievable air distance and includes corrections for OAT, slope and increased approach speed then the use of this AFM data with a 1.15 factor at the time of arrival is reasonable.*
- *If the AFM data based on CFR 25.125 is computed based on an air distance using the parametric method in AC 25-7C evaluated at 3.5 degree glide path and does NOT include corrections for slope, OAT or increased approach speed however is factored by 1/0.6 then the use of this AFM data at the time-of-arrival is accepted, this is stated in the FAA 8900.1 order for flight operations.*

- *These aforementioned concerns were alleviated by the TALPA operational standard which allowed the use of the standard 60% dispatch factor in conjunction with CFR 25.125 data as an adequate time of arrival check on dry runway in the event of a runway change or need to do a tailwind landing.*
    - *Note: this was limited to the 60% factor as the 80% factor associated with 135 Eligible on Demand operations and 91K Fractional Ownership operations could not be verified as having adequate margin unless the AFM data for CFR 25.125 accounted for slope, temperature and increased approach speed.*

Issue 2 – Concern over TALPA recommendation of 10% reduction of dry runway wheel brake force

Comment on issue 2: Two comments raised, one as to the potential of two different dry runway data sets and a second comment that it should be switched around essentially that you get credit for 100% dry runway demonstration of wheel braking force unless the authority demonstrates a 10% reduction is warranted.

- *The rationale for using a 10% reduced dry runway braking force from the 25.125 demonstrated wheel braking is related to manufacturers choosing runways and parts of runways that provide the best wheel braking possible. From the TALPA ARC submittal: "The recommended level of 90% of the dry runway capability is intended to account for the possible degradation due to the operational runway as compared to the runway used in flight test, if you will the selection of runway surface for flight test that is free of paint, heavy rubber build up etc. It is known and has been acknowledged that at times manufacturers have repeated tests or gone to different runways to achieve better results. The FAA has an additional concern that in line operations that on a dry runway on airplanes with high deceleration capability that maximum braking is not used. In general the group was not concerned as especially with the bigger airplanes it wasn't felt the time of arrival assessment will be onerous on normal dry runway observations."*
- *The TALPA ARC and AC 25-32 do provide the opportunity to use 100% of the 25.125 wheel braking force as tested. Note 1 to Table 2 on page 14 of AC 25-32 states: "100% of the wheel braking coefficient used to comply with § 25.125 may be used if the testing from which that braking coefficient was derived was conducted on portions of runways containing operationally representative amounts of rubber contamination and paint stripes."*

Issue 3 was on using the same factor on autobrake data as on maximum manual braking data.

Comment on Issue 3 - Final TALPA implementation did not include a factor on autobrake data for operations on a dry or a wet grooved/PFC runway. The factor was maintained on both maximum manual braking data on wet smooth and contaminated runways, the reasoning is these surfaces are significantly more likely to cause a friction limited braking situation and therefore unlike on a dry/wet grooved runway there is little or no benefit of overriding the autobrake with maximum manual braking.

Issue 4 was raised by TCCA which stated: For me "codifying TALPA" meant incorporating the CFR 25 aspects for wet and contaminated runways i.e. pretty much AC 25-31 and 25-32 or maybe even just 25-32. I think this is something we need to clarify. As I have commented before if we really mean all of TALPA then we need much more than this group and we should recommend reconstituting the TALPA ARC.

Comment on issue 4 – it is certainly reasonable to have concerns on buy in from all parts of a regulatory agency as to a change such as TALPA. It touches airports, operations and type certification.

- *Currently three regulatory or advisory bodies have incorporated or will be incorporating TALPA ARC recommendations in one form or another:*
    - *The FAA has incorporated TALPA ARC recommendations using a* ***voluntary*** *implementation as of (Oct. 1, 2016) TALPA. Codifying the recommendations for airports, flight standards, ATC, NOTAMs and transport standards would bring consistency of application across all airports, manufacturers, operators etc.*
    - *ICAO has updated its Standards and Recommended Practices for airports, flight standards, ATC, NOTAMs and transport standards for TALPA ARC recommendations with implementation in 2020. These modifications include changes to PANS-Aerodromes as well as a new Airplane Performance Manual which includes modifications for flight standards and transport standards.*
    - *EASA has published NPA 2016-011 which states "The NPA proposes standards for runway surface condition reporting, airworthiness standards for landing performance computation at time of arrival, an in-flight assessment of landing performance at time of arrival…………". These standards are based on ICAO adoption of TALPA ARC recommendations as documented in ICAO state letters which contain the*

recommended modifications to the various annexes. ICAO airports are targeting 2020 as final implementation date.

Issue 5 – Concern over CFR 25 retroactivity and manufacturers being required as to add data to the existing AFM's meeting AC 25-31 and 25-32.

*Comment on issue 5 – As noted in the section on **'Ease/cost of implementing the recommendation'** the TALPA ARC recommendations recognized issues with requiring retroactivity in AFM publication of data to the new standard and explicitly accepted non-AFM existing data (JAA/EASA) may be used (supplemented if necessary) and that manufacturers consider incrementing and/or factoring existing data to obtain TALPA consistent data. Generic factors were created for operators if the manufacturer does not provide appropriate data or guidance and can be "other acceptable data for operational use shall be available".*

Group Consensus

- No dissenting opinions received.
- 1 considered abstained due to lack of response.

Not all parties accepted the recommendation to codify TALPA recommendations without comment as noted above in the documentation of issues raised during the polling and discussions. There is a realization that there has been industry activity since the time the TALPA recommendations were submitted to the FAA in 2009. There is also recognition that original recommendations have been modified by FAA during the voluntary implementation, the ICAO has created a state letter laying out Standards and Recommended Practices which deviate from the original TALPA recommendations, and EASA has created an NPA working towards codification of the TALPA recommendations as modified by the ICAO. The significance of the deviations from the original TALPA recommendations does not have a consensus and would need to be part of a harmonization effort going forward.

Also it should be recognized that if this recommendation is accepted and forwarded, the logical body for harmonizing the CFR 25 codifications would be the Flight Test Harmonization Working Group.

***Recommended ARAC action**: if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the appropriate FAA/EASA/TCCA.*

Attachment 9D - Identification of Poor Performing Wet Runways

Recommendation

Airplane certification and operational performance organizations to work directly in a regulatory agency sponsored team with airport organizations on a method to quantitatively identify runway conditions leading to poor performing wheel braking on wet runways and using this information to identify poor performing wet runways.

Executive Summary

Airplane certification and operational performance organizations to work directly in a regulatory agency sponsored team with airport organizations on a method to quantitatively identify runway conditions leading to poor performing wheel braking on wet runways and using this information to identify poor performing wet runways.

If a runway cannot create adequate wet runway wheel braking performance, then a Field Condition report (FICON) should be published via NOTAM informing the operator that reduced wheel braking performance can exist when the specific runway is wet, that can also affect maximum cross-wind recommendation.

This concept is consistent with a TALPA recommendation to use reduced assumed wheel braking for TOA landing distance determination on runways where measured friction is below the minimum friction level as defined by the FAA AC or other applicable standard.

The current standards are reliant on Continuous Friction Measuring Equipment (CFME) which is typically not available at the runways that have reduced wet wheel braking capability. Other techniques of recognizing poor wet runways need to be established that can be used at airports that do not have access to CFME equipment or that can be used in combination with CFME's. These techniques need to be specific and have meaning as to airplane stopping performance.

Background

The goal of aviation safety should be every airplane is capable of landing at the destination airport and stopping on the runway with adequate margin covering either a runway with worse braking characteristics than is normally expected or reasonably foreseeable variations in pilot technique and other operational parameters between the time of dispatch and arrival.

An airplane stopping performance on any given wet runway is related to both the runway's capability of creating friction and the airplane's capability to convert the friction available into an effective stopping force. Per wheel braking theory, the ability of the runway to create friction when wet is related to 4 characteristics: the macrotexture, microtexture, water depth and drainage of the runway.

1st: A larger macrotexture (along with appropriate cross slope) is related to the ability to remove water from the surface of tire-runway interface. The result in these characteristics combined is good drainage minimizing the exposure to measureable depths of fluid above the effective braking surface.

2nd: Microtexture refers to the very small roughness of the braking surface. The microtexture breaks up the fluid continuity and is the actual friction creating mechanism at the tire-surface interface.

3rd: Water depth should be as small as possible thanks to good drainage. There is no (yet) real time water depth measurement on the immense majority of runways, resulting in a significant risk under very heavy rain, potentially combined with drainage deficiencies, of Airport not declaring RWY covered by standing water, over full or partial length.

4th: Drainage is ensured (along with appropriate macrotexture) by appropriate cross-slope, absence of significant waviness and of drainage deficiencies, including from RWY shoulders and drainage system. Most runways are double transverse slope, but some runways are still single transverse slope, with slope value not significantly higher than standard double transverse slope runways, creating a risk of abnormal water depth for a given precipitation rate, further increased by the risk of crosswind from the low RWY edge. A number of single transverse slope RWYs has frequently demonstrated inadequate water drainage properties and ICAO recommendations for such single transverse slope RWYs are probably insufficient.

In order to create a runway with excellent wet wheel braking it must have simultaneously good characteristics in the 4 areas of:

- appropriate water drainage
- reduced water depth present on RWY and ideally a real time assessment of abnormally high water depth condition
- macrotexture
- and microtexture.

If a runway has degraded in one, two, three or all four areas, then the ability of the airplane to create wheel braking needed to meet the expected wet runway performance is degraded and therefore one of the factors often associated with causes of overruns exists even before the landing has been initiated.

There are currently standards for airport design, construction and maintenance of runways. There also currently exist tests to measure macrotexture, and runway visual inspections at time of continuous rain to detect deficiencies in drainage. But there are not:

- tests to directly measure microtexture, rather microtexture may be inferred by the friction measurements on Continuous Friction Measuring Equipment (CFME) testing at high speeds (~95 km/h) on DRY RWY with a local artificial wetting just in front of measuring wheel supposed to create conditions of 1 mm water depth.

However evidence obtained following analysis of an airplanes ability to stop during overrun events on a wet runway show that there have been occurrences where the runway is not capable of creating the expected wet runway friction capability resulting in a reduced safety margin.

Essentially when this is a pre-existing condition, the contributing factors required for an overrun to occur are reduced.

Why this recommendation is important

The current method of defining wet runway dispatch performance for landing is a combination of CFR 25.125 dry runway capability in conjunction with certification methods to determine the dry runway landing distance which is then factored to create a wet runway landing distance. This factoring can vary depending on the operating rules. The fact that dry runway performance does not have the same physics when it comes to stopping an airplane as a wet runway leads to the real margin varying with operating rule, temperature, altitude, slope, reverse efficiency of the aircraft type, and the friction capability of any individual runway. The risk of the airplanes wheel braking capability varying significantly is greater on a wet runway than a dry runway.

Typically there is sufficient margin available because airplanes seldom operate on runways that are equal to their AFM required landing distance. This is especially true for the CFR 121 airlines however other segments of the industry such as business jet on commuter operations may well operate in a field length limited situation more often.

Nevertheless there are operations where the necessary landing distance on a wet runway is approaching or exceeding the regulatory minimum. If the airplane is at or near the regulatory landing distance, typically the wet runway stopping performance would be adequate to absorb one or two issues (long landing, tailwind, excessive approach speed, incorrect usage of stopping devices etc.) without an overrun occurring. However if it is raining moderate to heavy and the runway has a significant reduced friction capability or poor drainage, then there may not be adequate runway available to absorb even one of the issues mentioned above.

How do airports ensure they have adequate friction capability on their runways?

This is highly dependent on the state regulating the airport and the economics at individual airports. Major airports have Continuous Friction Measuring Equipment (CFME's) which they use to periodically check the friction *capability of the runway when wet. FAA AC 150-5320-12C gives guidance and methods* on how to determine when a runway is approaching a time when maintenance should be planned in order to ensure the runway friction capability is adequate. It also provides guidance on when the minimum allowable friction as defined by airports is being approached and when it is mandatory to do something to ensure the friction capability of the runway is improved.

As noted above this degraded friction due to the runway surface when wet has contributed to overruns. The NTSB recently (summer 2016) put out a report documenting six cases where they feel this wet friction capability reduction was a contributor to the overrun.

An accurate correlation method between CFME's measurements, maintenance/minimum friction thresholds and aircraft performance on WET RWY does not exist today as a standalone predictive tool as it cannot take into account other issues such as speed differences between airplanes and CFME's or airport drainage issue etc. This makes the practice of any "compensation" mechanism to mitigate low CFME's value in one area by high CFME's value in adjacent areas, or left/right, as allowed in FAA AC 150-5320-12C questionable and an issue that should be discussed by airport and airplane performance experts.

Equally important is to incentivize airports to ensure construction and maintenance of their runways is such that it provides good stopping performance when wet. It seems more appropriate to identify poor performing runways and take action to ensure adequate operating margin at those airports than penalize every airport and landing operation. Some airports have also grooved runway providing, if well built and maintained, better operating margin in comparison to smooth runway, that is if specific performance credit taking advantage of the grooves is not used.

Benefit of successful implementing the recommendation

We will use specific examples of the issue and how mitigation occurred after a number of overruns occurred appears to have significantly improved the situation.

Example 1: In 2011 an Airbus ran off the end of Rostov-on-the-Don airport in Russia when the runway was wet, in 2013 two more Airbus overran the Rostov runway. In 2012 a 737-800 ran off Rostov in light rain. In 2013 another 737-800 went off runway 22. In 2011 two separate 737-400's departed the runway while it was wet. Since the above mentioned multiple excursions Rostov has resurfaced the runway.

The Airbus analysis of their overruns at the airport showed a braking capability of "**close to POOR level**" without heavy rain intensity on the main portion of runway corresponding to the area aircraft use for stopping. Prior knowledge of this state may be used to improve tactical decision making. The airport had a poor reputation when wet but there was not a specific enforceable remedy to account for this.

Example 2: Another example of this type of operation occurred in Indonesia, in 2011 and 2012 at least nine runway excursions occurred when the runway was wet, 4 at one airport (2250 m length) and 3 on another runway (2240 m length). Four by a single airline (all overruns or veer off avoiding overrun). During the investigation it was determined that the runways had less than expected wet runway braking, This led to the airline creating specific policies for those runways (and any other runway 2500 m or less in length). The policy was to increase the landing flaps to the one resulting in the lowest approach speed as opposed to using the approach flap that met the minimum regulatory requirement and burned minimum fuel. The airline also increased the standard Autobrake setting used when the runways were wet to ensure full friction limited wheel braking was achieved early in the stop. Since 2016 the airline appears to have had only one overrun on a wet runway and on that overrun the nose gear was 2 meters past the end of the paved surface.

Identifying these poorly performing runways can materially improve safety by providing the operator knowledge especially at moderate length runways. This allows them the possibility to make tactical operating decisions to increase the margin available. Also operator knowledge of the runway friction state allows them to pressure airports to take maintenance action to improve the runway state.

A better, more cost effective way is needed to identify these poor performing runways before overruns occur, not after.

As noted above it is equally important to not reduce the airplane performance capability at good, well maintained runways that can demonstrate their effectiveness.

Ease/Cost
This is not an easy task; the following is some of the history that needs to be overcome:

1. The method of relating runway friction measurements with CFME's for runway maintenance purposes appears to go back to an analysis documented in Appendix 1 of ICAO Airport Services Manual Part 2 and is based on a research hypothesis that the friction level which produces ½ the dry runway capability on the 727 and 737-100/200 should be adequate for establishing the minimum friction level on a wet runway. Please note there was wet runway test data available on the 727 and 737 at the time.
2. The 727 and 737 test data at the time was accomplished at lower operating speeds than the current fleet often uses for landing and rejected takeoff speeds. Partly because of changing design requirements used by manufacturers over the years recognizing the changing operating and economical environments in the industry.
3. Economics of airports and the ability to buy modern equipment to facilitate an understanding of the runways wet runway capability.

This is also not easy because of the complexity of the issues, as noted earlier there are multiple issues, isolated or in combination, that can lead to the loss of friction when a runway is wet, and that might produce major aircraft performance loss without, being detected by existing CFME's with their recommended use. Issues identified are drainage (cross-slope, puddling due to local depressions in the wheel tracks and macrotexture, lack of real time water depth measurement) and wet friction capability of the surface (microtexture). Plus there is the additional complication that different size airplanes do not use the same part of the runway for braking due to variations in gear widths.

A question opened by a recent ESDU work is the potential sensitivity of CFME's readings to temperature. This effect has been recently checked and found to be insignificant on aircraft friction on wet runway by a Manufacturer (through aircraft flight tests, it is a work in progress to obtain data for a full temperature range), but a CFME's isolated experiment by a country on a runway may indicate that temperature has significant influence on CFME's readings performed on a dry runway wetted artificially and locally in front of the measuring wheel. It might contribute to the large measurement scatter observed between successive CFME's measurements that do not appear to have justification due to rubber contamination, polishing and runway cleaning actions.

A new ERA

The industry has demonstrated that it is possible to identify poor performing wet runways by systematically looking at data from landing aircraft as well as the aforementioned methods of using CFME's. In general the data necessary to do this can be gathered on the current fleet of CFR 25 certified airplanes through analysis of data which is available on Quick Access Recorders or FDR's. Typically this method of analyzing in-service data will only yield friction limited results at shorter runways. That is okay, shorter runways are where a reduced wet runway capability is critical.

Currently there are at least four companies looking seriously at systems of obtaining information that can be used to do this. As this is a new use of airplane technology there are still many issues being worked out and that need to be addressed.

One issue associated with obtaining this data directly from airplane sources has to do with de-identification of data to meet requirements from some pilot unions.

Another benefit of aggressively tracking this information is the possibility of identifying rain intensity effects also (that will need airport or runway short term rain intensity recording and accessibility at each airport, which might not always be the case today).

Real-time water depth measurement tools are starting to become available from several companies as ground equipment for airports, embedded in the runway or mounted on vehicles. At this point in time there isn't a specific defined use specified for this information (exception is Changi Airport which announces "a" water depth figure to aircraft in approach).

Identification of CFME's readings sensitivity (or absence of) to the pavement (or outside air) temperature at different measuring speeds is a necessary investigation to be done, both for Grooved and on smooth-non grooved RWY, in order to reevaluate existing practices if needed (measuring speeds, maintenance and minimum thresholds, compensation mechanism for some under-reading areas).

Conclusion

Historically there has been a segregation of airport runway guidance and regulation as to design and maintenance as compared to airplane performance and operating standards. For example, some airplane performance and operations have treated all wet grooved runways as equivalent to dry. This is demonstrably not factual especially in the presence of heavy rain.

Traditional methods of identifying poor wet runway characteristics have been primarily limited to friction measurements which may or may not accurately reflect the actual operational friction available at a runway depending one equipment, method of measuring the friction or lack of accountability for poor drainage.

It is recommended that a project be initiated including both airport specialist and airplane performance personnel to identify specific, quantifiable airport traits that lead to poor wet runway friction and significant build-up of standing water. However this information is not useful if not provided in a useful manner, therefore the additional recommendation is this group identifies specific parameters or conditions that should lead to a designation of the runway as slippery when wet in the airport NOTAMs.

Group Consensus

- No dissenting opinions received.
- 1 abstained, 1 considered abstained due to lack of response

Recommended ARAC action: *if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the appropriate FAA personnel when considering proposed FAA future research programs and to the Tech Center Airport research team for discussion in their upcoming "Expert" panel meeting on future wet runway research. The first meeting of this "Expert" panel is planned for mid-February of 2017.*

Attachment 9E – Codify CFR 25 wet runway requirement

State recommendation:

Create CFR 25 standard and operational factors that reflect the physics of stopping an airplane on a wet runway.

Background

Currently the operating requirements at dispatch for landing at a destination or alternate on a wet runway are not tied to the physics associated with landing and stopping an airplane on a wet runway. Also depending on ACO/manufacturer may be made based on methods in AC 25-7C that may not compatible with current regulation CFR 25.101(f) requiring the landing distance be determined "in accordance with procedures established by the applicant for operation in service". This second assertion is well known and has been accepted by the FAA for 40 years with typical arguments made in association with the "large" factor applied by the operating regulations, typically referring to the CFR 121/135 60% rule which may or may not apply to any specific FAA operation.

Below is a list of the pertinent operating requirements applied to a CFR 25.125 field length.

60% rule:
91.1037 (b) Large Transport: Turbine Engine
121.185 Reciprocating engines
121.195 (b) Transport: Turbine Engine
121.197 Transport: Alternates Turbojet
121.203 Non-transport
135.375 Large Transport: reciprocating engines
135.385 Large Transport: turbine engines
135.387 Large Transport: Turbojet: alternates
135.393 Large non-transport: destination (note no turbo-propeller exception)

70% rule:
121.185 Reciprocating engines: alternate if destination can't meet 185(a)(2)
121.187 Reciprocating engines: alternates
121.195 (c) Transport: Turbo-propeller alternate if destination can't meet 195(b)(2)
121.197 Transport: Turbo-propeller: alternate
121.205 Non-transport: alternate
135.375 Reciprocating engines: alternate if destination can't meet 375(a)(2)
135.377 Reciprocating engines: alternates
135.385 (c) Transport: Turbo-propeller alternate if destination can't meet 385 (b)(2)
135.387 Large Transport: Turbo-propeller: alternates
135.395 Large non-transport: alternate (note appears to apply to both turbojet and turbo prop)

80% rule

91.1037(c)(d)	Destinations in accordance with approved Destination Airport Analysis, & alternates
135.385(f)	Eligible on Demand
135.387(b)	Eligible on Demand alternate

EASA, ANAC and Transport Canada have operating standards on wet runway that are equivalent to CFR 121/135 standards however currently do not have the equivalent of the 80% rule that is in CFR 91 and 135 however EASA does have an NPA out for comment which would incorporate an 80% rule.

The dry operationally factored landing distance is then increased by 15% to obtain a wet runway landing distance.

The result of these varying dry factors with the aggressive nature of dry runway CFR 25 flight testing/certification and calculation of the CFR 25 dry runway distance has led to the current situation where:

- Significant margin variations exist from airplane to airplane when compared to a wet runway landing distance calculation based on a more representative physical model.
- Flight crews have limited knowledge of the actual landing distance margin on a wet runway surface and it is therefore difficult to evaluate whether actions should be taken on a degraded wet runway.
- There may be reduced margin for airplanes operating in ISA+ temperatures or at high altitudes.

Physics

First and foremost the effect of speed on the friction characteristics is different between an aircraft tire on a dry runway and on a wet runway. This difference cannot be modeled by a simple factor and maintain consistent margins across the operating envelope. On a dry runway the effect of speed on available friction is relatively low resulting in near constant braking coefficients with speed. On a wet runway the effect of speed on the wheel braking capability is significant. The high speed wheel braking coefficients on a wet runway can be from ½ to ¼ or even less of the wheel braking coefficients on a dry runway. However at very low speed the wet runway may act similar to a dry runway. This fact has been proven by research flight testing (NASA, Canadian Research Council among others) and manufacturer flight testing in support of research and certification. This physics phenomenon has been codified in the CFR 25 regulatory standards in CFR/CS 25.109 (and TC, ANAC equivalent). This codified wet runway performance is used for computing the stopping performance on a Rejected Takeoff calculation on a wet runway and is also used by AC 25-32, Landing Performance Data for Time-of-Arrival Landing Performance Assessments for wet runway (Good Braking Action).

A second physics-based issue has to do with the resulting margin variation to a common physics-based calculation from manufacturer to manufacturer based on how their dry runway landing performance was certified.

Literally the current operators dispatch landing distances on a wet runway can be shortened significantly by:

- Adding torque capability to a brake by adding an additional rotor/stator to the brake stack while keeping the same tire and anti-skid performance (affects airplane dry runway performance but not wet runway performance)
- By changing allowed air distance certification methods (AC 25-7C)

A study was accomplished when this topic was initiated which compared the regulatory dispatch distance based on current combination of certification and operating requirements to a physics-based unfactored wet runway landing distance recommended by the TALPA ARC and AC 25-32, "Landing Performance Data for Time-of-Arrival Landing Performance Assessments". The table below summarizes these results:

Current dispatch landing distance based on 1.92 times CFR 25.125 dry

The current dispatch distance is greater than the physics-based wet runway landing distance using TALPA standard by the following margin				
	Sea level, std. day	Sea level, ISA+20	5000', ISA+20	10000' ISA+20
Largest Margin Airplane	71%	69%	63%	59%
Lowest Margin Airplane*	20%	13%	9%	6%

Current dispatch landing distance based on 1.44 times CFR 25.125 dry (91K regulation)

The current dispatch distance is greater than the physics-based wet runway landing distance using TALPA standard by the following margin				
	Sea level, std. day	Sea level, ISA+20	5000', ISA+20	10000' ISA+20
Largest Margin Airplane	28%	27%	22%	19%
Lowest Margin Airplane*	-10%	-15%	-18%	-21%

*Note: the lowest margin airplane has poor thrust reverser effectiveness with values approaching a no reverser airplane, recommends VREF+5 minimum approach speed, does not include temperature accountability in the current AFM.

The two different operating standards used in the table above show the margin based on the current regulation can be less than the generally accepted margin of 15% for calculations based on operational parameters (AC 121-195 (d)-1a, TALPA ARC time-of-arrival operating standard and EASA contaminated runway AFM data standard). It can also be seen that under the 91K standards the margin can be negative.

The margins quoted in the table above include credit for reverse thrust and do not include an accounting for downhill slope or extreme temperatures like ISA+30. Since MMEL's do not have reverser inoperative performance penalties because the current CFR 25.125 dry runway calculation does not include thrust reverser credit in the calculation any time a reverser is inoperative the margin available is reduced. Runways may actually have downhill slope and temperatures may well exceed ISA+20, the margins can be even less than the values in the table.

Some reasons for these variations in margin between the AFM based dispatch distance and physics-based wet runway calculation.

- Method of air distance certification
- Method of transition time certification
- Accountability for temperature and slope (some manufacturers have included accountability in the AFM, some do not)
- Airplane reverser capability and/or number of reversers on the airplane
- Manufacturer recommended operational approach speed as compared to regulatory approach speed used in CFR 25 certification

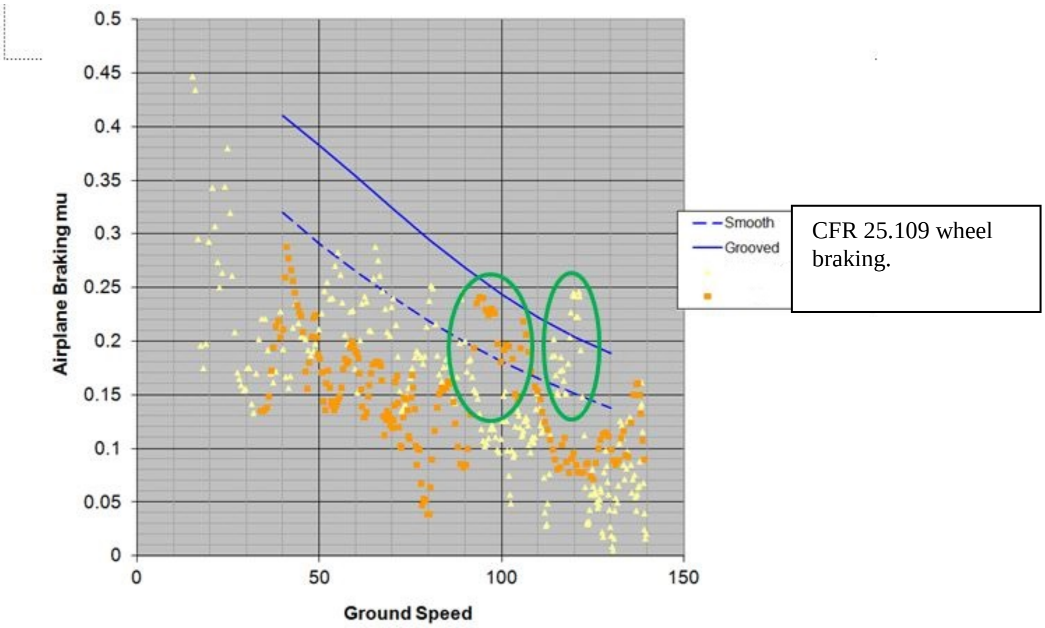
Observed wet runway wheel braking

As noted above the current standard used when looking at an individual runways capability to create friction based on observed deceleration rate or stopping distance is CFR 25.109 for wet smooth or wet grooved/PFC runways. There have been incidents/accidents, manufacturer and research testing showing the variability on the airplanes ability to create wet runway braking efficiency.

Factors affecting the ability to create a level of wet runway braking are specific to a runway design and maintenance practices specifically as to macro- and micro-texture, drainage and "how wet is wet". Airport operational factors that affect the runway's capability to create friction when wet are rubber contamination, polishing, rutting, cross slope and drainage capability. There are airport standards on how to build and maintain a runway for good wet runway drainage and roughness and therefore good wet runway braking however the adherence to these standards are a matter of regulatory oversight, interpretation of the standard at individual airports and of course money available at individual airports and countries.

Because of all these factors the group that originally created the wet runway wheel braking standard for RTO took what they felt was a reasonable but conservative standard when determining the standard of wheel braking to be included in the regulations. However more information has come to light pointing out the problem of significantly reduced wheel braking on some wet runway operations.

The following shows an example of the issue:



In this case two airplanes landed back to back just following a time of heavy rain. The yellow data is the incident airplane, the orange data an airplane that landed 4 minutes earlier. The first airplane stopped on the runway the second airplane did not due to a flight crew procedure issue. The runway was a grooved runway and as can be seen here both airplanes demonstrated wheel braking well below the nominal wet smooth (non-grooved) regulatory definition except for a short segment of the runway where it did meet or approach the regulatory definition for a wet grooved runway. This variation is because the cross runway is significantly newer and made of a significantly higher texture material as well as better friction material. The location of the high wheel braking corresponds with this cross section. This plot shows how the actual runway surface and the amount of wetness involved can affect the airplanes stopping capability on a wet runway. In this case if the nominal braking level for wet smooth runway as defined in CFR 25.109 had been attained the airplane would have stayed on the runway even with the flight crew procedural issue. Also it should be noted that the wheel braking in this graphic would include any drag associated with any significant standing water as it was not removed from the deceleration force and the reduced braking is encountered at speeds well below the expected hydroplaning speeds for the airplane.

Poor wet braking capability due to the condition of the runway and presence of moderate to heavy rain can negate any assumed operational margin when landing on a runway at or near the performance limited distance. Degraded wet braking capability exposes the airplane to other landing performance issues which individually may not be serious, but in combination could lead to a runway excursion.

One of the issues in the jet fleet operation is the expansion of airports/runways serviced by increasingly larger airplanes. As the demand for efficiency and capacity increases, there has been demand for stretched airplanes and larger designs that were not in mind when an airport was designed. There are also cases where the investment in airport infrastructure has not kept up with the current fleet operating at these airports for economic reasons.

Discussion

There are multiple issues that can affect the margin available on a wet runway. One issue is the actual physics of stopping an airplane on a wet runway and how it is influenced by the runway construction, maintenance and precipitation rate. Another issue is assumptions made using the current certification and dispatch requirements for determining dry runway CS/CFR 25 landing distance, including the relevant operating factors.

As a reminder, the manufacturer's DRY runway AFM-based data may or may not take into account:

- Manufacturer recommended approach speed for operating the airplane
- Temperature variation from ISA
- Slope effects
- Operational methods of flying the airplane

It is certainly explainable to and understandable by most people that the margin available on a wet runway will be affected by items that affect the actual wheel braking capability on a wet runway, the speed carried to the threshold, the flight crews flare technique, or anything else that affect the physics of landing and stopping an airplane on a wet runway.

However, it is much more difficult to explain the complexity in determining the actual margin using the combination of the AFM dry runway data and operating factors. This margin may be significantly less than the flight crew/dispatcher/engineer assume is in the data for some conditions. It is also difficult to justify why airplanes without thrust reversers are allowed to have less operational margin than airplanes that employ thrust reversers (assuming they are operative).

One method to remedy this is to have a CFR 25 landing distance based on wet runway wheel braking and more operationally representative criteria. This would require a modification of current CFR 25 landing standards to include a wet runway performance determination during type certification and a modification of operating standards to reflect this change.

A second method to remedy this is to have a CFR 25 landing distance based on wet runway wheel braking and the same criteria as used for the current CFR 25 dry runway certification. This would require a modification to CFR 25 landing standards as to assumed wheel braking determination for wet but not necessarily any other parameters.

Finally since a reason for topic 9 to exist is the reduced wet runway wheel braking observed in some overrun incidents and accidents it is fair that this issue is part of any discussion on a new standard whether the reduced wheel braking is due to poor runway characteristics, heavy rain or some combination of both.

Various members of the group have proposed the concept of having wet and dry runway performance based on the same methods and assumptions to provide consistency to the operators. It is felt this concept helps with the operator of the airplane understanding the data basis and what is required by the flight crew. Other members commented that this may not be beneficial to safety (dry landing distance has not been identified as an issue) and the change would have large impacts to the business side of the industry. This will be worked during the completion of the task.

Not a new concept

Having a wet runway standard based on more representative physics of landing an airplane and then stopping it on a wet runway is not a new concept; currently the operating requirements of 121.195 and 135.385 contain the following language:

"(d) Unless, based on a showing of actual operating landing techniques on wet runways, a shorter landing distance (but never less than that required by paragraph (b) of this section) has been approved for a specific type and model airplane and included in the Airplane Flight Manual, no person may take off a turbojet powered airplane when the appropriate weather reports and forecasts, or a combination thereof, indicate that the runways at the destination airport may be wet or slippery at the estimated time of arrival unless the effective runway length at the destination airport is at least 115 percent of the runway length required under paragraph (b) of this section."

The bolded section where the actual showing of the airplanes capability on a wet runway has been used by manufacturers for demonstrating the wet grooved runway performance however for the basic wet runway performance on a wet smooth runway this method has not been used since the 727 (to the best of knowledge of any participants).

This historical method for this is contained in AC 121-195(d)-1a.

Accountability for reduced wet runway wheel braking

A reason for topic 9 to exist is the reduced wet runway wheel braking observed in some overrun incidents and accidents. Creating new CFR 25 standards may allow a means to account for the observed reduced wheel braking which has been observed in these wet runway incidents and accidents.

Why recommendation is important

Current FAA operating factors applied to a Part 25 dry runway certified distance do not lead to knowledge of the margin on a wet runway especially if it is a somewhat degraded surface. This also leads to different margins depending on altitude, temperature, runway slope and manufacturer operating recommendations such as increased approach speed above VREF.

This has been exacerbated by changes in the industry since the original FAA wet runway rule in 1964. Things like the advent of higher approach and landing speeds, in some cases less effective reverse thrust, changes in certification methods etc.

Finally there is a variation in margin based on whether the airplane has reversers and if those reversers are effective. Currently airplanes with reversers or more effective thrust reversers have additional margin when compared to airplanes without effective thrust reversers. Because no direct performance benefit was available before the RTO wet runway regulatory criteria there was not a direct regulatory incentive to keep thrust reversers on jet aircraft. Having a wet runway requirement which provides credit for reverse thrust further incentives to keep reversers on the airplanes and hopefully lead to improved reverser designs.

It is also considered important that manufacturers will still be able to compete on airplane performance for landing distance as they do today. This will include items like airplane configuration affecting approach speed, reverse thrust design and philosophy, airplane flare characteristics and anti-skid system capability.

Ease/Cost

Any change in performance has a cost associated with it. In this case the cost varies based on methods used for CFR 25 dry runway certification and current AFM construction, potentially operating rules being currently used, airports being considered and manufacturer design philosophy.

In a pure certification cost, there would be no/minor additional testing determining the anti-skid efficiency as this is typically done for rejected takeoff compliance with 25.109 also the current methods allow the use of default anti-skid efficiencies plus the wet runway wheel braking would be defined. On testing for air distance, it would be similar to the options available in the advisory material today and presumably not a significant change. Credit for reverse thrust should not significantly increase the cost as the performance and reliability aspects are already determined when certifying for RTO reverse thrust credit on a wet runway. This is also the case for the wet runway wheel braking characteristics.

Because of the large variation of certification methods and AFM construction for CFR 25 dry runway data it is not possible to give a simple quantification of the effect of whatever method would ultimately be proposed. There will be cases where the proposal may result in shorter distances than today and there will be cases where the resultant dispatch distance may well be longer than today especially at altitude and higher temperatures.

It should be pointed out that a small number of total operations are limited by the wet runway requirements but where it is limited it may be significant.

This improved physics based wet runway CFR 25 requirement would not be considered for retroactivity. Making this an and-on change from a future point of time will allow manufacturers time to consider design issues etc. to minimize any negative aspects of a rule change.

Conclusion

An improved physics based wet runway landing distance should be part of future CFR 25 certification as well as an accounting for a reduced wheel braking wet runway condition. If this is done, then consistent, acceptable margins will exist for the normal operating environment at the point of dispatch and the large variation in margin based on certification methods and AFM construction will be reduced or eliminated.

Group Consensus

- No dissenting opinions received.
- 1 considered abstained due to lack of response.

As this recommendation documenting the rationale for continued work on task 3 towards physics based wet runway dispatch rule all acceptances are contingent on final proposal to be delivered in the final report. There is possible dissent with the final recommended rule depending on specifics. The state of the current proposal is discussed in the report section - Topic 9 Wet Runway Stopping Performance Task 2 and 3.

Recommended ARAC action: *if the ARAC concurs with the recommendation it is requested that no other action be taken and the FTHWG will continue forward with Task 2 and 3 as assigned in the original tasking*

Attachment 9F - Ground Spoiler not armed warning regulation/guidance in CFR 25

1- Rationale:

1a- Analysis:

The automatic deployment of GROUND SPOILERS (lift dumpers), frequently used in aircraft design:

- The system needs to be reliable since a failure to deploy at touchdown may be hazardous, in particular (but not only) for a potentially significant loss of wheel braking performance due to slippery and contaminated runways and/or mechanically available drag,
- The system is also required to be extremely robust to spurious activation, as deployment airborne (at more than a few feet height) may be potentially catastrophic.

The design of automatic GROUND SPOILERS deployment devices and logics has been subject of several NTSB safety recommendations and FAA AD's following several landing accidents in the 1970's (including the 1st B737 fatal accident in the final approach of CHICAGO-MIDWAY RWY31L, UAL Flt 553 on Dec. 8th, 1972) leading to the now familiar **§25.697 Lift and drag devices, controls**.

Following several accidents on Take-Off, the requirement for a **Take-Off Warning System** was been introduced by **FAR §25.703** in 1978. However, the AAL Flight 1420 LITTLE ROCK MD-82 accident **at landing** on June 1st 1999 with the GROUND SPOILERS lever not armed led only to the request of GROUND SPOILERS armed to be part of "before landing check list" and reinforcement (training) of verification/call out by crew. For aircraft having automatic deployment of ground spoilers on ground conditioned by arming them prior landing***, no requirement*** *was recommended for a warning to prevent the crew from being unaware that the GROUND SPOILERS automatic deployment function has not been armed.*

However there are risks, at least on WET or slippery surfaces that:

- The absence of GROUND SPOILERS deployment during landing in combination with the absence of mitigation by REVERSER selection (no REVERSE use or no mechanical device or logic to force ground spoilers to extend with REVERSE selection) will lead to significant increase of landing distances.
- And that unusual low aircraft deceleration in maximum pedal braking or lateral control difficulty exacerbated without ground spoilers extended may not be immediately evident to the crew and may prevent expected crew actions as per Standard Operating Procedures.

In a relevant incident, SWA Flight WN-1919 B737 overran the end of MDW RWY13C on April 26th 2011 with degraded WET friction:

- The GROUND SPOILERS lever was not armed in flight, nor on ground.
- REVERSE was not selected on ground until well down the runway, probably due to crew stress from the unexpected absence of deceleration initially encountered.
- No crew check/call out were performed as per Operator and Manufacturer Standard Operating Procedures.
- **If GROUND SPOILERS had been armed, the crew would likely have selected REVERSE (in MAX) early and no overrun would have occurred,** even with the abnormal low WET friction the aircraft experienced. An indication of this is the previous B737 landing on same RWY with same degraded WET friction successfully completed the stop.

Increased reliance on Auto-Brake as Standard Operating Procedure even at landing on wet or slippery surfaces can only increase the consequence of GROUND SPOILERS non-deployment as Auto-Brake activation typically depends on GROUND SPOILERS deployment.

1b- Concern for new warning unintended consequences vs. efficiency:

One Manufacturer has experience with a specific implementation of a new in-flight warning in the centralized Aircraft Monitoring F/CTL system which generates a GND SPLRS NOT ARMED warning. This warning activates below 500 FT with the gear down (and with F/CTL SPEED BRAKES STILL OUT in case of speed brakes use at very low height). It has been implemented to a legacy single lever design for both SPEED BRAKES / GROUND SPOILER functions and may not be generalized to all designs. The retrofit of this warning on thousands of aircraft of this Manufacturer over the last 10 years has shown:

- No report of any nuisance for crews.

- Even on models with an electronic Check-List and a GRND SPLRS ARM check prior to landing, this new warning has prevented several landings in which Ground Spoilers were not armed because the crew had to use SPEED BRAKES after the Landing Check List was completed and then forgot to re-arm the GROUND SPOILERS following the retraction of SPEED BRAKES.

2- Proposed new requirement:

For aircraft designs with GROUND SPOILERS automatic deployment at landing, which need a crew manual action in approach preparation to arm the GROUND SPOILER for an appropriate automatic deployment at landing, a warning should exist to prevent the consequences of a landing without GROUND SPOILERS deployment.

This general requirement makes explicit the new regulatory objective to prevent landing with landing configuration inadequate for GROUND SPOILERS, while:
- Exempting designs that do not need crew manual action of arming spoilers prior to landing.
- Allowing in guidance Advisory Material (AMC) flexibility to cope with detailed design specificities.

3- Advisory Material:

A backup for GROUND SPOILER extension through REVERSE selection is needed, and in itself is not a sufficient safety mitigation means for crew forgetting to arm GROUND SPOILER prior landing.

For aircraft with the flexibility offered by a Centralized Alert/Warning System, a combination of the electronic check list in approach preparation and a warning at low altitude to alert the crew that GROUND SPOILERS are not armed is a means to satisfy the intent of the new regulatory objective.

Specific logics and/or warnings may exist in the case of a combined SPEED BRAKE LEVER / GROUND SPOILERS ARMING device, when speed brakes are used, to satisfy the intent of the new regulatory objective.

An on-ground warning in case of non-deployment of GROUND SPOILERS at landing to trigger appropriate crew reaction, if shown to adequately lead to timely deployment of GROUND SPOILERS at landing is a means to satisfy the intent of the new regulatory objective.

Group Consensus

- No dissenting opinions received.
- 1 abstained as their products do not require such a system. 1 considered abstained due to lack of response.
- 1 accepted but noted for new TC's only, 1 accepted but noted not required for airplanes with automatic speed brake deployment without the need to arm the system.

Recommended ARAC action: *if the ARAC concurs with the recommendation it is requested either the ARAC communicate with or instruct the FTHWG to communicate with the Transport Standards organizations of the FAA/EASA/TCCA.*

Attachment 9G – Task 1 and Interim Report Acceptance/Dissent/Comments

The following table documents the response and comments received from the voting members.

Acceptance does not contain qualifier that would affect current status as interim report.
Abstain - self evident
Rejection

	Airbus	ALPA	Boeing
Wet Runway Topic 9 Interim Report	Accept, **conditionned to** the final results of on going discussions.	Accept	Accept
1. Landing Safety Training Aid	Accept - LSTA content regarding Dispatch vs. TOA should be harmonized EASA/FAA DRY/WET, but also explicitly define no harmonization for CONTA, as no Dispatch CONTA for FAA.	Accept	Accept, same comments as Airbus, needs harmonization for Dry/Wet, not contaminated.
2. Codify TALPA ARC Recommendations	Accept - For **existing designs**, there was provisions in TALPA ARC. Could it remain only recommended without stronger incentive ? To be discussed. We are perceiving the start of statistical overrun improvement in our fleet, not due to ROPS (still a too small overall number of aircraft fitted) but due to TALPA ARC implementation on all our fleet, up to first A300B4 included, only BELUGA excluded. If true, it would mean that TALPA ARC with semi-LSTA part of it is improving safety of landings, therefore could we neglect 90% of existing worldwide fleet ?	Accept	Accept, with applicability mandatory for new TC only
3. Identification of Poor Performing Wet Runways:	Accept See line below Item 6	Accept	Accept
4. Create CFR 25 standard reflecting the physics of stopping an airplane on a wet runway.	Accept **conditioned to** wet landing landing distance physics based with: - including a mitigation of WET friction degradation that is the purpose of this FTHWG Topic 9 WET RWY (identification above is more difficult than what most people might believe) - N REV avail at Dispatch - Landing configuration of the SOP: If Vref based without consideration for VAPP for models that do not perform Standard approaches at Vref even with no wind, this is not physics. And factor to compensate would not be legitimate for models that do routinely approach at Vref.	Accept	Accept with concerns - Agree that a mitigation for Wet fricton degradation is needed - N rev avail at Dispatch (with appropriate operational factor) - Flexibity for Vref approach when appropriate. I understand there is a level-playing field issue here between Airbus and Boeing. - My concern is that the yet to be decided operational factor will be driven to be too conservative. If we do our best to account for runway mu, temp, alt, slope, Vapp, N rev, etc.. on dispatch then we do not need an unreasonable factor. The factor should be close to the TALPA level, just accounting for more uncertainty. If the factor is base lined to be longer than we currently have at SL STD then it will penalize the industry (loss of capacity) for an issue that seems mainly driven by a degraded (wet) runways.
5. Ground spoiler not armed warning regulation/guidance	Accept with other Manufacturers agreement only for new TC and on models that do need a pilot manual action to arm ground spoilers prior landing. If an alert exists on ground, to be explicitly recognized as an acceptable means of compliance on existing designs.	Accept	Accept for new TC and where practical in existing designs.
6. **Require of a ROPs/RSAT/Smart Landing type systems for CFR 25**	Accept, an evidence for the long term for Airbus the only Manufacturer to have several years of in-service experience. However if Airbus can be considered competent on the issue, it can be considered also as having interests in such a requirement. The opinion that such a requirement, if published to-day, might be slightly premature is also respectable, for the following reasons: - 1 clear overrun avoidance only since 2009, and on POOR, "thanks to" a crew error corrected by a ROPS alert on ground; GO-AROUND events said to have been "supported" by ROPS alerts, but difficult to pretend that even without ROPS alert, the crew would not have, by himself, performed a GA. But several marginally safe landings in-service would have been avoided by ROPS on Airbus fleet if fitted. - EUROCAE / NPA on-going, still very draft, with some involved persons with limited practical experience of such systems up to Certification and In-Service issues, and with limited knowledge of degraded wet friction (not saying Airbus knowledge is complete ...). Airbus supports but it will still take effort and time ... - The only ROPS systems in-service to-day are not "SAFO 15009 compatible".	Accept	Accept, but the concept seems to not be mature across the industry yet. Different implementations may have different levels of effectiveness so a mandate may not have the desired effect. May need study of early-adopters (like Airbus) to understand effectiveness of system on safety.
7- Research on degraded WET friction ? Included in Item 3 "Identification of …" ?	A lot of actions are on-going in Europe to measure in real time water depth, LYON LFLL is preparing one runway (MUNICH already fitted) with Airbus intention to support with flight tests. French STAC assistance requested from Airport which have been "stigmatized" by Airbus Flight Tests and published a NOTAM. But known unknowns remain on the combination of water depth, pavement friction / texture, drainage, transverse slope, that need further research.	Accept, Item 7 I'm in favor/accept research but of particular interest was the ESDU model for calculating wet runway friction. The ESDU model had the ability to calculate a friction coefficient based on other runway contaminants. I feel this would be advantageous from an operational perspective. However, I do question the accuracy of this model and would like to have an independent evaluation on its accuracy or have another entity develop a similar type method.	Abstain, Reasearch is appropriate, especially if it can isolate the effect of the unknowns, but combined unknowns is very challenging.

	Bombardier	Dassault	EASA
Wet Runway Topic 9 Interim Report	Accept, **conditionned to** the final results of on going discussions.	Dassault acceptance opinion is conditional to on going discussions findings. If requisites for acceptance position were not fullfilled, could become a dissenting opinion.	
1. Landing Safety Training Aid	Accept LSTA is a good idea as there are more and more Landing Distance definitions: we need to send a clear message to the operators.	Accept - should include explecitely preflight and in-flight assessment. LSTA content should be EASA/FAA harmonized to avoid training cost duplication.	
2. Codify TALPA ARC Recommendations	Accept The Bombardier aircraft fleet is just beginning to use TALPA OLD data so there is no statistical evidence that OLD will reduce the number of overruns (limited number in any case). However, in the long run, it is believed that there will be an improvement in safety and Wet runway dispatch based on OLD would improve safety too.	Accept - Dassault supports the codification of TALPA if (if not, potential dissenting opinion) : - applicability is mandatory for new TC only. - it remains recommended for legacy aircrafts (as currently). Means that it should not become required through operational requirements (EASA NPA 2016-11).	
3. Identification of Poor Performing Wet Runways:	Accept from an overall safety point of view (this is regarded more as an operational topic for airlines)	Accept - Note that Bijzet operators may not be in position to implement or accept airplane sourced data.	
4. Create CFR 25 standard reflecting the physics of stopping an airplane on a wet runway.	Accept conditioned that the proposal accounts for all variables discussed in FTHWG meetings: actual speed at 50 ft, account for downward slope effects on air distance, agree on a suitable operational factor, define acceptable air distance model (7 sec, 96% decay) etc. The report does not provide these important details (guidance will be provided separately?).	Accept - Dassault supports this proposal and identify no need to change current LDdry requirements as per CFR 25.125 to address LDwet safety issue. A N-1 reverse thrust assumption should yield a Dassault dissenting opinion as : - real safety credit of efficient reverse is to improve safety @TOA (already achieved codifying TALPA) - it discourages manufacturers effort to improve T/R reliability - it is penalizing at dispatch for aircrafts fitted with one reverser without improving actual safety at TOA. It even penalises safety on contam runways for A/C with one reverser usable down to full stop which are particularly efficient on poor braking conditions In addition, Dassault suggests that guidance material for airborne phase characteristics not specific to a given runway condition be discussed within the frame of AC25-7C evolution, consistently for wet and dry LD and independently of LDwet safety issue.	
5. Ground spoiler not armed warning regulation/guidance	Accept Airbus concept final verbiage still to be reveiwed	Abstain - Falcons do not need ground spoilers arming to automatically deploy spoilers on ground.	
6. **Require of a ROPs/RSAT/Smart Landing type systems for CFR 25**	Accept the concept **for future aircraft** but forcing the use of such a system to all aircraft is considered outside the mandate of the FTHWG. There were a lot of questions unanswered when EASA proposed this via NPA a few years ago. Bombardier questioned the cost of development of such a system (if not using Airbus`s system...). We understand that Airbus developed a great system but forcing the use of such a system (Airbus or other) to all aircraft requires discussions that exceed our mandate.	Abstain - Wait for conclusions from EUROCAE Group and future EASA NPA.	
7- Research on degraded WET friction ? Included in Item 3 "Identification of …" ?	Accept more data will help define better models. Bombardier participation is another question ($$$...) !		

	Embraer	FAA	Gulfstream
Wet Runway Topic 9 Interim Report	Accept, **conditioned to** the final results of on going discussions.	Accept, **conditioned to** the final results of on going discussions.	Accept, conditioned to the final results of on going discussions.
1. Landing Safety Training Aid	Accept	Accept	Accept
2. Codify TALPA ARC Recommendations	Accept, with applicability mandatory for new TC only	Accept - However as presumably with the other regulators it must be recognized that other interested parties may have reservations especially since the FAA changed course a number of years ago do to prioritization of other issues plus limitations on FAA rulemaking apparatus.	Accept, for non-dry runways for reasons previously identified and discussed in the report. Applicability mandatory for new TC only.
3. Identification of Poor Performing Wet Runways:	Accept	Accept - This recommendation is in line with other FAA efforts and potential future research.	Accept
4. Create CFR 25 standard reflecting the physics of stopping an airplane on a wet runway.	Accept **provided this new CFR 25 standard:** - is not retroactive to current designs. - takes credit for N reversers OR a fraction of the total available reverse thrust (not N-1 rev). - allows, as an option, for the air distance to be measured in actual flight tests (if we are trying to reflect the "physics" then mandating a fixed air time and speed decay is contradictory). - the operational factors to be used with the wet landing distances are such that do not cause the factored landing distances to depart too much from the current levels (either increasing or decreasing the landing distances).	Accept - This recommendations intent is to confirm moving ahead with task 3 of the original work plan and not an acceptance of a specific final proposal. However a qualifier for this item is reduced wet runway wheel braking whether it be as a separate calculation or a demonstration that a factor on the final wet runway calculation is adequate to accommodate a certain amount of reduced braking that may be associated with poor runways or heavy rain scenarios.	Accept, to move forward pursuing this task. However, a number of issues have been raised and final acceptance is dependent on the resulting majority position. Concerned that the resulting data basis will be significantly different than item 2 above (codify TALPA), resulting in the need for two sets of wet runway data (and the associated operational factors) for dispatch and enroute calculations.
5. Ground spoiler not armed warning regulation/guidance	Accept - Additionally, we believe that implementation of fully automatic ground spoiler systems (the ones that do not require action from the pilots to arm the spoilers prior to landing) should not only be exempted, but somehow encouraged (although not mandated).	Accept Airbus recommendation	Accept Airbus recommendation
6. **Require of a ROPs/RSAT/Smart Landing type systems for CFR 25**	Accept the idea in principle, but we would recommend waiting for the EUROCAE group discussions to access the practical consequences of mandating this kind of implementation for future designs.	Abstain - Current FAA position in answering NTSB safety recommendation is this is not required because systems are moving ahead however they are not mature enough to direct rulemaking. Conclustions from EUROCAE Group working on standards as well as strong potential of EASA NPA in the near future based on standard in developement by EUROCAE will be considered when complete.	Abstain - Wait for conclusions from EUROCAE Group and future EASA NPA.
7- Research on degraded WET friction ? Included in Item 3 "Identification of …" ?	Abstain	In first quarter of 2017 the FAA will launch an experts panel reviewing direction of future FAA research into wet runway issues.	Abstain, no objection to further research.

	TCCA	Textron	Operators AAL/DAL
Wet Runway Topic 9 Interim Report	TCCA can only accept those parts of the report pertaining to CFR 25. See below.	Accept, **conditioned to** the final results of on going discussions.	Accept
1. Landing Safety Training Aid	Abstain	Accept. Should be harmonized to the greatest extent possible. Should be written to benefit the largest possible audience (including private owner/operators). Should clearly define terminology used (not all OEMs use common labels/terms). Desirable to clearly describe the current operating rules and be maintained for future ops changes.	Accept
2. Codify TALPA ARC Recommendations	TCCA accepts the recommendation to codify those parts of TALPA that affect CFR 25. TCCA representation on this working goup has no authority to accept changes to operational regulations. It is noted that operationl regulations vary from country to country.	Accept, with caveats and depending on future work. Can not support codification of all current content in AC 25-31/32, as some of it was added post TALPA ARC recommendations and without industry discussion. Concerns remain over acceptable air distance methods and potential dry runway reform (cost vs benefit). Existing JAR/CS 25.1591 data should remain acceptable for existing airplanes.	Accept
3. Identification of Poor Performing Wet Runways:	Abstain	Accept. Not penalizing every operation for the sake of known bad runways seems logical. However, understand that there are significant issues with identification/enforcement. Must also recognize that any on-board solutions need time to mature becoming economically viable for small aircraft.	Accept - I would have dissented if there was no remedy for operaters. I will accept this because it includes the conclusion that the runway be considered slippery when wet, where there is an established remedy.
4. Create CFR 25 standard reflecting the physics of stopping an airplane on a wet runway.	Accept. TCCA position is fixed ari distance model per TALPA recommendation and accountability for permanent increments on Vref. i.e if the OEM specified approach speed Is always Vref + 5 then this should be accounted for in landing distance.	Accept, with concerns. Have historically provided advisory data that meets the intent of this proposal. Support accounting of temp, slope, speed @ 50'. Still have concerns with covering degraded runways, depending on implementation, performance level, and potential impact to operations to/from many thousands of smaller airports. Do not support 7s air time for all aircraft.	Accept, that this goes forward. I am not accepting any conclusions as the discussions are not over. I maintain that if we add parameters such as approach speed, temperature, runway slope, and etc., that we need to also add these to the dry runway rule.
5. Ground spoiler not armed warning regulation/guidance	Accept in principle. Details to be discussed.	Accept for new type certifications. Details to be discussed.	Accept
6. **Require of a ROPs/RSAT/Smart Landing type systems for CFR 25**	TCCA agrees that it is appropriate to wait until the EASA proposal is available for comment.	Abstain - Interesting topic for future work, as technology/industry experience mattures. Would not support retroactivity to existing fleet, or creation of near-term requirement to small CFR 25 aircraft.	Accept that we wait and see what the EASA proposal is and potentially comment on it at that time
7- Research on degraded WET friction ? Included in Item 3 "Identification of …" ?	Abstain Althouugh more research and better informationis alwaysa good thing there is thw question of who is going to do it and how it will get funded.	Abstain - agree in principle that additional research would be beneficial, and would strongly advocate involvement from a range of OEMs / airplane types, but can not commit support at this time.	Accept the recommendation for research.

Appendix 6 Topic 10 Runway Excursion Hazard Classification

FAA Aviation Rulemaking Advisory Committee
FTHWG Topic 10
Runway Excursion hazard Classification

Recommendation Report – Rev A
March, 2017

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Executive Summary

The Flight Test Harmonization Working Group has been tasked to develop harmonized guidance on environmental and off-runway conditions for classification of runway excursion hazard levels following system failures during takeoff and landing.
The task consisted of reviewing:

- Existing guidance materials
- Airplane manufacturers best practices, methodology and criteria in terms of controllability, performance, and environmental assumptions,
- Accidents/incidents data related to runway excursions,
- Intensifying factors and their relevance to runway excursion hazard level assessment (runway dimensions, surface conditions, presence of runway safety areas, crosswind, etc….).

As a conclusion of this in-depth review, the FTHWG recommends to amend AC 25-7X to include detailed criteria used for establishing Runway Excursion Hazard Classification following system failure in Chapter 6, Section 1, Paragraph 174 'Equipment, Systems, and Installations- §25.1309'.

Background

The severity of runway excursions depends on many factors, such as airplane kinetic energy and configuration, environmental conditions, and other threats in the airport environment. Service history of transport category airplanes indicates that high speed runway excursions can be catastrophic. However, the service history also indicates that excursions at low speed and low thrust conditions usually result in no injuries or damage to the airplane. Current certification guidance material may not be adequate or detailed enough in terms of controllability, performance criteria, and environmental conditions (e.g. wind, runway conditions, etc…) to assess hazard levels due to runway excursions and are not harmonized amongst authorities. Consequently, airplane manufacturers have not consistently applied hazard classifications nor used the same controllability and performance criteria and environmental considerations in the development of their safety analysis, potentially leading to level playing field issues amongst airplane manufacturers.

Details of the task have been defined at the working level in the work plan (Topic 10, Runway Excursion Hazard Classification) resulting from Phase 1 final report, included as Attachment 10 A.

A. What is the underlying safety issue addressed by the JAR/FAR?

Failure in certain systems including flight controls, nose or main landing gear, brakes, and propulsion, could cause a runway excursion (either off the side or the end of the runway). The stated task is to develop harmonized guidance establishing the level of severity for this hazard and therefore ensuring a consistent level of safety across the manufacturers when conducting their safety analysis (FHA/SSA).

B. What is the task?

The task consisted of reviewing:

- Existing guidance materials
- Airplane manufacturers best practices, methodology and criteria in terms of controllability, performance, and environmental assumptions,
- Accidents/incidents data related to runway excursions,
- Intensifying factors and their relevance to runway excursion hazard level assessment (runway dimensions, surface conditions, presence of runway safety areas, crosswind, etc….)

Finally, in light of this in-depth review and commensurate with the observed safety threat, develop harmonized guidance on environmental and off-runway conditions for classification of runway excursion hazard levels following system failures during takeoff and landing.

C. Why is this task needed?

Currently the authorities do not have common/harmonized policy/guidance for classifying systems failures that could cause runway excursions. FAA PS, EASA CRI, and TCCA CM have different perspectives and guidance. The FAA tasking seeks industry inputs to assist the authorities develop harmonized policy.
This resulted in a wide range of situations for compliance (e.g. from direct compliance or increased certification burden for some, up to performance penalties or design changes for others), depending on each OEM's in-house methodology/criteria for controllability/performance/environmental conditions used to compute the aircraft speed when departing the runway.

The elaboration of harmonized guidance on environmental and off-runway conditions (controllability and performance) will complement the off-runway hazard classification criteria and will ensure a level playing field among manufacturers in the future.

D. Who has worked the task?

This task has been worked by the Topic 10 sub-team of specialists on Stability and Control, Performance and Safety from the following organisations:

- Authorities : FAA, EASA, TCCA, JCAB*, CAAI*
- Manufacturers : Airbus, Boeing, Bombardier, Dassault, Embraer, Gulfstream, Textron
- Airlines : American Airlines, Delta Airlines*
- Labour Union: ALPA

(*) non-voting members

E. Any relation with other topics?

Although the proposed majority position is related to dry runway only, dissenting opinion requesting consideration of wet runways would require coordination with Topic 9 –Wet Runway Stopping Performance.

In addition, it is proposed that the dissenting opinions related to the methodology to be used for crosswind accountability in case of lateral excursion following system failure be further discussed/addressed in next Phase 3-Topic 17 Failure assessment methodology and Topic 16 Handling Qualities Rating Method (HQRM). Also, the dissenting opinion related to the scope of usage of the speed-based methodology needs to be further discussed in next Phase 3-Topic 17 Failure assessment methodology.

Historical Information

The JAA Flight Study Group started discussing runway excursion hazard classification back in 2000, in support of a Working Group dealing with “Uncontrollable High Engine Thrust”.
At this occasion, some OEMs presented their methodology, based on fleet in-service survey resulting in the JAA Flight Working Paper 749 (FWP 749) which proposed failure classification according to aircraft excursion speed (for longitudinal and lateral) . The EASA CRI currently used was developed from JAA FWP 749 established in 2000 and was applied by the majority of the manufacturers. The FAA did not agree with the FWP and issued the FAA policy PS-ANM-25-11 in 2013, which used different criteria for hazard classification (refer to paragraph D below).

A. What are the current regulatory and guidance material CS 25 and FAR 25?

Rules : 25.109, 25.125, 25.1309(b), 25.671 (c), 25.672 (c), 25. 901 (c)
Guidance Material : FAA AC 25.1309-1A (1988), FAA AC 25.1309 –Arsenal (2002), FAA policy PS-ANM-25-11 (2013), EASA AMC 25.1309, AC 25-7X

B. What, if any, are the differences in the existing regulatory and guidance material CS 25 and FAR 25?

FAA policy PS-ANM-25-11 dated 11/13/13, was different from EASA/TCCA CRI/CM

C. What are the existing CRIs/IPs (SC and MoC)?

EASA CRI/MoC, FAA IP/MoC and policy PS-ANM-25-11 dated 11/13/13, TCCA CM/MoC (on all recent aircraft)

D. What, if any, are the differences in the Special Conditions (CRIs/IPs) (SC and MoC) and what do these differences result in?

EASA CRI/MoC and TCCA CM/MoC are different, but equivalent means of compliance have been accepted:

Depending on the speed at which the aircraft depart from the runway, the classification is as follows:
0-30 kt/MAJOR, >30-60 kt/HAZARDOUS, >60 kt/ CATASTROPHIC

FAA IP/MoC in line with FAA policy PS-ANM-25-11 dated 11/13/13:

0-30 kt/ HAZARDOUS, >30 kt /CATASTROPHIC (Default classifications if not further substantiated)
The FAA policy is more stringent because it does not include the MAJ category (below 30 kt) as compared to EASA CRI and TCCA CM compliance and includes CAT category starting at 30 kt instead of 60 kt compared to EASA CRI and TCCA CM, potentially resulting in either performance penalties or design related modifications, or significant certification burden (since, as stated in the FAA policy, all non-compliant failure case scenarios need to be presented to the FAA during the certification exercise).

Runway excursion speed	**0 kt**	**30 kt**	**60 kt**
EASA CRI-longitudinal	**MAJ**	**HAZ**	**CAT**
EASA CRI-lateral	**MAJ**	**HAZ to CAT** (pending capability to come back on the runway)	

Runway excursion speed	**0 kt**	**High Taxi Speed**
PS-ANM-25-11	**HAZ** (Default classification if not further substantiated)	**CAT (**Default classification if not further substantiated)

Note * :“The high end of taxi speeds is approximately 30 kt” according to FAA policy PS-ANM-25-11

Consensus/Findings

The FTHWG recommendations are based on the findings following in-depth review of the 3 different items below and are representative of an OEMs harmonized proposal:

1) Existing guidance materials: As expressed in the ‘Historical information’ paragraphs, different guidance has been used by the airplane manufacturers, and lack of controllability/performance/environmental condition criteria led to different impact/compliance and level playing field issues between manufacturers.

2) Airplane manufacturers best practices, methodology and criteria, in terms of controllability, performance, and environmental assumptions were provided from various manufacturer’s in-house methodologies and used by the FTHWG to establish a list of parameters and intensifying factors to be considered (temperature, winds, runway width, runway length, runway conditions….)

3) Accidents/incidents data base related to runway excursions : In light of OEMs in-service database sharing from 1980 to 2014 (analysis was initiated in 2015), Commercial Aviation Safety Team (CAST) Working group consultation, including their final report on ‘runway excursion’ dated 12 February 2015 (which does not identify the system failure as a significant contributor to runway excursion), and FAA data base information, the FTHWG has acknowledged that the percentage of runway excursion caused by system failures remains low compared to the total runway excursion occurrences: estimated from 1% to 5%. This percentage includes inflight annunciated failures, which is out of scope for the FHA criteria discussed in this document, since annunciated failures will require a diversion to a suitable runway of sufficient length to mitigate stopping performance), therefore, the percentage of un-annunciated failures leading to runway excursion is even smaller. Failure to follow the mitigation procedure is not part of the FHA process.

- The FTHWG recommendation below represents the majority position agreed by all the manufacturers (Airbus, Boeing, Bombardier, Dassault, Embraer, Gulfstream, Textron). It represents, in their opinion, an acceptable and reasonable methodology for determining the aircraft speed at which a runway excursion may occur and the associated hazard classification. The expected level of safety, using this methodology, has been found commensurate with the in–service record (refer to Table below stabling acceptable criteria for runway excursion speed computation for hazard assessment and their associated rationale).

Parameter	Criteria	Rationale
Longitudinal runway excursion speed	0-30 kt MAJ >30-60 kt HAZ > 60 kt CAT	In line with EASA CRI, operational data and ICAO Annex 14 end runway safety areas existence
Lateral runway excursion speed	0-30 kt MAJ (if all MLG exit runway) 30-60 kt HAZ (if all MLG exit runway) > 60 kt CAT (if all MLG exit runway) *Next lower classification to be used if any MLG remains on the runway	In line with the in-service data history FTHWG analysis of ICAO Annex 14 recommendations concludes that even 2 codes airplanes letters above the ICAO Standard(for codes F airplane on a D runway) there is still a positive clearance to any non-frangible obstacle that might be hit, and the surfaces should support the airplane (i.e. shoulders).

Take off Field Length	AFM Take Off Field Length limited weight for the design case (Outside Air Temperature & Field elevation & weight/cg specified below) Without credit of stop way or clearway or obstacle clearance	This is the shortest Take off field length for the weight under consideration (always Accelerate-Stop-Distance limited Field length)
Speed for Failure consideration (during Take off)	Longitudinal : At decision speed V1. Lower than V1 may be accepted if supported by rationale(e.g. control surface failure message before V1) Lateral : Between brake release and V1 for Rejected Take off and between V1 and V_{LOF} for a Continued Take off.	Longitudinal : V1 is conservative because it results in longer distance. Credit for lower speed if failure is annunciated or detected by the pilot below V1 Lateral : All failures contributing to a significant lateral excursion below V1 are expected to result in a Rejected Take off.
Landing Field Length (Longitudinal analyses)	At the choice of the applicant : 1) Consistent with a reasonable take off distance for the type of operation, OR 2) Runway length based on 90% statistics of historical operations for airplane of their type, size and gross weight Combined with 90% statistics of field elevation and Outside Air Temperature (parameters defined below) (refer to §g.) Should not be greater than the 1.67 field length at MLW	Those are 2 ways of defining a reasonably short runway for a design case. 1) This option recognizes that the vast majority of short runways utilized by transport category airplanes reside on an airfield with a single runway. This runway must be of a length to allow takeoff with reasonable mission capability to be anticipated in service and used for hazard analysis. A reasonable mission capability to use would be that used for design structural fatigue analysis. 2) Reasonable short landing field length based on Operational data

Runway Width	Use ICAO airport design level letter code or narrower. Operational guidance or other mitigations should be provided for operations (unlimited or frequent) on runway narrower than that used for the Type Certification safety analysis, if the hazard failure classification would be increased.	Refer to note (§i.) on ICAO annex 14
Weight and CG	Longitudinal and Lateral : - For Take off: critical weight & CG between minimum TOW (1 hour mission and 25% passenger) to MTOW - For Landing: critical weight & CG between minimum Landing Weight (25% passenger + reserve fuel) up to a Landing Weight consistent with the criteria for the design runway field length (refer to §g.)	Rejected Take off: cover full range of operations Landing: Representative of operations (ref to §g.)
Runway Surface Condition (Longitudinal analyses)	Dry	- Uncertainties due to future wet rule change for landing (ref FTHWG- topic 9) - Dry has been accepted in the past. Fleet history has shown no issues with non annunciated failures on wet runway -Wheel braking failure did not result in more critical hazard assessment on wet compared to dry -No evidence in history that system hazard mis-classification has led to excursion
Runway Surface Condition (Lateral analyses)	Dry	-Nose Wheel Steering hard-over or asymmetric braking failures more critical on dry than wet. -Model for lateral gear forces on a wet runway difficult to validate. -Dry has been accepted in the past. Fleet history has shown no issues with non annunciated failures on wet runway -No evidence in history that system hazard mis-classification has led to excursion

Crosswind (Lateral analyses)	At the choice of the applicant Method 1) OR 2): <u>Method 1)</u> 10kt (wind prob 1): FC from 10-9 to 10-7 20kt(wind prob 10-2):FC from 10-7 to10-6 25kt(wind prob 10-3): FC from 10-6 and above (Failure Case proba may include exposure time) OR <u>Method 2)</u> 10kts basic scenario (proba 1) 25kts aggravating factor (proba 10-3) * but need not to be more stringent than AC 25-7X Appendix 5 Fig 8 (HQRM) **Failure Case probability including exposure time	- Two representative methods EU/US at the option of the applicant -Larger Crosswind beyond 25 kt need not to be considered because: Failure conditions relevant for combination with high crosswind above 25 kt are usually of such a nature (e.g. loss of rudder control) that they are, by design, less probable than 10-4. With AC 25-7X Appendix 5 guidance that crosswinds above 25 kt can be considered 10^{-5}, consideration of crosswinds above 25 kt for failure conditions is unnecessary. In addition,§ 25.237 does not require to apply more than 25kt
Field Elevation	Up to an altitude sufficient to cover at least 90% of the intended operation at Type Certificate. If data on the intended operation is missing use a default value of 5000 ft.	In combination with other parameters, addresses the vast majority of operations Refer to §g. example methodology Refer to §h. specific risk versus average
Outside Air Temperature	Up to a temperature sufficient to cover at least 90% of the intended operation at Type Certificate. If data on the intended operation is missing use a default value of ISA deg C	In combination with other parameters, addresses the vast majority of operations Refer to §g. example methodology Refer to §h. specific risk versus average

TABLE : Runway Excursion Hazard Criteria

- <u>Rationale for using MAJOR below 30 kt for hazard assessment:</u>

  As called for in the work plan, this working group employed industry subject matter experts to review accident/incident available databases related to runway excursions. Despite the concern that excursions with compounded intensifying factors could have serious consequences below 30 kt, the data from the past 30 years over numerous airplane models, with hundreds of millions of operations and every conceivable combination of intensifying factors, does not support a HAZARDOUS classification below 30 kt. Rather, the use of MAJOR was consistent with the data for excursions below 30 kt. Furthermore, the industry study suggested that overruns associated with system failures occurred in only 1%-5% of runway excursions.
  In addition, no in-service runway excursions have been identified where a system failure contributed to the excursion and an incorrect hazard classification was identified as a contributing factor.

Note : Major, Hazardous and Catastrophic classification, as defined in EASA AMC 25.1309 -7a) and FAA AC 25.1309-1A (1988) or FAA AC 25.1309- Arsenal (2002)

- <u>Fleet in service record :</u>

  Fleet safety data show that the consequence of a runway excursion increases with speed and that catastrophic runway excursions are most likely to happen when the speed of the excursion is greater than 60 kt. The following tables summarize the consequences of the known runway excursions of most of the modern commercial and business jet fleet certified starting from the 1980s through 2014 (study was initiated in 2015). This study includes the fleets of Airbus, Boeing, Bombardier, Dassault, Embraer, Gulfstream, and Textron. Note that for some events excursion speed was not available, but could be reasonably estimated from excursion distance and report information.

Commercial Airplane Fleet Runway - Excursion Events

Number of Runway Excursion Events Consequence	Excursion Speed < 30 kt	Excursion Speed 30 kt to 60 kt	Excursion Speed > 60 kt
None to Major Damage	59	67	29
Major to Substantial Damage	0	15	18
Substantial Damage and Multiple Fatalities	0	1	5

Note: The commercial airplane data includes two events with excursions below 60 knots that involved one or more fatalities and damage. These events were not related to system failures.

Event	Number of Fatalities	Damage Level	Excursion Speed (kt)	Rationale to support proposed methodology
737-800 Overrun at Midway (12/08/05)	1 (on ground)	Major	53	The runway (31C) at the time of the accident had no engineered material arresting system (EMAS) and was not ICAO Annex 14 compliant. Subsequently, an EMAS was added to runway 31C at Midway. (Based on AC 25.1309-Arsenal damage and effect criteria, this result would be classified Hazardous.)
A320 Overrun at Tegucigalpa (05/30/08)	3 (onboard) 2 (on ground)	Hull loss	54	The aircraft dropped down a 20 meter embankment located at the end of the runway (30ft distance). The runway at the time of the accident had no EMAS, no RESA. This aerodrome was not ICAO Annex 14 compliant. In May 2009, a runway extension was completed.

Business Jet Fleet - Runway Excursion Events

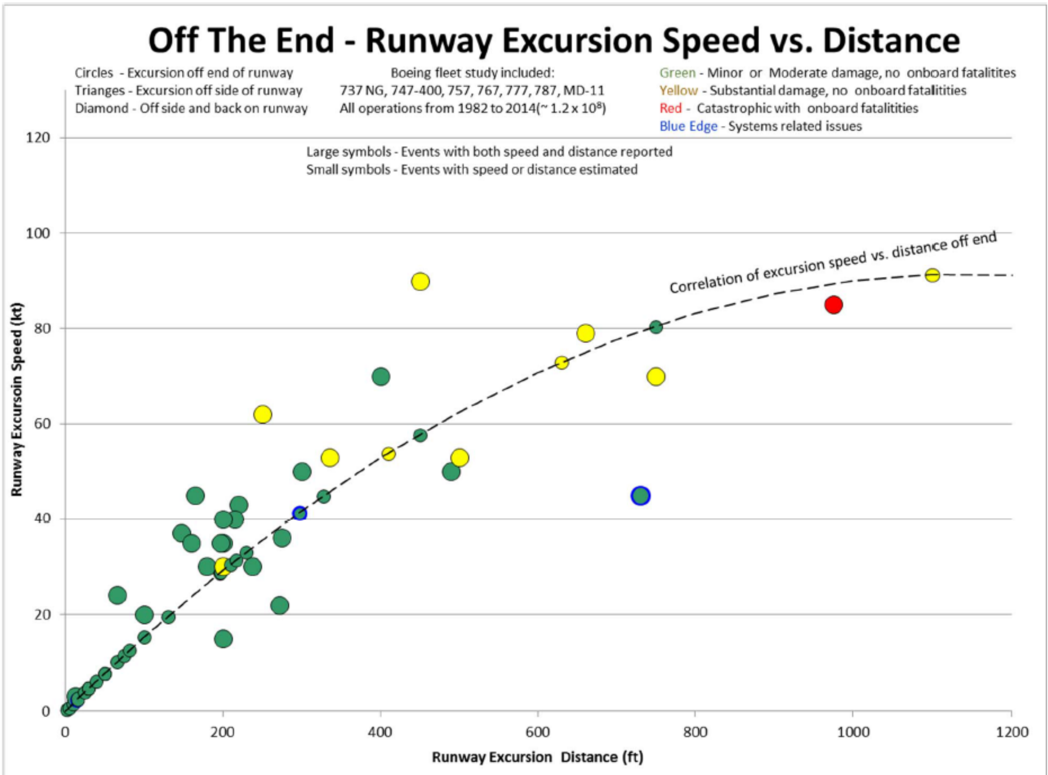
Number of Runway Excursion Events Consequence	Excursion Speed < 30 kt	Excursion Speed 30 kt to 60 kt	Excursion Speed > 60 kt
None to Major Damage	54*	42*	8*
Major to Substantial Damage	0	16	2
Substantial Damage and Multiple Fatalities	0	0	9

*Some speeds and damage extent estimated from report information

Note: There are an additional number of events in the business jet fleet (not in above table) in which the excursion speeds and damage levels are unknown including 248 non-fatal events and 11 fatal events. None of these 11 fatal excursion events were related to system failures and the majority of them were caused by the pilots' attempt to perform a go-around after touchdown.

The following figure from a Boeing study correlates runway excursion distance to excursion speed and severity of consequence. It shows that the Boeing fleet data supports the FTHWG proposal.

Boeing Runway Excursion Study For FTHWG



The overall conclusion from this commercial and business jet fleet safety data is that it supports the use of MAJOR as a hazard classification for excursions below 30 kt and HAZARDOUS for excursions from 30 kt to 60 kt. The study includes over 200 million flight cycles and only identified one catastrophic accident from a runway excursion below 60 kt on a non ICAO compliant airport. It should also be noted that this sample of fleet data show no correlation between un-annunciated system failures and hazardous or catastrophic runway excursions. This is evidence that the historic hazard assessment criteria used by the industry for the past 30 years has proven to be robust.

The FAA referenced the Commercial Aviation Safety Team (CAST) report titled, “The Runway Excursion Joint Safety Analysis Team Final Report, Feb 12, 2015”, in which CAST approved development of 16 Safety Enhancement (SE) concepts. These SE’s included Aircraft Design, in the context of new systems to improve situational awareness, and Landing Distance Assessment, with the concept that “Flight crews should assess landing performance based on conditions actually existing at time of arrival (rather than the conditions presumed at dispatch).” System failures are only mentioned in the context of air carriers publishing and training proper techniques to manage directional control issues. The CAST report does not identify system failures or landing dispatch calculations as areas of concern, or provide a statistical breakdown of their contribution to the overall risk. The

CAST report does not provide a quantitative correlation of the excursion speed to the severity of the consequence, but does provide example cases. It is notable that the CAST report examples (which actually listed runway excursion speeds) support the industry study in that events with serious consequences had excursions well over 30 kt, and provided no excursion examples with serious consequences below 30 kt.

- Rationale statement for coverage of specific risk versus average risk

The excursion speed criteria proposed by the FTHWG was developed based on industry experience and hundreds of millions of cycles of service history representing multiple aircraft manufacturers. This historic data naturally takes into account all of the possible variables (intensifying factors) as well as the frequency of operations into specific airports, with specific airlines, with various quality crews, etc. Per AC/AMJ 25.1309, classification of Failure Conditions should always be accomplished with consideration of all relevant factors, including intensifying and alleviating factors.

The FTHWG considered relevant intensifying and alleviating factors and defined a set of factors by which to assess or simulate failures to define relevant combinations of failures for a probability assessment. These factors do not just consider the average operational and environmental conditions, but define a combination of conditions that envelope the vast majority of departures and landings. Therefore the FTHWG proposed factors and approach is much more conservative than the literal interpretation of 'average risk'. This approach should not be confused with specific risk, which is not considered appropriate for runway excursions as explained below.

Specific risk is 'the risk on a given flight due to a particular condition'. As one could imagine, there is the potential that a particular condition or combination of conditions could be such that a runway departure (even at low speed) is catastrophic (e.g. an off-runway obstacle). Likewise, a particular condition or combination of factors could be such that the combination of failures and operational and environmental factors resulting in the failure condition were inadvertently excluded. There are no regulatory criteria for specific risk, that is, there is no regulatory basis that says for a specific combination of airport, environmental conditions, and operational considerations that the aircraft must meet. Rather, the aircraft must be able to perform (without failures) to the specifications in the FAR/CS; this, and the applicable criteria for airport design, have proven to be robust in all but the most extreme specific risk conditions as evident in the historical data. It should be noted that when an ARAC ASAWG committee addressed specific risk, their recommendations refined how average risk was performed with respect to operational and environmental conditions, but did not set criteria for operational and environmental specific risk conditions.

The factors associated with runway excursion criticality: field length, runway width, weight and CG, runway surface condition, crosswind, elevation, temperature, reaction time, off-runway obstacles, etc., are not all independent, and it is impossible to conclude what the likelihood of being in a particular condition (a combination of these variables) will be. Engineering judgment, and fleet history was used in selecting a set of factors that when combined would envelope the extremes of any one condition where it was practical to do so.

➔ There are 3 dissenting opinions coming from FAA, EASA and ALPA as follows :

- <u>FAA dissenting opinion</u> :

- 90% criteria is not numerically substantiated and is not apparently consistent with 1309 which considers the entire operating envelope in which the airplane is approved to operate.

  <u>FTHWG answer</u>: FTHWG majority position is that the proposed approach is far more conservative than 'average risk'. It has been developed based on hundreds of millions of cycles of service history, relevant intensifying factors, and defines a combination of conditions that envelope the vast majority of departures and landings (refer to paragraph above 'Rationale statement for coverage of specific risk versus average risk'). In addition, landing field length method 2) usage example has been included in material guidance ref §g.
  The combination of different factors, each intensified to the level of 90% of all operations, results in a method that represents the entire operating envelope.

- Dry runway ONLY is not explained or substantiated. The absence of wet runway accountability is not adequately explained and would appear to be the critical case in some circumstances. Furthermore it is not expressly stated in the table included in the report but the manufacturers intend to take credit for the part 121/135 1.67 factor on a dry runway. For business jets this brings up the issue of what if any factor should be considered acceptable, if a factor is deemed acceptable, for a dry runway it should be 1.25 associated with 135 Eligible on Demand and 91K Fractional Ownership as well as in the EASA NPA 2016-011 for Reduced Landing Distance operation. However taking credit for this large dry runway factor is in conflict with a current FAA policy in work addressing the use of landing factors which may not be available at the time-of-arrival i.e. the dispatch factors. This concern can be withdrawn if the consideration of runway condition includes both dry and wet and if the landing consideration includes wet time-of-arrival calculation methods with a 1.15 factor. Attachment 10B, 174 (c) (2) (g) (4) includes the procedure for choosing the field length to be considered during the assessment. At a minimum choosing the 4th bullet of that paragraph, TALPA style wet runway calculation as a basis for the analysis results in a defendable position throughout the operational envelope.

  <u>FTHWG answer</u>: Consideration of wet runway conditions either for longitudinal or lateral excursion would go beyond some OEMs current practice and would add significant associated costs without commensurate increase in safety. As explained in "Consensus/Findings" paragraph, only 1 to 5% of runway excursions have been attributed to system failures.

- Rationale for not considering crosswinds above 25 kt should be explained or substantiated.

  FTHWG answer: refer to crosswind criteria rationale in the table above: Failure conditions relevant for combination with high crosswind above 25kt are usually of such a nature (e.g. loss of rudder control) that they are, by design, less probable than 10-4. With AC 25-7X Appendix 5 guidance that crosswinds above 25 kt can be considered 10^{-5}, consideration of crosswinds above 25 kt for failure conditions is unnecessary. In addition, § 25.237 does not require a Part 25 airplane to be capable of take off or landing in a crosswind more than 25kt for normal operation.

- Crosswind: method1 is not in line with 25. 1309 because this method makes assumptions about hazards that are more appropriately a fallout of system safety assessment process.

  FTHWG Answer: As mentioned in this report section 'Background' – paragraph E 'Any relation with other topics' this subject is proposed to be further discussed/addressed in next Phase3- Topic 17 Failure assessment methodology and Topic 16 Handling Qualities Rating Method (HQRM).

- Update 25.1309 AC (arsenal or not) instead of updating AC 25-7X because this topic more closely aligns with the topics in that AC.

  FTHWG Answer: Consideration of updating AC 25-1309 was discussed but not elected by the group because it did not fall within FTHWG scope. The FTHWG majority position found that updating AC 25-7X would be acceptable since hazard assessment process involves Handling Qualities and Performance criteria and found existing similar precedent (e.g. failure case assessments with HQRM are also addressed in AC 25-7X Appendix 5).

- FAA believes that the following disclaimer is an appropriate additional clarification: The speed-based methodology is only applicable when engine thrust is reduced to a point where the airplane is not accelerating as it departs the runway. Failures where that is not the case should be examined on a case-by-case basis to determine if the speed-based methodology is appropriate.

  FTHWG answer: The group did not have enough time to discuss this disclaimer in details and could not reach a consensus. This disclaimer would need further discussions in next Phase3- Topic 17 Failure assessment methodology.

  - EASA dissenting opinion regarding Crosswind Method 1 and Method 2:

- Method 1: The crosswind value used for the failure condition classification should not be determined based on the occurrence probability of the system failure. The method, as presented in this table, relieves the applicant from investigating the effects on the aeroplane controllability in the operating envelope of the aeroplane (e.g. stopping the assessment at a 10kts crosswind based on the rationale that the system failure has an occurrence probability of 1.10^{-8}).

- Method 2: The crosswind value used for the failure condition classification should be determined by investigating the effects on the aircraft controllability. The method, as presented in this table, may lead the applicant to directly select a 25kts crosswind without any further analysis, conclude that the failure condition is catastrophic, and take credit of the 10^{-3} in the quantitative analysis, whereas the failure condition was already catastrophic with a 15kts crosswind.
- To ensure that failure conditions are correctly classified, there should be an overarching method to allow determination of the crosswind value at which point the system failure would become catastrophic, hazardous, or major. The failure condition probability (which includes the system failure in combination with the external event(s) such as crosswind) can then be determined

FTHWG Answer: Method 2 could not lead the applicant to directly select 25kts without further analysis. According to the table, at least 2 analysis should be done: one with 10kts xwind (with probability 1) and a second one with 25kts xwind (prob. 10-3).
The proposal is to use method 1 OR method 2, but inside method 2 we have 10kts AND 25kts.
As mentioned in this report section 'Background' – paragraph E 'Any relation with other topics' this subject is proposed to be further discussed/addressed in next Phase3-Topic17 Failure assessment methodology and Topic16 Handling Qualities Rating Method (HQRM)

- ALPA dissenting opinion :

ALPA does not agree/support the Lateral runway excursion speed criteria: 0-30kt MAJ (if all MLG exit runway), 30-60kt HAZ (if all MLG exit runway), >60kt CAT (if all MLG exit runway) with the use of next lower classification if any Main Landing Gear (MLG) remains on the runway.
ALPA supports the criteria: above 30 kt CAT if all the MLG exit runway

FTHWG answer: The proposed lateral criteria have been found in accordance with the incident/accident data base review and the use of HAZ classification between 30 kt and 60 kt. FTHWG analysis of ICAO Annex 14 recommendations concludes that even 2 codes airplanes letters above the ICAO Standard (for codes F airplane on D runway) there is a positive clearance to any non-frangible obstacle that might be hit, and the surfaces should support the airplane (i.e. shoulders).
Historical data have shown no lateral Catastrophic events below 60 kt. In addition, ICAO standards are a reasonable target for aircraft system design, as that is increasingly the expected state of runway design.

➔ There is one comment from Textron as follows :

Textron shares the goal of reducing the number of runway excursions with the community of OEMs and authorities. Service history is quite clear that the overwhelming cause of runway excursions is poor decision making both prior to landing, and at least in the case of business jets, after landing as indicated by attempts to take off again after mismanaged approaches. Textron believes that continued efforts to increase awareness of and adherence to disciplined flying habits with respect to weather, runway conditions and flying stabilized approaches is a far more effective approach to minimizing the number runway excursions than policy changes that effectively increase reliability standards for airplane systems.

In the interest of a harmonized outcome, Textron Aviation is not dissenting on the FTHWG Task 10 recommendations but continues to believe that both FAA Policy PS-ANM-25-11 and recent EASA CRIs constitute an unwarranted change in criteria that drive unneeded weight and complexity into otherwise simple designs that have proven effective and have not been associated with runway excursions. Textron Aviation's recent experience with implementing PS-ANM-25-11 is that it does drive increased complexity into proven flight control system design architectures. And because of the lack of Part 23 guidance, we are very concerned the Part 25 material will be applied to Part 23 aircraft.

Despite the unpredictable nature of the environment off the runway, Textron believes that speed-based criteria sets for classifying the hazards of runway excursions, as have been used for many years, are effective in driving the development of safe systems. Textron encourages the authorities to revisit the current direction and adopt standards more in line with what have been proven to generate safe results.

Recommendation

FAA should consider using the 30 kt-60 kt category and the use of MAJOR below 30 kt in line with EASA CRI and TCCA CM compliance. FAA policy PS-ANM-25-11 (2013) should be cancelled and AC 25-7X guidance should be updated for 25.1309, as defined below.

A. Rulemaking

1. What is the proposed action?

No action to modify the rule, only guidance material is recommended to be updated. See paragraph of the section B (Advisory Material) below.

2. How does this proposed standard address the underlying safety issue?

Not applicable – no rule change

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

Not applicable – no rule change

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

Not applicable – no rule change

5. **Who would be affected by the proposed change?**

Not applicable – no rule change

6. **Does the proposed standard affect other HWG's and what is the result of any consultation with other HWGs?**

Not applicable – no rule change

B. Advisory Material

1. **Is existing FAA advisory material adequate? If not, what advisory material should be adopted?**

The FTHWG believes that the current FAA policy PS-ANM-25-11 (2013) should be cancelled and the advisory material AC 25 -7C, Paragraph 174 'Equipment, Systems, and Installations - § 25. 1309' should be amended to establish a harmonized acceptable method of assessing the hazard classifications of airplane system failure conditions leading to runway excursions during takeoff and landing for compliance with §25.1309 (b). Proposed material is provided in Attachment 10B.

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

EASA and TCCA guidance material should be updated and CRI/CM eliminated.

Economics

A. What is the cost impact of complying with the proposed standard (it may be necessary to get FAA Economist support to answer this one)?

Given the low rate of runway excursions attributed to system failures (1-5%) and none identified as related to incorrect FHA/SSA classifications, the proposed methodology isn't expected to significantly affect aircraft safety or associated accident rates/costs.
Since the recommended hazard classification criteria are similar to the current OEM practice, no significant increase in cost or certification burden is anticipated.

B. Does the HWG want to review the draft NPRM prior to publication in the Federal Register?

Yes.

ICAO Standards
How does the proposed standard compare to the current ICAO standard?

There are no specific ICAO standards relating to runway excursion hazard classification following system failures during takeoff and landing. Nevertheless, ICAO Annex 14 (and equivalent FAA AC 150/5300-13A) gives Standards and Recommended Practices for aerodrome design, determined in relation with the characteristics of the airplane. These Standards and Recommended Practices include consideration of an aircraft's lateral geometry (wing span and gear span) which are related to minimum width and shoulders width recommended for designing an airfield expected to host this aircraft.

The proposed material guidance is consistent with ICAO Annex 14 (FAA AC 150-5300-13A Runway environment) and has been found to have an equivalent level of conservatism.

- <u>Lateral runway excursion</u>: FTHWG analysis of the ICAO Annex 14 standards conclude that for lateral runway excursion, for one main landing gear still on the runway, there is positive clearance to any non-frangible obstacle that might be hit for all aircraft categories and the surfaces should support the airplane (e.g. runway shoulders). Therefore this is consistent with using a lower hazard classification if any Main Landing Gear remains on the runway.

- <u>Longitudinal runway excursion</u>: there is no credit taken for a clearway or stop way from ICAO annex 14 runway end safety areas in the reference field length (without failure) when calculating the excursion speed. The ICAO Standards and Recommended Practices mitigate the effect of excursion speed at the end of the reference field length and therefore minimize the consequence of the longitudinal excursions.

Attachment 10A Phase 1 Final Report-Workplan

Work Plan – Runway Excursion Hazard Classification

1. What is the task?
Develop a harmonized guidance material on environmental and off-runway conditions for classification of runway excursion hazard levels following system failures during takeoff and landing: - Review the available existing guidance material, and - Review OEM's best practices, methodology and criteria (handling qualities & performance, environmental assumptions) used on past certifications for runway excursion hazard classification assessment. - Review accidents/incidents database available related to runway excursions - Review General configurations, features, and characteristics of airport runways and relevance to hazard level assessment during excursion (runway dimensions, surface conditions, presence of runway safety areas, crosswind, etc.)
2. Who will work the task?
The Flight Test Harmonization Working Group (FTHWG) will have primary responsibility for this task. The group should be augmented as necessary with subject matter experts in the areas of safety specialists and/or airport aerodrome design
3. Why is this task needed? (Background information)
Service history of transport category airplanes indicates that runway excursions can be catastrophic. However, the service history also indicates that excursions at low speed and low thrust conditions usually result in no injuries or damage to the airplane. Current certification guidance material may not be adequate or not detailed enough (e.g. in terms of environmental conditions e.g. wind/runway conditions, etc.) to assess hazard levels due to runway excursions and they are not harmonized amongst authorities. Consequently, airplane manufacturers have not consistently applied appropriate hazard classifications in the development of their safety assessment for runway excursions.
4. References (existing regulatory and guidance material, including special conditions, CRIs, etc.)
AC 25.1309-1A, EASA 25.1309-1A, AC 25-7X, AC 150/5300-13 Airport Design, FAA ANM-25-11 dated 11/13/13 and its associated position of public comments, A350 IP S-1, Embraer IP S-5, Bombardier S-12, EASA CRIs on biz jet.
5. Working method

It is envisioned that 4-5 face-to-face meeting days will be needed to facilitate the discussion needed to complete these tasks. Telecons and electronic correspondence will be used to the maximum extent possible.
6. Preliminary schedule (How long?)
Provide recommendations to ARAC Transport Airplanes and Engines Subcommittee within 18 months of the initiation of work on these tasks.
7. Regulations/guidance affected
25.109, 25.125, AC 25.1309-1A, EASA AMC 25.1309, AC 25-7X, 901 c) Uncontrollable High Engine Thrust
8. Additional information
Background: The JAA Flight Study Group started discussing runway excursion hazard classification in support to the STPCM group for “Uncontrollable High Engine Thrust” subject in the years 2000. At this occasion, OEMs like Airbus presented their methodologies. Airbus methodology is based on fleet in-service survey and runway excursion aircraft speed criterion (one parameter to support the safety assessment but not the only one) refer to FWP 699. Later, the application to the A380 was presented to the JAA Flight Study Group (ref to FWP 749)

Attachment 10B Recommended Guidance Material

Update AC 25-7X, Paragraph 174 to include an acceptable method for runway Excursion Hazard classification assessment (markup are identified in blue characters):

174. Equipment, Systems, and Installations - § 25.1309.

a. Explanation. The following procedures outline and paraphrase the appropriate provisions of § 25.1309. Further definition and explanation, if required, may be found in part 25 and in AC 25.1309-1A, "System Design and Analysis," dated June 21, 1988.

Specific guidance is also provided to establish an acceptable method of assessing the hazard classifications of airplane system failure conditions leading to runway excursions during takeoff or landing for compliance with §25.1309(b). These same criteria can also be used to show that the airplane is capable of continued safe flight and landing for failure conditions for compliance with §§25.671(c), 25.672(c) and 25.901(c). The severity of runway excursions depends on many factors, such as airplane kinetic energy and configuration, and environmental conditions. Other threats, like airport environment, are treated separately in aerodrome designs in ICAO Annex 14.

b. Procedures - General.

(1) Evaluate functioning of required installed equipment to verify that performance is as intended under any foreseeable operating and environmental conditions.

(2) Evaluate failure conditions, as appropriate, to determine their impact on the capability of the airplane or the ability of the crew to operate it.

(3) Review, as appropriate, any design analyses, proposals, studies, or tests that correlate probabilities of failure condition occurrence with the effects of those failure conditions, to determine that they are properly categorized for the appropriate criticality level.

(4) Verify that adequate warnings are provided of unsafe conditions, and that these warnings enable the flight crew to take appropriate corrective action with a minimum of error.

(5) In accordance with § 25.1310, for probable operating combinations of required electrical installations, verify that the following power loads are provided for probable durations:

(a) Loads connected to the system with the system functioning normally;

(b) Essential loads after failure of any one prime mover, power, converter, or energy storage device;

(c) Essential loads after failure of one engine on a two-engine airplane;

(d) Essential loads after failure of two engines on airplanes with three or more engines;

(e) Essential loads for which an alternate source of power is required, after any failure or malfunction in any one power supply system, distribution system, or other utilization system.

(6) For probable operating combinations of required electrical installations that must be provided with an alternate source of power in accordance with § 25.1331(a), verify that power is provided for probable durations after failure of any one power system.

c. Procedures - Runway Excursion Hazard Assessment.

(1) Background:

a. The service history of transport category airplanes indicates that high speed runway excursions can be catastrophic. However, that service history also indicates that excursions at low speed and low thrust conditions usually result in no injuries or damage to the airplane. A catastrophic event (in terms of multiple fatalities, usually with the loss of the airplane) is less probable at low speed because of lower airplane kinetic energy, a higher survivability margin for the airplane, and a higher controllability margin to avert the excursion or to lessen its severity.

b. Failure in certain systems, including flight controls, nose or main landing gear, brakes, and propulsion, could cause a runway excursion (either off the side or the end of the runway) and the effects should be included in the functional hazard assessment for these systems.

c. In assessing the criticality of a failure condition, the safety analyst typically considers intensifying factors in accordance with the guidance in AC 25.1309-1A 'System Design and Analysis' dated June 21, 1988 or AC 25.1309-Arsenal, System Design and Analysis, dated June 10, 2002 (if applicant request an equivalent level of Safety finding to §25.1309). These factors include, but are not limited to, atmospheric conditions expected to be encountered in service, such as temperature, crosswind and runway width and length.

(2) Hazard Assessment :

a. As with other functional hazard assessments, a combination of analysis, simulation and flight testing can be used to determine the effects of the failure and assess the associated hazard to the airplane and occupants. The deceleration capability of the airplane following failures affecting wheel braking or other deceleration devices should be determined in a manner consistent with that used to determine compliance with §§25.109, 25.113 and 25.125 and associated guidance provided in this AC.

b. The hazard for each functional failure that results in loss of deceleration capability during landing or during a rejected takeoff should be assessed individually and in combination with other failures. A rejected takeoff initiated due to external events or ATC instruction need not to be considered when assessing the runway hazard for system failures that are un-annunciated and un-detectable by the pilot (i.e. the pilot can be assumed to continue the Take off rather than reject the Take off under certain failure conditions).

c. The hazard for each functional failure that results in a lateral deviation from runway centerline during takeoff or landing where there is potential for departing the runway should also be assessed individually and in combination with other failures.

d. The pilot recognition and reaction time appropriate for each failure condition should be established commensurate with the flight deck annunciations, airplane response to the failure condition and pilot workload expected at the time of the failure. The recognition time for the failure condition is defined as the time from the failure condition to the point at which a pilot in service operation may be expected to recognize the need to take action. The pilot reaction time is defined as the time following recognition of the failure condition until initial action by the crew to counteract or otherwise respond to address the failure condition. Total delay = Recognition time + Reaction time.

e. Recognition of the malfunction may be through the behavior of the airplane or an appropriate alerting system. Pilot control movements alone should not be used for recognition. The recognition time should not normally be less than 1 second unless justification is provided for the specific failure condition based upon piloted simulation or flight test that reflect the cues available to the pilot. The pilot reaction time should not normally be less than 1 second for failures requiring the pilot to initiate a new action (such as initiating a rejected takeoff, activation of an alternate braking mechanism, alternate ground spoiler selection, selection of thrust reversers, differential braking, etc.), unless piloted simulation or flight testing can justify a lower reaction time. For directional control on the runway following failures that generate lateral deviations from centerline, it can be assumed that the pilot will apply recovery inputs to controllers normally used during takeoff or landing (e.g., rudder pedals, control wheel/lateral stick, nose wheel steering tiller, etc.) at the recognition point without delay.

f. All deceleration devices, including thrust reversers, and ground directional control devices, including nose wheel steering and differential braking, can be used for hazard assessment if they would be available during the failure condition under assessment, consistent with applicable procedures (normal procedures up to the point of the failure recognition and abnormal procedures following the failure recognition).

g. Example methodology to identify the design conditions and classify hazard level for longitudinal runway landing excursions.
   1. Define intensified airport conditions to a level that represent an appropriate level of aggravated risk:
      - Field elevation should be intensified per criteria in Table 1
      - Ambient temperature should be intensified per criteria in Table 1
      - Engineering judgment may be necessary when considering further intensifying factors
   2. Determine design mission weight:
      - A typical mission weight should be used to determine a design mission takeoff weight. Typical assumptions need to be made for the payload and reserves, similar to fatigue design conditions.
   3. Determine takeoff limited field length:
      - From the design mission takeoff weight and intensified airport conditions above, determine the best (shortest) takeoff field length.
   4. Determine the baseline landing weight from the takeoff limited field length for the minimum design mission weight defined above:

- Using the takeoff limited field length as the baseline (no failures) landing distance; determine the landing weight limit for the baseline case using the aggravated condition assumptions. This weight should not exceed maximum landing weight.
- It may be assumed that the baseline landing distance represents un-factored CFR 25.125 landing distance. This assumption is conservative, but is not considered representative of the actual operations of many fleets.
- An alternate method is to assume the baseline represents the AFM dispatch landing distance for the aggravated risk conditions. This distance may include an operational landing distance factor as appropriate for the particular certification basis (e.g. CFR 121.195: factor is 1.67 for dry runway) and fleet operations.
- Another acceptable method is to assume the baseline represents an operational landing distance including an operational factor (e.g. TALPA: factor is 1.15).

5. Analyze landing case with un-annunciated failure(s) or failures occurring during the landing phase.
    - Using the same landing weight and aggravated risk condition as the baseline case, determine the speed at the point of overrun (baseline distance).
6. Classify hazard level based on speed of overrun

Another method may be the comparison of the aggravated risk landing failure condition to a minimum field length established from fleet operational data. In this comparison, it would be appropriate to include maximum landing weight as an intensifying factor for the failure condition.

The following is a numerical example of the methodology above used to design a hypothetical airplane.

1. Define intensified airport conditions to a level that represent an appropriate level of aggravated risk:
    - Using data from a fleet similar to the airplane being designed, a 2,500 ft elevation was identified to represent 90% of the expected operations.
    - Using world meteorological data, and knowledge of the operational latitudes of the fleet, a conservative estimate of ISA+20 was identified to represent 90% of the expected operations.
    - A forward center of gravity is conservatively assumed for takeoff and landing performance.
2. Determine design mission weight:
    - A typical 3 hour mission with an 85% load factor was selected for a design mission, similar to flutter design analysis. Assuming the intensified temperature and elevation conditions, this mission requires a 140,000 lb design takeoff weight.
3. Determine takeoff limited field length:
    - The 140,000 lb design takeoff weight requires a 5,000 ft field length.
4. Determine the baseline landing weight from the takeoff limited field length:
    - Using 5,000 ft as the baseline landing distance, and assuming the intensified conditions above, a design landing weight of 120,000 lb. It is known that this fleet operates in a Part 121 operational environment that requires a 1.67 factor on landing dispatch.

- Note that it is known from similar fleet data that 99% of operations are anticipated on runways over 6,000 ft long, and most considerably longer. This may be a consideration when using maximum landing weight as an intensifying factor.

5. Analyze landing case with un-annunciated failure(s):
   - Using 120,000 lb landing weight, and the same intensified conditions, each of the identified un-annunciated failure cases (at landing touchdown) are analyzed and compared to the baseline landing field length to determine the potential excursion speeds.
6. Classify hazard level based on speed of overrun:
   - The speed of the overrun for each failure case will determine its hazard classification.

h. Rationale statement for coverage of specific risk versus average risk

The excursion speed criteria proposed by the FTHWG was developed based on industry experience and hundreds of millions of cycles of service history representing multiple aircraft manufacturers. This historic data naturally takes into account all of the possible variables (intensifying factors) as well as the frequency of operations into specific airports, with specific airlines, with various quality crews, etc. Per AC/AMJ 25.1309, classification of Failure Conditions should always be accomplished with consideration of all relevant factors, including intensifying and alleviating factors.

The FTHWG considered relevant intensifying and alleviating factors and defined a set of factors by which to assess or simulate failures to define relevant combinations of failures for a probability assessment. These factors do not just consider the average operational and environmental conditions, but define a combination of conditions that envelope the vast majority of departures and landings. Therefore the FTHWG proposed factors and approach is much more conservative than the literal interpretation of 'average risk'. This approach should not be confused with specific risk, which is not considered appropriate for runway excursions as explained below.

Specific risk is 'the risk on a given flight due to a particular condition'. As one could imagine, there is the potential that a particular condition or combination of conditions could be such that a runway departure (even at low speed) is catastrophic (e.g. an off-runway obstacle). Likewise, a particular condition or combination of factors could be such that the combination of failures and operational and environmental factors resulting in the failure condition were inadvertently excluded. There are no regulatory criteria for specific risk, that is, there is no regulatory basis that says for a specific combination of airport, environmental conditions, and operational considerations that the aircraft must meet. Rather, the aircraft must be able to perform (without failures) to the specifications in the FAR/CS; this, and the applicable criteria for airport design, have proven to be robust in all but the most extreme specific risk conditions as evident in the historical data. It should be noted that when an ARAC ASAWG committee addressed specific risk, their recommendations refined how average risk was performed with respect to operational and environmental conditions, but did not set criteria for operational and environmental specific risk conditions.

The factors associated with runway excursion criticality: field length, runway width, weight and CG, runway surface condition, crosswind, elevation, temperature, reaction time, off-runway obstacles, etc., are not all independent, and it is impossible to conclude what the likelihood of being in a particular condition (a combination of these variables) will be. Engineering judgment, and fleet history was used in selecting a set of factors that when combined would envelope the extremes of any one condition where it was practical to do so.

When defining the design conditions to prevent runway excursions due to system failures, it is assumed that the construction of the runway and surrounding terrain are compliant with ICAO Annex 14 standards. While any specific runway may have some manner of deviation from the ICAO standards, it would be impractical to design systems generally to account for every known deviation in airport construction. Furthermore, existing airplane crashworthiness requirements are complementary to the prevention of runway excursions, by reducing the consequence when excursions occur. The crashworthiness standards focus on protecting airplane occupants from a crash, minimizing the development and severity of a potential crash fire, and ensuring the rapid evacuation of airplane occupants.

i. Table 1. below provides specific criteria that have been found acceptable for longitudinal and lateral runway excursion hazard assessments and are relevant for ICAO Annex14 compliant aerodromes: these are acceptable design assumptions and not intended to require mandatory AFM limitations.

TABLE 1.: Runway Excursion Hazard Criteria

Parameter	Criteria
Longitudinal runway excursion speed	0-30 kt MAJ >30-60 kt HAZ > 60 kt CAT
Lateral runway excursion speed	0-30 kt MAJ (if all MLG exit runway) 30-60 kt HAZ (if all MLG exit runway) > 60 kt CAT (if all MLG exit runway) *Next lower classification to be used if any Main Landing Gear (MLG) remains on the runway
Take off Field Length	AFM Take Off Field Length limited weight for the design case (Outside Air Temperature & Field elevation & weight/cg specified below). Without credit of stop way or clearway for obstacle clearance
Speed for Failure consideration (during Take off)	Longitudinal : At decision speed V1. Lower than V1 may be accepted if supported by rationale(e.g. control surface failure message before V1) Lateral : Between brake release and V1 for Rejected Take off and between V1 and V_{LOF} for a Continued Take off.
Landing Field Length (Longitudinal analyses)	At the choice of the applicant (ref §g. for methodology explanation) : 1) Consistent with a reasonable take off distance for the type of operation, OR 2) Runway length based on 90% statistics of historical operations for airplane of their type, size and gross weight Combined with 90% statistics of field elevation and Outside Air Temperature. Should not be greater than the 1.67 field

	length at MLW.
Runway Width	Use ICAO airport design level letter code or narrower. Operational guidance or other mitigations should be provided for operations (unlimited or frequent) on runway narrower than that used for the Type Certification safety analysis, if the hazard failure classification would be increased.
Weight and CG	Longitudinal and Lateral : - for Take off: critical weight & CG between minimum TOW (1 hour mission and 25% passenger) to MTOW - for Landing : critical weight & CG between minimum Landing Weight (25% passenger + reserve fuel) up to a Landing Weight consistent with the criteria for the design runway field length (refer to §g.)
Runway Surface Condition (Longitudinal analyses)	Dry
Runway Surface Condition (Lateral analyses)	Dry
Crosswind (Lateral analyses)	At the choice of the applicant Method 1) OR Method 2) : Method 1) 10kt (wind prob. 1): FC from 10-9 to 10-7 20kt(wind prob. 10-2):FC from 10-7 to10-6 25kt(wind prob. 10-3):FC from 10-6 and above (Failure Case prob. may include exposure time)

	OR Method 2) 10kt basic scenario (prob. 1) 25kt aggravating factor (prob. 10-3) * but need not to be more stringent than AC 25-7X Appendix 5 Fig 8 (HQRM) **Failure Case probability including exposure time
Field Elevation	Up to an altitude sufficient to cover at least 90% of the intended operation at Type Certificate. If data on the intended operation is missing use a default value of 5,000 ft. (ref §g. and §h. for further details)
Outside Air Temperature	Up to a temperature sufficient to cover at least 90% of the intended operation at TC. If data on the intended operation is missing use a default value of ISA deg C (ref §g. and §h. for further details)

Appendix 7 Topic 11 Stall in Ground Effect Final Report

FAA Aviation Rulemaking Advisory Committee
FTHWG Topic 11
Stall In Ground Effect

Recommendation Report
December, 2016

Table of Contents

Executive Summary

In response to a Gulfstream Aerospace Corporation GVI (G650) flight test accident in Roswell, NM on April 2, 2011, NTSB investigations identified the need for improved awareness and understanding of ground effects on stall angle-of-attack and maximum lift coefficient during the conduct of takeoff performance related flight testing and development of takeoff speeds. Tasking was identified by the FAA and assigned to the ARAC Flight Test Harmonization Working Group (FTHWG) to review current regulations and guidance pertaining to determination of Transport Category airplane takeoff and landing performance to ensure that ground effects on the aerodynamics of the airplane are sufficiently understood and accounted for to prevent inadvertent stall during ground transition both during flight testing and for determination of the airspeeds used for airplane operation in accordance with the Airplane Flight Manual.

The FTHWG recommends that existing regulations for takeoff and landing performance determination be left unchanged. However, it is recommended that the guidance for takeoff performance testing included in AC 25-7C be revised to raise awareness of ground effects on stall angle-of-attack and maximum lift and to ensure adequate margins to in-ground-effect stall angle-of-attack are maintained during flight testing and determination of takeoff speeds.

Background

As a result of the 20 March, 2014 ARAC meeting, the FAA assigned and ARAC accepted tasking which would utilize the existing Flight Test Harmonization Working Group (FTHWG). The part of the tasking described in this Appendix for Stall In Ground Effect is:

1) Review current 14 CFR Part 25 Subpart B rules, associated guidance and airworthiness information pertaining to takeoff and landing speeds to ensure the effect of ground proximity on the aerodynamics of the airplane is sufficiently accounted for to prevent inadvertent stall during ground transition.

2) Recommend accurate and consistent industry guidelines (analysis, simulation, CFD, wind tunnel tests) for use in the development and verification of takeoff and landing speeds prior to the start of developmental and certification flight testing.

3) Provide recommendations for any proposed revisions or further technical information. Also provide recommendations for any Airworthiness Authority actions to insure a harmonized approach is achieved when updating the guidance material.

Details of the task have been defined at the working level in the work plan (Topic 11, Stall In Ground Effect) resulting from the FTHWG Phase 1 Recommendation Report (Rev A dated Jan 30, 2014), included as Attachment 11A.

Although landing speeds were identified in the tasking as an area to be addressed by the FTHWG, the group concluded that the primary risk for in-ground-effect stall is during takeoff. Current regulations that establish minimum landing reference speed (V_{REF}) and maneuver margin requirements at V_{REF} have historically been sufficient to ensure adequate margin to stall in ground effect. And, the dynamics of the landing maneuver are such that approaches to stall angle-of-attack in ground effect just prior to touchdown (where ground effects are most significant) pose substantially less risk than one occurring near liftoff during a takeoff. As such, this recommendation from the FTHWG focuses on providing improved awareness and test safety guidelines for ground effects during takeoff performance testing and determination of takeoff speeds presented in the Airplane Flight Manual.

The FTHWG has identified risks associated with inadequate accounting of ground effects during airplane takeoff performance flight testing, particularly during Minimum Unstick Speed (V_{MU}) determination and during takeoff demonstrations associated with expected in-service variations in takeoff rotation speed and technique, with the potential for any or all of the following events:

a) Reduced stall warning margins
b) Loss of artificial stall warning and stall definition or protection (based on use of the out-of-ground-effect lift curves)
c) Inaccurate margins as displayed to the pilot through pitch limit indications
d) Inadvertent stall while in ground effect

A. What is the underlying safety issue addressed by the JAR/FAR?

Following the flight test accident of Gulfstream Aerospace Corporation GVI (G650) in Roswell, NM on April 2, 2011, investigations and intra-industry consultations have identified the need for improved awareness and understanding of ground effects on stall angle-of-attack and maximum lift coefficient. Certain flight tests required for determination of takeoff performance and takeoff speeds can place the airplane and crew near the stall angle-of-attack in ground effect. A thorough understanding of the reductions in stall angle-of-attack and maximum lift coefficient while in ground effect, along with active monitoring of the margins to the predicted stall angle-of-attack, are included in the recommended AC/AMC advisory material to reduce the risk of a similar accident in the future.

B. What is the task ?

See Attachment 11A.

C. Why is this task needed ?

See Attachment 11A.

D. Who has worked the task ?

The Flight Test Harmonization Working Group during Phase 2 activities. Participants in this FTHWG task included:

Airframe Manufacturers: Boeing, Airbus, Gulfstream, Bombardier, Dassault, Textron, Embraer

Airworthiness Authorities: FAA, EASA, TCCA (CAAI and JCAB as observers)

Operators: American Airlines, Delta Airlines

Labor Union: ALPA

E. Any relation with other topics?

The Envelope Protection – Topic 1 is relevant to the takeoff speeds requirements of §25.107 due to the potential for designs that incorporate envelope protections during takeoff to prevent tail-strike or in-ground-effect stall. It was discussed during development of the proposed guidance that airplanes providing such tail-strike protection or other pitch attitude limiting during takeoff should be afforded the same reduced liftoff speed margins allowed for geometry limited airplanes in §25.107(e)(1)(iv)(B). This is expected to be addressed in the Topic 1 proposal and the associated guidance material changes will need to be integrated with the recommended guidance changes for this Topic.

The Adaptation for Flight in Icing – Topic 2 is also relevant due to changes proposed to the regulatory and guidance material associated with §§ 25.105 and 25.107. The associated guidance material changes will need to be integrated with the recommended guidance changes for this Topic.

Historical Information

A. What are the current regulatory and guidance material CS 25 and FAR 25?

Although no changes are recommended to the CS-25 and 14 CFR Part 25 regulations, the related regulatory content is included for context and reference for the recommended guidance changes.

Current 14 CFR Part 25 Regulations related to Takeoff Performance:

§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 used to show compliance with §25.121(b), and with the most critical of the takeoff ice accretion(s) defined in appendices C and O of this part, as applicable, in accordance with §25.21(g):

(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).

(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.

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-92, 63 FR 8318, Feb. 18, 1998; Amdt. 25-121, 72 FR 44665, Aug. 8, 2007; Amdt. 25-140, 79 FR 65525, Nov. 4, 2014]

§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 §25.149(e).

(2) V_1, in terms of calibrated airspeed, is selected by the applicant; however, V_1 may not be less than V_{EF} plus the speed gained with 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) 1.13 V_{SR} 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 stall speed;

(2) 1.08 V_{SR} 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 stall speed; and

(3) 1.10 times V_{MC} established under §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 §25.121(b) but may not be less than—

(1) V_{2MIN};

(2) V_R plus the speed increment attained (in accordance with §25.111(c)(2)) before reaching a height of 35 feet above the takeoff surface; and

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

(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 paragraphs (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 §25.111(c)(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 —

(A) 110 percent of V_{MU} in the all-engines-operating condition, and 105 percent of V_{MU} determined at the thrust-to-weight ratio corresponding to the one-engine-inoperative condition; or

(B) If the V_{MU} attitude is limited by the geometry of the airplane (i.e., tail contact with the runway), 108 percent of V_{MU} in the all-engines-operating condition, and 104 percent of V_{MU} determined at the thrust-to-weight ratio corresponding to the one-engine-inoperative condition.

(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 paragraphs (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 §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 §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(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.

[Doc. No. 5066, 29 FR 18291, Dec. 24, 1964, as amended by Amdt. 25-38, 41 FR 55466, Dec. 20, 1976; Amdt. 25-42, 43 FR 2320, Jan. 16, 1978; Amdt. 25-92, 63 FR 8318, Feb. 18, 1998; Amdt. 25-94, 63 FR 8848, Feb. 23, 1998; Amdt. 25-108, 67 FR 70826, Nov. 26, 2002; Amdt. 25-121, 72 FR 44665, Aug. 8, 2007; Amdt. 25-135, 76 FR 74654, Dec. 1, 2011]

Current CS-25 Regulations related to Takeoff Performance:

There are no substantive differences between CS-25 and 14 CFR §§ 25.105 and 25.107, apart from the lack of regulatory coverage for takeoff surface conditions to be used for seaplanes and amphibians on water, and skiplanes on snow in CS 25.105(c), as shown below;

CS 25.105

(c) The take-off data must be based on:

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

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

[Amdt No: 25/3]
[Amdt No: 25/16]

Current FAA Guidance Material

FAA guidance material for 14 CFR §§25.105 and 25.107 is contained in Section 2 of AC25-7C, 'Flight Test Guide for Certification of Transport Category Airplanes'. The recommended guidance material for this Topic is presented in Attachment 11B as a mark-up of the current AC25-7C text.

Current CS-25 Guidance Material

No existing guidance exists in CS-25 Book 2 for CS 25.105.

AMC 25.107(d)
Take-off Speeds

1 If cases are encountered where it is not possible to obtain the actual V_{MU} at forward centre of gravity with aeroplanes having limited elevator power (including those aeroplanes which have limited elevator power only over a portion of the take-off weight range), it will be permissible to test with a more aft centre of gravity and/or more than normal nose-up trim to obtain V_{MU}.

1.1 When V_{MU} is obtained in this manner, the values should be corrected to those which would have been attained at forward centre of gravity if sufficient elevator power had been available. The variation of V_{MU} with centre of gravity may be assumed to be the same as the variation of stalling speed in free air with centre of gravity for this correction.

1.2 In such cases where V_{MU} has been measured with a more aft centre of gravity and/or with more than normal nose-up trim, the V_R selected should (in addition to complying with the requirements of CS 25.107(e)) be greater by an adequate margin than the lowest speed at which the nose wheel can be raised from the runway with centre of gravity at its most critical position and with the trim set to the normal take-off setting for the weight and centre of gravity.

NOTE: A margin of 9,3 km/h (5 kt) between the lowest nose-wheel raising speed and V_R would normally be considered to be adequate.

2 Take-offs made to demonstrate V_{MU} should be continued until the aeroplane is out of ground effect. The aeroplane pitch attitude should not be decreased after lift -off.

AMC 25.107(e)(1)(iv)
Take-off Speeds

V_{MU} Testing for Geometry Limited Aeroplanes.

1 For aeroplanes that are geometry limited (i.e., the minimum possible V_{MU} speeds are limited by tail contact with the runway), CS 25.107(e)(1)(iv)(B) allows the V_{MU} to V_{LOF} speed margins to be reduced to 108% and 104% for the all-engines-operating and one-engine-inoperative conditions, respectively. The V_{MU} demonstrated must be sound and repeatable.

2 One acceptable means for demonstrating compliance with CS 25.107(d) and 25.107(e)(1)(iv) with respect to the capability for a safe lift-off and fly-away from the geometry limited condition is to show that at the lowest thrust-to-weight ratio for the all-engines-operating condition:

2.1 During the speed range from 96 to 100% of the actual lift -off speed, the aft under-surface of the aeroplane should be in contact with the runway. Because of the dynamic nature of the test, it is recognised that contact will probably not be maintained during this entire speed range, and some judgement is necessary. It has been found acceptable for contact to exist approximately 50% of the time that the aeroplane is in this speed range.

2.2 Beyond the point of lift-off to a height of 11m (35 ft), the aeroplane's pitch attitude should not decrease below that at the point of lift-off, nor should the speed increase more than 10%.

2.3 The horizontal distance from the start of the take-off to a height of 11 m (35 ft) should not be greater than 105% of the distance determined in accordance with CS 25.113(a)(2) without the 115% factor.

AMC 25.107(e)(3)
Take-off Speeds

In showing compliance with CS 25.107(e)(3) –

a. Rotation at a speed of V_R-9,3 km/h (5 kt) should be carried out using, up to the point of lift -off, the same rotation technique, in terms of control input, as that used in establishing the one-engine inoperative distance of CS 25.113 (a)(1);

b. The engine failure speed used in the V_R-9,3 km/h (5 kt) demonstration should be the same as that used in the comparative take-off rotating at V_R;

c. The tests should be carried out both at the lowest practical weight (such that V_R-9,3 km/h (5 kt) is not less than V_{MCG}) and at a weight approaching take-off climb limiting conditions;

d. The tail or tail skid should not contact the runway.

AMC No 1 to CS 25.107(e)(4)
Take-off Speeds

Reasonably expected variations in service from established take-off procedures should be evaluated in respect of out-of-trim conditions during certification flight test programmes. For example, normal take-off should be made with the longitudinal control trimmed to its most adverse position within the allowable take-off trim band.

AMC No 2 to CS 25.107(e)(4)
Take-off Speeds

1 CS 25.107(e)(4) states that there must be no marked increase in the scheduled take-off distance when reasonably expected service variations, such as over-rotation, are encountered. This can be interpreted as requiring take-off tests with all engines operating with an abuse on rotation speed.

2 The expression ‘marked increase’ in the take-off distance is defined as any amount in excess of 1% of the scheduled take-off distance. Thus the abuse test should not result in a field length more than 101% of the scheduled field length.

3 For the early rotation abuse condition with all engines operating and at a weight as near as practicable to the maximum sea-level take-off weight, it should be shown by test that when the aeroplane is rotated rapidly at a speed which is 7% or 19 km/h (10 kt), whichever is lesser, below the scheduled V_R speed, no ‘marked increase’ in the scheduled field length would result.

B. What, if any, are the differences in the existing regulatory and guidance material CS 25 and FAR 25?

There are no substantive differences between CS-25 and 14 CFR 25.105 and 25.107, apart from the lack of regulatory coverage for takeoff surface conditions to be used for seaplanes and amphibians on water, and skiplanes on snow in CS 25.105(c).

There are significant differences in existing guidance material of CS-25 Book 2 in comparison to the FAA AC 25-7C. Specifically, CS-25 Book 2 does not include any guidance related to compliance with CS 25.105 while AC 25-7C, although limited, contains guidance related to establishing takeoff performance using procedures that can be consistently executed in service by crews of average skill. The takeoff procedures are to use methods and devices that are safe and reliable, and account for appropriate time delays in pilot actions, and the use of exceptional piloting techniques, such as control forces or pitch rates higher than would occur in operational service are prohibited (by §25.105(b)). Also discussed in AC25-7C is the need to account for potential indicated airspeed lag during takeoff related to electronic airspeed displays where filtering and time delays during flight testing and in the presentation of takeoff speeds in the AFM.

AC 25-7C also provides guidance related to §25.107(a) for criteria related to V_{EF} and V_1, §25.107(b) and the basis of V_{2MIN}, and a §25.107(c) discussion relating to the constraints on V_2. Similar guidance is not included in CS-25 Book 2.

CS-25 Book 2 AMC 25.107(d) most notably differs from AC25-7C guidance where it specifies criteria for airplanes with limited elevator control power at the forward center of gravity similar to the V_{MU} assurance tests of AC25-7C in paragraph 10.b.(8)(h). However, the criterion of AMC 25.107(d) differs by specifying that a speed margin between V_R and lift-off of the nosewheel of 5 kts is considered adequate when using up to maximum elevator deflection at the critical forward center or gravity, while AC25-7C states that the mainwheel lift-off speed should be at least 5 kt below the normally scheduled lift-off speed under the same conditions.

In general, AC 25-7C provides more extensive guidance related to compliance with §§25.107(d) and 25.107(e)(1)(iv) than does CS-25 Book 2, where guidance identifying the thrust-to-weight range to be tested is specifically provided only for geometry limited (tail or tail skid contact) airplane configurations.

CS-25 Book 2 AMC 25.107(e)(3) provides guidance for the one-engine-inoperative takeoff testing with a rotation speed 5 kts below than the normal V_R. However, it lacks the FAA accepted means of compliance related to airspeed achieved at 35 ft above the takeoff surface during these tests where AC25-7C specifies the speed at 35 ft height should not be less than the scheduled V_2 minus 5 kts. In addition, the AMC 25.107(e)(3) specifies that the tail or tail skid should not contact the runway during the tests while the AC25-7C guidance allows that "non-damaging" inadvertent tail or tail skid contact is acceptable provided there is a prompt recovery to the normal OEI takeoff pitch attitude.

CS-25 Book 2 AMC 25.107(e)(4) includes accepted means of compliance for all-engines-operating takeoff tests that address reasonably expected variations in takeoff procedures. This guidance is consistent with AC25-7C interpretation that "no marked increase" in takeoff distance is satisfied if the resulting takeoff distance does not exceed 101% of the normally scheduled takeoff field length, and that expected rotation speed variation should include demonstrations of all-engines-operating takeoffs with a rotation speed 10 kts (or 7%) below the normally scheduled V_R. However, combined with the early rotation speed, AC25-7C explains that the "over-rotation" specified in the regulation should include 1) rapid rotation rate to the normal takeoff attitude, and 2) over-rotation of 2 degrees above the normal attitude after liftoff at the normal rotation rate. AMC 25.107(e)(4) identifies only the rapid rotation test to be combined with the early rotation airspeed. There has also been other means of compliance accepted by EASA based upon JAA NPA 25B-335, which identifies similar criteria to AC25-7C, except that it allows the early rotation speed takeoff tests be combined with either an over-rotation of 2 deg OR a rapid rotation rate – allowing the applicant select one or the other abuse case for test.

C. What are the existing CRIs/IPs (SC and MoC)?

There are no related existing CRIs or Issue Papers.

D. What, if any, are the differences in the Special Conditions (CRIs/IPs) (SC and MoC) and what do these differences result in?

There are no related existing CRIs or Issue Papers.

Consensus

The recommendation to make no changes to the regulatory standard and the recommendation for the changes to guidance material as presented in Attachment 1E is supported by a full consensus within the FTHWG; all members agree with the conclusions and with the recommended guidance changes.

Recommendation

There are no recommended changes to regulations for related takeoff performance and takeoff speeds certification. The recommended guidance change selects the FAA AC25-7C as the initial basis for the takeoff performance testing guidance and adds background material to improve awareness of ground effects on stall angle-of-attack and maximum lift coefficient. It also adds guidance for proper monitoring of margins to stall angle-of-attack in ground effect to reduce the flight test risks to OEMs and other organizations conducting takeoff field performance flight testing (e.g., companies developing after-market improvements/upgrades to existing airplane models and certifying them through STC).

High fidelity computational fluid dynamics analysis expertise and/or high Reynolds number wind tunnel testing are necessary to obtain reliable stall angle-of-attack and maximum lift predictions in ground effect. Both are quite expensive and may not be available for smaller organizations that may be involved in takeoff performance flight testing. General guidelines for ground effects and improved awareness are provided by the recommended guidance, but elevated risk of in-ground-effect stall will remain for this portion of the industry where uncertainty remains. In those cases, conservatism is recommended in the guidance.

It is recommended that the FAA adopt the proposed guidance changes at the next opportunity for revision of AC 25-7C. Further, the FAA should liaise with other airworthiness authorities to ensure consistent implementation in their guidance material.

A. Rulemaking

1. What is the proposed action?

The FTHWG has recommended no change to the regulatory standards for transport category airplanes. Only changes to guidance related to takeoff performance flight testing and takeoff speed determination are proposed to be made.

2. What should the harmonized standard be?

No changes to existing standards are proposed for this Topic.

3. How does this proposed standard address the underlying safety issue?

No changes to existing standard are proposed for this Topic.

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

No changes to existing standards are proposed for this Topic. However, the increases in the understanding of ground effects on stall angle-of-attack and awareness of flight test risks associated with in-ground-effect stall are expected to increase safety.

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

No changes to existing standards are proposed for this Topic. However, the increases in the understanding of ground effects on stall angle-of-attack and awareness of flight test risks associated with in-ground-effect stall are expected to increase safety for some manufacturers and maintain the same level for others who already possess ground effects expertise and have implemented measures to mitigate the flight test risks.

6. Who would be affected by the proposed change?

Manufacturers developing new or derivative transport category airplanes and other organizations (e.g., companies developing after-market improvements/upgrades to existing airplane models and certifying them through STC) conducting takeoff field performance flight testing may use the revised guidance material.

7. Does the proposed standard affect other HWG's and what is the result of any consultation with other HWGs?

No. No other HWGs were consulted during the development of the recommendation for this FTHWG Topic.

B. Advisory Material

1. Is existing FAA advisory material adequate? If not, what advisory material should be adopted?

The FTHWG believes that the current FAA and EASA advisory material is not adequate. Recommended changes are provided in Attachment 11B.

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

   AC 25-7C [Paragraph 10. Takeoff and Takeoff Speeds - §§ 25.105 and 25.107] and CS-25 Book 2 AMC 25.107(d) Take-off Speeds, AMC 25.107(e)(1)(iv) Take-off Speeds, AMC 25.107(e)(3) Take-off Speeds, AMC No 1 to 25.107(e)(4) Take-off Speeds, AMC No 2 to 25.107(e)(4) Take-off Speeds

Economics

A. What is the cost impact of complying with the proposed standard (it may be necessary to get FAA Economist support to answer this one)?

There is no expected increase in cost to manufacturers or operators. There is no change in the standards and the recommended changes in guidance material do not modify the means of compliance or increase the amount of takeoff performance flight testing to show compliance for those applicants who currently use the means of compliance included in AC25-7C. For those applicants using the current EASA accepted means of compliance for takeoff performance testing and not AC25-7C, a small number of additional takeoff conditions may be necessary when these recommendations are adopted by EASA and implemented in CS-25 Book 2. The recommended guidance changes are intended to enhance the awareness of the aerodynamic influence of ground effects on the stall angle-of-attack and maximum lift coefficient within the flight test community and reduce the risks associated with takeoff field performance flight testing.

B. Does the HWG want to review the draft NPRM prior to publication in the Federal Register?

Yes.

ICAO Standards
How does the proposed standard compare to the current ICAO standard?

There are no known ICAO standards relating to takeoff speeds and takeoff field performance flight testing.

Attachment 11A: Phase 1 Final Report

Work Plan – Stall in Ground Effect

1. What is the task?
Review current 14 CFR Part 25 Subpart B rules, associated guidance and airworthiness information pertaining to takeoff and landing speeds to ensure the effect of ground proximity on the aerodynamics of the airplane is sufficiently accounted for to prevent inadvertent stall during ground transition. Recommend accurate and consistent industry guidelines (analysis, simulation, CFD, wind tunnel tests) for use in the development and verification of takeoff and landing speeds prior to the start of developmental and certification flight testing. Provide recommendations for any proposed revisions or further technical information. Also provide recommendations for any EASA action to insure a harmonized approach is achieved.
2. Who will work the task?
The Flight Test Harmonization Working Group (FTHWG) will have primary responsibility for this task.
3. Why is this task needed? (Background information)
Inaccurate accounting of ground effect stall for takeoff speed schedule development may impact maximum performance flight tests such as V_{MU} and abused takeoff demonstrations and can result in any or all of the following events: a) Reduced stall warning margins b) Loss of artificial stall warning and stall definition (based on use of the out of ground effect lift curves) c) Inaccurate margins as displayed to the pilot thru pitch limit indications d) Inadvertent stall while in ground effect
4. References (existing regulatory and guidance material, including special conditions, CRIs, etc.)
<u>FAA 14 CFR Part25 Subpart B:</u> a) Performance: 25.107 & 25.125 **<u>EASA CS-25 A-13:</u>**
a) Performance: 25.107 & 25.125
<u>FAA Special Airworthiness Information Bulletin:</u> a) SAIB NM-13-12 **<u>AC 25-7C Flight Test Guide for Certification of Transport Category Airplanes</u>**
<u>NTSB Accident Report</u> a) NTSB/AAR-12/02 PB2012-910402 Crash During Experimental Test Flight, Gulfstream Aerospace Corporation GVI (G650), N652GD. Roswell, New Mexico April 2,2011

5. Working method
It is envisioned that 3-4 face-to-face meetings days will be needed to facilitate the discussion needed to complete these tasks. Telecons and electronic correspondence will be used to the maximum extent possible.
6. Preliminary schedule (How long?)
Provide recommendations to the ARAC Transport Airplanes and Engines Subcommittee within 18 months of the initiation of work on these tasks.
7. Regulations/guidance affected
Regulations noted in Section 4 above
8. Additional information

Attachment 11B: Recommended Guidance Material

[Mark-ups to FAA AC 25-7C]

10. Takeoff and Takeoff Speeds - §§ 25.105 and 25.107.

a. Explanation. Section 25.105 specifies the conditions that must be considered in determining the takeoff speeds, accelerate-stop distances, takeoff path, takeoff distance, and takeoff run in accordance with part 25 requirements. The primary objective of the takeoff tests required by § 25.107 is to determine the takeoff speeds for all takeoff configurations at all weight, altitude, and temperature conditions within the operational limits selected by the applicant.

(1) Background Information.

This information is not related to means of compliance for §§ 25.105 and 25.107, but is included to increase awareness of the risks associated with in-ground-effect stall during execution of the required flight testing. The information is based upon previous industry experience and recommended best practices, much of which resulted from investigations following a flight test accident during takeoff performance testing. It is recommended that the following considerations be included in the applicant's flight test hazard assessment in preparation for the takeoff performance flight testing.

(a) Ground Effect Considerations. It is important to understand the aerodynamic characteristics of the airplane in ground effect to avoid an inadvertent stall while operating at high angles of attack in close proximity to the ground. Ground effect is the phenomenon that modifies a body's aerodynamic characteristics when it is generating lift close to the ground. The proximity of the ground suppresses downwash and wing tip vortices and can also cause a blockage of flow between the airplane and the ground, causing a slowing of the airstream under the wing, producing a positive pressure or buoyancy field. The impact of ground effect is largely dependent on the height of the wing above the ground and the magnitude of the resultant pressure field that exists between the underside of the wing and the ground plane. When the distance between the wing and ground is small (typically 5-10% of wing span), the pressure field and extent of upwash/downwash suppression is large. When a significant blockage effect is experienced, the excess flow that cannot pass under the wing traverses the wing upper surface causing increased suction on the wing leading edge and increased lift at low angles of attack; this effect growing with larger and more powerful trailing edge flaps and their proximity to ground at liftoff attitude. The increased leading edge suction tends to steepen the adverse pressure gradient behind the suction peak that can promote early aerodynamic flow separation, especially if the wing is already characterized by a leading edge stall. It is especially important to note that when this effect is large, it will not only reduce the stall angle-of-attack but it can also consequently decrease the maximum lift of the airplane in ground effect below the value observed in free air. Also important to understand is the effect that Mach number has on the stall angle-of-attack in the range expected for takeoff. Experience has shown that reductions in stall angle-of-attack with increasing Mach number observed in free air conditions can also be considered applicable in ground effect.

Due to remaining uncertainties in the in-ground-effect stall angle-of-attack, the test pilots involved in the takeoff testing should be familiar with the free air stall characteristics of the airplane, any predicted changes in the stall characteristics in ground-effect, and have established stall recovery techniques in the event that a stall is encountered, including allowance for stall angle-of-attack hysteresis to re-attach the airflow in the recovery.

(b) Ground Effect Estimation Methods: Industry experience has shown that a reduction in stall angle-of-attack in ground effect relative to free air of 4-5 degrees for takeoff flap deflections is a reasonable estimate in the absence of more configuration-specific data, though due to configuration differences there is no assurance that this estimate will be conservative in all cases. Wind tunnel results obtained at lower Reynolds numbers than full-scale flight should be used with extreme caution when predicting ground effects. While the "linear range" effects of such sub-scale testing can be accurate, the impact of ground effect on stall may not be captured at low Reynolds numbers. Computational Fluid Dynamics (CFD) results have been shown to produce useful indications of in-ground-effect stall, but the undertaking of predicting stall angles with CFD is in general, not trivial. Before using wind-tunnel or CFD predicted in-ground-effect stall angles, comparisons should be made with results from free air stall flight testing in order to understand and/or improve the accuracy of the predictions. Caution should be exercised to ensure that conservative margins are identified for flight test use.

b. Procedures.

(1) Section 25.105(c)(1) requires the takeoff performance data to be determined for smooth, dry and wet, hard-surfaced runways. Paragraph 11 of this AC describes methods for determining the accelerate-stop distances required by § 25.109. Paragraph 13 describes methods for determining the takeoff distance and takeoff run required by § 25.113.

(2) In accordance with § 25.101(f), testing for determining the accelerate-stop distances, takeoff flight paths, and takeoff distances should be accomplished using procedures established by the applicant for operation in service. In accordance with §25.101(h), these procedures must be able to be consistently executed in service by crews of average skill, use methods or devices that are safe and reliable, and include allowances for any time delays in the execution of the procedures that may reasonably be expected in service. These requirements prohibit the use of exceptional piloting techniques, such as higher control force inputs or higher pitch rates than would occur in operational service, from being used to generate unrealistic takeoff distances. The intent of these requirements is to establish takeoff performance representative of that which can reasonably be expected to be achieved in operational service.

(3) Attention should be paid to all potential sources of airspeed error, but special consideration should be given to airplanes with electronic instruments in the cockpit that apply electronic filtering to the airspeed data. This filtering, which causes a time delay in the airspeed indication, can be a source of significant systematic error in the presentation of airspeed to the flightcrew. With normal takeoff acceleration, the airplane will be at a higher speed than is indicated by the cockpit instrument, which can result in longer distances than are presented in the AFM, particularly in the event of a rejected takeoff near the indicated V_1 speed. The effects of any time delays caused by electronic filtering, pneumatic system lag, or other sources should be adequately addressed in the AFM speed and distance presentations. Further explanation of airspeed lag, particularly pertaining to airplanes with electronic instruments in the cockpit, and procedures for calibrating the airspeed indicating system (§ 25.1323(b)) are presented in paragraph 177 of this AC.

(4) Section 25.107(a)(1) - Engine Failure Speed (V_{EF}). The engine failure speed (V_{EF}) is defined as the calibrated airspeed at which the critical engine is assumed to fail and must be selected by the applicant. V_{EF} cannot be less than the ground minimum control speed (V_{MCG}).

(5) Section 25.107(a)(2) - V_1. V_1 may not be less than V_{EF} plus the speed gained with the critical engine inoperative during the time interval between V_{EF} and the instant at which the pilot takes action after recognizing the engine failure. This is indicated by pilot application of the first deceleration means such as brakes, throttles, spoilers, etc. during accelerate-stop tests. The applicant may choose the sequence of events. Refer to paragraph 11 of this AC, addressing § 25.109, for a more complete description of rejected takeoff

(RTO) transition procedures and associated time delays.

(6) Section 25.107(b) - Minimum Takeoff Safety Speed (V_{2MIN}).

(a) V_{2MIN}, in terms of calibrated airspeed, cannot be less than:

1 1.1 times the V_{MC} defined in § 25.149.

2 1.13 times V_{SR} for two-engine and three-engine turbopropeller and reciprocating engine-powered airplanes and for all turbojet airplanes that do not have provisions for obtaining a significant reduction in the one-engine inoperative power-on stalling speed (i.e., boundary layer control, blown flaps, etc.). The value of V_{SR} to be used in determining V_{2MIN} is the free air reference stall speed in the applicable takeoff configuration, landing gear retracted, except for those airplanes with a fixed landing gear or for gear-down dispatch.

(b) V_{2MIN} may be reduced to 1.08 times V_{SR} for turbopropeller and reciprocating engine-powered airplanes with more than three engines, and turbojet powered airplanes with adequate provisions for obtaining significant power-on reference stall speed reduction through the use of such things as boundary layer control, blown flaps, etc.

(c) For propeller-driven airplanes, the difference between the two margins, based upon the number of engines installed on the airplane, is because the application of power ordinarily reduces the stalling speed appreciably. In the case of the two-engine propeller-driven airplane, at least half of this reduction is eliminated by the failure of an engine. The difference in the required factors therefore provides approximately the same margin over the actual stalling speed under the power-on conditions that are obtained after the loss of an engine, no matter what the number of engines (in excess of one) may be. Unlike the propeller-driven airplane, the turbojet/turbofan powered airplane does not show any appreciable difference between the power-on and power-off stalling speed. This is due to the absence of the propeller, which ordinarily induces a slipstream with the application of power causing the wing to retain its lift to a speed lower than the power-off stalling speed. The applicant's selection of the two speeds specified will influence the nature of the testing required in establishing the takeoff flight path.

(7) Section 25.107(c) - Takeoff Safety Speed (V_2). V_2 is the calibrated airspeed that is attained at or before the airplane reaches a height of 35 ft. above the takeoff surface after an engine failure at V_{EF} using an established rotation speed (V_R). From the liftoff point, the takeoff surface extends to the end of the takeoff distance continuing at the same slope as the runway. During the takeoff speeds demonstration, V_2 should be continued to an altitude sufficient to assure stable conditions beyond the 35 ft height. V_2 cannot be less than V_{2MIN}. In addition, V_2 cannot be less than the liftoff speed, V_{LOF}, which is defined in § 25.107(f). In accordance with § 25.107(c), V_2 in terms of calibrated airspeed may not be less than V_R plus the speed increment attained before reaching a height of 35 feet above the takeoff surface using a takeoff maneuver that can be executed consistently by crews of average skill per the requirement of 25.101(h)(1) and a speed that provides the maneuvering capability specified in § 25.143(h). Due to the constraints on V_R and V_{LOF} specified in section 25.107(e), and also accounting for other constraints required for safe operation such as maintaining adequate margin to the in-ground-effect stall angle-of-attack during a dynamic takeoff maneuver, V_2 may be forced to be greater than V_{2MIN} for some, if not all, of the thrust/weight range of operation. In addition, § 25.111(c)(2) stipulates that the airplane must reach V_2 before it is 35 feet above the takeoff surface and continue at a speed *not less than* V_2 until it is 400 feet above the takeoff surface. These requirements were first expressed in Special Civil Air Regulation No. SR-422, Turbine-Powered Transport Category Airplanes of Current Design (SR-422A), paragraphs 4T.114(b)(4) and (c)(3) and 4T.116(e). The concern that the regulation change was addressing was the overshoot of V_2 after liftoff under the previous

requirement that the airplane attain V_2 on, or near, the ground. The intent of the current requirement is to allow an acceleration to V_2 after liftoff but not to allow a decrease in the field length required to attain a height of 35 feet above the takeoff surface by attaining a speed greater than V_2, under low drag ground conditions, and using the excess kinetic energy to attain the 35 foot height.

(a) In the case of turbojet powered airplanes, when most of the one-engine-inoperative data have been collected using throttle chops, V_2, and its relationship to V_R, should be substantiated by at least a limited number of fuel cuts at V_{EF}. For derivative programs not involving a modification that would affect thrust decay characteristics, demonstrations of fuel cuts may be unnecessary.

(b) For propeller-driven airplanes, the use of fuel cuts can be more important in order to ensure that the takeoff speeds and distances are obtained with the critical engine's propeller attaining the position it would during a sudden engine failure. The number of tests that should be conducted using fuel cuts depends on the correlation obtained with the throttle chop data and substantiation that the data analysis methodology adequately models the effects of a sudden engine failure.

(8) Section 25.107(d) - Minimum Unstick Speed (V_{MU}).

(a) Section 25.107(d) states, "V_{MU} speeds must be selected by the applicant." An applicant can either determine the lowest possible V_{MU} speeds or select a higher speed that supports the takeoff performance targets of the airplane. Regardless of how the applicant selects the V_{MU} speeds, compliance must be shown with § 25.107(d), (e)(1)(iv), (e)(3), and (e)(4) to show that the selected V_{MU} speeds allow the airplane to safely lift off the ground and continue the takeoff.

(b) An applicant should comply with § 25.107(d) by conducting minimum unstick speed (V_{MU}) tests with all engines operating and also with one engine inoperative. During these tests, the takeoff should be continued until the airplane is out of ground effect. The airplane pitch attitude should not be decreased after liftoff.

(c) V_{MU} testing to demonstrate the lowest V_{MU} speed is a maximum performance flight test maneuver, and liftoff may occur very near the angle-of-attack for maximum lift coefficient in ground effect with the minimum margin to in-ground-effect stall occurring in the vicinity of liftoff. As discussed in para 10.a.(1) of this AC, to ensure flight test safety, a thorough understanding of the stall angle-of-attack in ground effect and appropriate angle-of-attack margins should be established and maintained during testing (see Figure 10-1). Also, even though pitch attitude may be held fairly constant during the maneuver, environmental conditions and transiting through ground effect may result in changes in angle-of-attack. It is permissible to lift off at a speed that is below the normal stall warning speed, provided no more than light buffet is encountered. The use of a flight test device that restricts the on-ground pitch attitude has been found useful by some manufactures in reducing the risk of over-rotation and in-ground-effect stall.

1 It is important for the flight test team to understand the control laws and any transitions between control laws during takeoff (e.g., based on weight on wheels) for an electronic flight control system that may present unique hazards that should be taken into account.

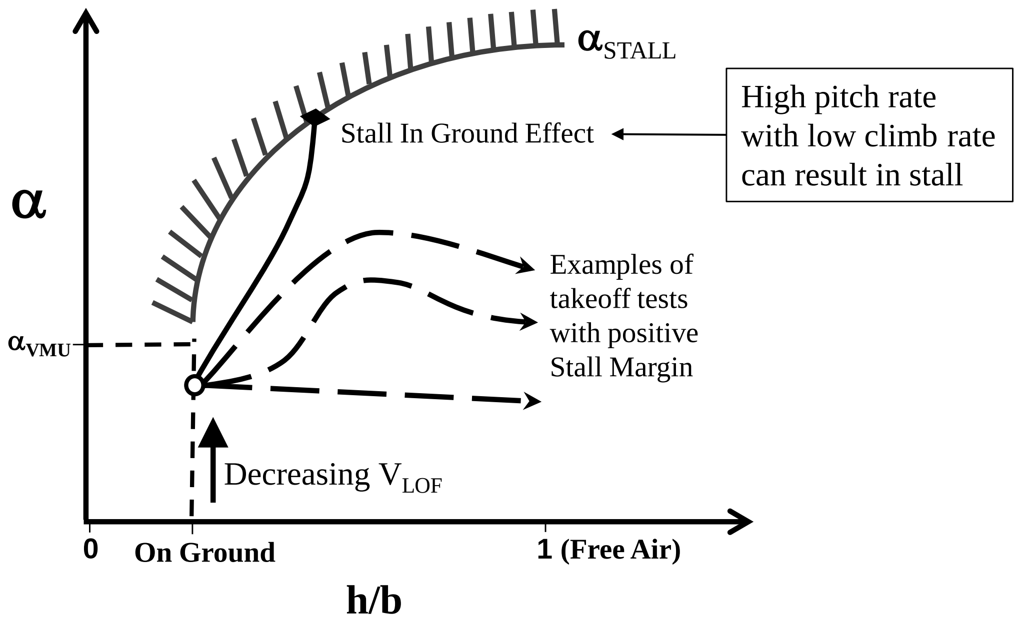
2 An artificial stall warning system (e.g., a stick shaker) may be disabled or adjusted to a more suitable value during V_{MU} testing~~, although doing so will require extreme caution and depend upon a thorough knowledge of the airplane's stall characteristics, both in and out of ground effect~~.

3 If the airplane is equipped with a stick pusher, ~~angle-of-attack limiter~~ high angle-of-attack limiting function, or other system that may affect the conduct of the test, the angle of attack setting for

activation of the system may be selected by the applicant and differ from the nominal setting. The system may alternatively be disabled or its activation delayed for test purposes until a safe altitude is reached. However, for airplanes equipped with a stick pusher that is not designed to be inhibited during takeoff, the V_{MU} test demonstrations will need to be assessed and will only remain valid if the stick pusher would not have activated with the angle-of-attack indication means set at the lowest angle within production tolerances.

4 Note that due to changes to an airplane's aerodynamic stall angle due to ground effect, a stall warning system, stick pusher, or high angle-of-attack limiting function that is not specifically designed to account for ground effect may not activate prior to aerodynamic stall during a V_{MU} test. The airplane's stall angle-of-attack and angle-of-attack sensor corrections, both in and out of ground effect, must be thoroughly understood by the test crew to determine if these systems will provide the benefit of protecting the airplane during V_{MU} testing.

Figure 10-1. In-Ground-Effect Stall Margin



(d) In lieu of conducting one-engine-inoperative V_{MU} tests, the applicant may conduct all-engines-operating V_{MU} tests if all pertinent factors that would be associated with an actual one-engine-inoperative V_{MU} test are simulated or otherwise taken into account. To take into account all pertinent factors, it may be necessary to adjust the resulting V_{MU} test values analytically. The factors to be accounted for should include at least the following:

1 Thrust/weight ratio for the one-engine-inoperative range.

2 Controllability (may be related to one-engine-inoperative free air tests, such as V_{MCA}).

3 Increased drag due to use of lateral/directional control systems.

4 Reduced lift due to use of devices such as wing spoilers for lateral control.

5 Adverse effects of use of any other systems or devices on control, drag, or lift.

(e) The number of V_{MU} tests needed may be minimized by testing only the critical all-engines-operating and one-engine-inoperative thrust/weight ratios, provided the V_{MU} speeds determined at these critical conditions are used for the range of thrust/weights appropriate to the all-engines-operating and one-engine-inoperative configurations. The critical thrust/weight is established by correcting, to the V_{MU} speed, the thrust that results in the airplane achieving its limiting one-engine-inoperative climb gradient at the normally scheduled speed and in the appropriate configuration.

(f) Amendment 25-42, effective March 1, 1978, revised §§ 25.107(d) and 25.107(e)(1)(iv) in order to permit the one-engine-inoperative V_{MU} to be determined by all-engines-operating tests at the thrust/weight ratio corresponding to the one-engine-inoperative condition. As revised, § 25.107(d) specifies that V_{MU} must be selected for the range of thrust/weight ratios to be certificated, rather than for the all-engines-operating and one-engine-inoperative conditions as was previously required. In determining the all-engines-operating thrust/weight ratio that corresponds to the one-engine-inoperative condition, consider trim and control drag differences between the two configurations in addition to the effect of the number of engines operating. The minimum thrust/weight ratio to be certificated is established by correcting, to the V_{MU} speed, the thrust that results in the airplane achieving its limiting engine-out climb gradient in the appropriate configuration and at the normally scheduled speed.

(g) To conduct the V_{MU} tests, rotate the airplane as necessary to achieve the V_{MU} attitude. It is acceptable to use some additional nose-up trim over the normal trim setting during V_{MU} demonstrations. Even on airplanes that have sufficient control authority to achieve the target V_{MU} attitude prior to liftoff, use of additional nose-up trim can be beneficial to the conduct of the test by giving the pilot additional time to stabilize on the V_{MU} attitude prior to lifting off. If additional nose-up trim is used ~~required~~, the additional considerations of paragraph (h)~~(g)~~, below, apply. V_{MU} is the speed at which the weight of the airplane is completely supported by aerodynamic lift and thrust forces. Some judgment may be necessary on airplanes that have tilting main landing gear bogies. Determining the liftoff point from gear loads and wheel speeds has been found acceptable in past programs. After liftoff, the airplane should be flown out of ground effect. During liftoff and the subsequent climbout, the airplane should be fully controllable.

(h) V_{MU} Testing for Airplanes Having Limited Pitch Control Authority.

1 For some airplanes with limited pitch control authority, it may not be possible, at forward c.g. and normal trim, to rotate the airplane to a liftoff attitude where the airplane could otherwise perform a clean flyaway at a minimum speed had the required attitude been achieved. This may occur only over a portion of the takeoff weight range in some configurations. Though generally associated with the inability of the pitch control surfaces to provide adequate pitching moment to rotate the airplane to the desired pitch attitude at low thrust/weight ratio conditions, the same phenomenon may occur at high thrust/weight ratio conditions for airplanes with high thrust lines (e.g., aft engines mounted high on the fuselage). When limited pitch control authority is clearly shown to be the case, V_{MU} test conditions may be modified to allow testing aft of the forward c.g. limit and/or with use of more airplane nose-up trim than normal. The V_{MU} data determined with this procedure should be corrected to those values representative of the appropriate forward limit; the variation of V_{MU} with c.g. may be assumed to be like the variation of free air stalling speed with c.g. Although the development of scheduled takeoff speeds may proceed from these corrected V_{MU} data, additional tests are required (see paragraph 2 below) to check that the relaxed V_{MU} criteria have not neglected problems that might arise from operational variations in rotating airplanes with limited pitch control authority.

2 In the following assurance test, the airplane should demonstrate safe flyaway characteristics.

(aa) Minimum speed liftoff should be demonstrated at the critical forward c.g. limit with normal trim. For airplanes with a cutback forward c.g. at heavy weight, two weight/c.g. conditions should be considered. The heavy weight tests should be conducted at maximum structural or maximum sea level climb-limited weight with the associated forward c.g. The full forward c.g. tests should be conducted at the highest associated weight. Alternatively, testing may be conducted at a single weight if an analysis is provided that identifies the critical weight/c.g. combination with regard to limited pitch attitude capability for liftoff.

(bb) These assurance tests should be conducted at the thrust/weight ratio that is most critical for attaining a pitch attitude that will provide a minimum liftoff speed.

(i) For airplanes that are limited by low thrust/weight conditions, tests should be conducted at the minimum thrust/weight ratio for both the simulated one-engine-inoperative test (i.e., symmetrical reduced thrust) case and the all-engines-operating case.

(ii) For airplanes that are limited by high thrust/weight conditions, tests should be conducted at the highest thrust/weight ratio within the airplane's operating envelope for both the simulated one-engine-inoperative case (i.e., symmetrical reduced thrust) and the all-engines-operating case.

(cc) One acceptable test technique is to hold full nose-up control column as the airplane accelerates. As pitch attitude is achieved to establish the minimum liftoff speed, pitch control may be adjusted to prevent over-rotation, but the liftoff attitude should be maintained as the airplane flies off the ground and out of ground effect.

(dd) The resulting liftoff speeds are acceptable if the test proves successful and the liftoff speed is at least 5 knots below the normally scheduled liftoff speed.

(ee) This minimum 5 knot margin from the scheduled liftoff speed provides some leeway for operational variations such as mis-trim, c.g. errors, etc., that could further limit the elevator authority. The reduced V_{MU} margins arising from this test, relative to those specified in § 25.107(e)(1)(iv), are considered acceptable because of the reduced probability of a pitch control authority-limited airplane getting into a high drag condition due to over-rotation.

(i) V_{MU} Testing for Geometry Limited Airplanes.

1 For airplanes that are geometry limited (i.e., the minimum possible V_{MU} speeds are limited by tail contact with the runway), § 25.107(e)(1)(iv)(B) allows the V_{MU} to V_{LOF} speed margins to be reduced to 108 percent and 104 percent for the all-engines-operating and one-engine-inoperative conditions, respectively. The V_{MU} demonstrated should be sound and repeatable. As discussed in para 10.a.(1) of this AC, to ensure flight test safety, a thorough understanding of the stall angle-of-attack in ground effect and appropriate angle-of-attack margins should be established and maintained during testing.

2 An airplane that is deemed to be geometry limited at the conditions tested is expected to be geometry limited over its entire takeoff operating envelope. If this is not the case, the airplane is not considered geometry limited and the reduced V_{MU} to V_{LOF} speed margins do not apply. Also, if a flight-test device is used with the intent to artificially restrict the rotation attitude (typically more than 0.5 degrees below the production configuration) to prevent over-rotation, and the airplane would not otherwise be

geometry limited, this airplane would not be considered geometry limited and the reduced V_{MU} to V_{LOF} speed margins do not apply.

3 One acceptable means for demonstrating compliance with §§ 25.107(d) and 25.107(e)(1)(iv) with respect to the capability for a safe liftoff and fly-away from the geometry limited condition is to show that at the lowest thrust-to-weight ratio for the all-engines-operating condition:

(aa) In the speed range from 96 to 100 percent of the actual liftoff speed), the aft under-surface of the airplane should be in contact with the runway. Because of the dynamic nature of the test, it is recognized that contact will probably not be maintained during this entire speed range, so some judgment is necessary. It has been found acceptable for contact to exist approximately 50 percent of the time that the airplane is in this speed range.

(bb) Beyond the point of liftoff to a height of 35 feet, the airplane's pitch attitude should not decrease below that at the point of liftoff, nor should the speed increase more than 10 percent.

(cc) The horizontal distance from the start of the takeoff to a height of 35 feet above the takeoff surface should not be greater than 105 percent of the distance determined in accordance with § 25.113(a)(2) without applying the 115 percent factor.

(j) V_{MU} for a Stretched Version of a Tested Airplane.

1 V_{MU} speeds obtained by flight testing one model of an airplane type may be used to generate V_{MU} speeds for a geometry-limited stretched version of that airplane. If the short body airplane met the criteria for the 104/108 percent V_{MU}/V_{LOF} speed margin for geometry limited airplanes as permitted by § 25.107(e)(1)(iv)(B) and discussed in paragraph 10b(8)(i)1, the flight tests described in paragraph 10b(8)(i)3 should be performed on the stretched derivative. Otherwise, the flight tests described in paragraph 10b(8)(j)2(bb) should be performed on the stretched derivative.

2 Since the concern for tail strikes is increased with the stretched airplane, the following should be accomplished, in addition to normal takeoff tests, when the V_{MU} schedule of the stretched derivative is derived from that of the shorter body parent airplane:

(aa) The minimum unstick speed (V_{MU}) of the stretched derivative airplane should be determined by correcting the V_{MU} of the shorter body tested airplane for the reduced runway pitch attitude capability and revised c.g. range of the stretched airplane. Alternatively, stretched airplane V_{MU} speeds not determined in this manner should be substantiated by flight testing or a rational analysis. Scheduled rotation speeds (V_R) for the stretched airplane should result in at least the required liftoff speed margins above the corrected V_{MU} required by § 25.107(e)(1)(iv) for the one-engine-inoperative and all-engines-operating takeoff conditions.

(bb) At both the forward and aft c.g. limits, and over the thrust-to-weight range for each takeoff flap, the following takeoff tests should be accomplished. The tests described in paragraphs (i) and (ii), below, should be accomplished with not more than occasional, minor (i.e., non-damaging) tail strikes. As discussed in para 10.a.(1) of this AC, to ensure flight test safety, a thorough understanding of the stall angle-of-attack in ground effect and appropriate angle-of-attack margins should be established and maintained during testing.

(i) All-engines-operating, early rotation tests specified in paragraph 10b(9)(c)2, including both the rapid rotations and over-rotations as separate test conditions.

(ii) One-engine-inoperative, early rotation tests specified in paragraph 10b(9)(b).

(iii) All-engines-operating, moderate rotation rate (i.e., more rapid than normal) takeoff tests, using the scheduled V_R and normal pitch attitude after liftoff. Tail strikes should not occur for this condition.

(9) Section 25.107(e) - Rotation Speed (V_R).

(a) The rotation speed, (V_R) in terms of calibrated airspeed, must be selected by the applicant. V_R has a number of constraints that must be observed in order to comply with § 25.107(e):

1 V_R may not be less than V_1; however, it can be equal to V_1 in some cases.

2 V_R may not be less than 105 percent of the air minimum control speed (V_{MCA}).

3 V_R must be a speed that will allow the airplane to reach V_2 at or before reaching a height of 35 ft. above the takeoff surface, when the takeoff is conducted using normal takeoff procedures.

4 V_R must be a speed that will result in liftoff at a speed not less than 110 percent of V_{MU} (unless geometry limited) for the all-engines-operating condition and not less than 105 percent of the V_{MU} (unless geometry limited) determined at the thrust/weight ratio corresponding to the one-engine-inoperative condition for each set of conditions such as weight, altitude, temperature, and configuration when the airplane is rotated at its maximum practicable rate. For this requirement, maximum practicable rate depends on the airplane configuration, type of pitch controller, flight control system design and the takeoff procedure. The rotation rate need not be increased beyond the point that prevents capturing the normal takeoff rotation attitude without using exceptional piloting skill or strength. Rotation rates between 120% and 150% of the nominal rate used in determination of the takeoff performance in accordance with §§ 25.105, 25.111 & 25.113 have previously been found acceptable. Alternatively, this rotation rate can be determined analytically as a representatively high rotation rate from a significant sampling of takeoffs performed during the flight test program, including the takeoff field performance tests.

5 V_R may not be less than the speed necessary to demonstrate the one-engine inoperative and all-engines-operating in-service variation tests (early rotation, over-rotation, out-of-trim) from the requirements of 25.107(e)(3)&(4) without encountering unsafe characteristics. As discussed in para 10.a.(1) of this AC, to ensure flight test safety, a thorough understanding of the stall angle-of-attack in ground effect and appropriate angle-of-attack margins should be established and maintained during testing. It should be noted that ensuring successful demonstrations for these in-service variation criteria may in some cases require increasing V_R (and thus V_2) to a higher speed than what would otherwise be required by § 25.107(e)(1).

(b) Early rotation, one-engine-inoperative test.

1 In showing compliance with § 25.107(e)(3), some guidance relative to the airspeed attained at the 35 ft. height during the associated flight test is necessary. As this requirement only specifies an early rotation (V_R-5 knots), it is interpreted that pilot technique is to remain the same as normally used for a one-engine-inoperative condition. With these considerations in mind, it is apparent that the airspeed achieved at the 35 ft. point can be somewhat below the normal scheduled V_2 speed. However, the amount of permissible V_2 speed reduction should be limited to a reasonable amount as described below.

2 These test criteria apply to all unapproved, new, basic model airplanes. They also apply to previously approved airplanes when subsequent testing is warranted. However, for those airplanes where these criteria are more stringent than those previously applied, consideration will be given to permitting some latitude in the test criteria.

3 In conducting the flight tests required by § 25.107(e)(3), the test pilot should use the normal/natural rotation technique associated with the use of scheduled takeoff speeds for the airplane being tested. Intentional tail or tail skid contact is not considered acceptable. Non-damaging contact due to inadvertent over-rotation is acceptable provided there is a prompt recovery to the normal one-engine-inoperative takeoff pitch attitude. Further, the airspeed attained at the 35 ft. height during this test should not be less than the scheduled V_2 value minus 5 knots. These speed limits should not be considered or used as target V_2 test speeds, but rather are intended to provide an acceptable range of speed departure below the scheduled V_2 value. To ensure flight test safety, the maximum angle-of-attack as a function of height above ground expected for this maneuver should be confirmed to either fall below those previously demonstrated by V_{MU} tests or provide conservative margin to predicted in-ground-effect stall angle-of-attack as a function of height above ground (see Figure 10-1). (Note: Experience has shown that the lowest margin to in-ground-effect stall angle-of-attack occurs in the vicinity liftoff.)

4 In this test, the simulated engine failure should be accomplished sufficiently in advance of the V_R test speed to allow for engine spin-down, unless this would be below the V_{MCG}, in which case V_{MCG} should govern. The normal one-engine-inoperative takeoff distance may be analytically adjusted to compensate for the effect of the early power or thrust reduction. Further, in those tests where the airspeed achieved at the 35-ft. height is slightly less than the V_2-5 knots limiting value, it will be permissible, in lieu of conducting the tests again, to analytically adjust the test distance to account for the excessive speed decrement.

(c) All-engines-operating tests.

1 Section 25.107(e)(4) states that there must not be a “marked increase” in the scheduled takeoff distance when reasonably expected service variations such as early and excessive rotation and out-of-trim conditions are encountered. This has been interpreted as requiring takeoff tests with all engines operating with:

(aa) A lower than scheduled rotation speed, and

(bb) Out-of-trim conditions, but with rotation at the scheduled V_R speed.

NOTE: The expression “marked increase” in the takeoff distance is considered to be any amount in excess of 1 percent of the scheduled takeoff distance. Thus, the tests should not result in field lengths more than 101 percent of the takeoff field lengths calculated in accordance with the applicable requirements of part 25 for presentation in the AFM.

2 For the early rotation condition with all engines operating, and at a weight as near as practicable to the maximum sea level standard day takeoff weight limit, it should be shown by tests that when the airplane is rotated at a speed below the scheduled V_R, no “marked increase” in the scheduled AFM field length will result. For these tests, the airplane should be rotated at a speed equal to the scheduled V_R minus 7 percent or the scheduled V_R minus 10 knots, whichever results in the higher rotation speed. Tests should be conducted at: (1) a rapid rotation rate to the normal takeoff attitude, and as a separate test, (2) an over-rotation of 2 degrees above normal attitude after liftoff at the normal rotation rate. For this requirement, the rapid rotation rate achievable at V_R-10 kt (or -7%) depends on the airplane configuration, type of pitch

controller, flight control system design and the normal takeoff procedure. The rotation rate need not be increased beyond the point that prevents capturing the normal takeoff rotation attitude without using exceptional piloting skill or strength. For tests using over rotations, the resulting increased pitch attitude should be maintained until the airplane is out of ground effect. Tail strikes during this demonstration are acceptable if they are minor and do not result in unsafe conditions. The maximum angle-of-attack as a function of height above ground expected for both of these maneuvers should be confirmed to either fall below those previously demonstrated by V_{MU} tests or provide conservative margin to the predicted in-ground-effect stall angle-of-attack as a function of height above ground (see Figure 10-1). (Note: Experience has shown that the lowest margin to in-ground-effect stall angle-of-attack occurs in the vicinity of liftoff.)

3 For reasonably expected out-of-trim conditions with all engines operating and as near as practicable to the maximum weight allowed under sea level standard day conditions, it should be shown that there will not be a “marked increase” in the scheduled AFM takeoff distance when rotation is initiated in a normal manner at the scheduled V_R speed. The amount of mistrim should be the maximum mistrim that would not result in a takeoff configuration warning, including taking into account the takeoff configuration warning system rigging tolerance. It is permissible to accept an analysis in lieu of actual testing if the analysis shows that the out-of-trim condition would not present unsafe flight characteristics or a “marked increase” in the scheduled AFM field lengths.

4 Section 25.107(e)(4) also states that the reasonably expected variations in service from the established takeoff procedures for the operation of the airplane may not result in unsafe flight characteristics. For example, for an airplane loaded to obtain a forward c.g. position and mistrimmed for an aft c.g. loading, it may not be possible to rotate at the normal operating speeds due to excessive control force or lack of primary pitch control authority. This may result in an excessive delay in accomplishing the rotation. Such a condition would be considered an unsafe flight characteristic. Similarly, for an airplane loaded to obtain an aft c.g. position and mistrimmed for a forward c.g. loading, it may not be possible to readily arrest a self-rotating tendency. This rotation, if abrupt enough and rapid enough, could lead to stall. Qualitative assessments should be made by the test pilot in the following takeoff tests with all engines operating:

(aa) The test pilot should determine that no unsafe characteristics exist with the airplane loaded to the forward c.g. limit and the stabilizer mistrimmed in the airplane nose-down direction. The amount of mistrim should be the maximum mistrim that would not result in a configuration warning (including taking into account takeoff warning system tolerances). Rotation should be initiated at the scheduled rotation speed for the airplane weight and ambient conditions. Unsafe characteristics include an excessive pitch control force to obtain normal airplane response or an excessive time to achieve perceptible rotation.

(bb) The test pilot should determine that no unsafe characteristics exist with the airplane loaded to the aft c.g. limit and the stabilizer mistrimmed in the airplane nose-up direction. The amount of mistrim should be the maximum mistrim that would not result in a configuration warning (including taking into account takeoff warning system tolerances). The airplane should be rotated at the scheduled rotation speed for the airplane weight and ambient conditions. Unsafe characteristics include: an abrupt self rotating tendency that cannot be checked with normal control input, or an excessive pitch control force required to maintain the airplane in the normal pitch attitude prior to the scheduled rotation speed or during rotation and initial climb.

(cc) For the tests described in paragraphs (aa) and (bb) above, the flight characteristics should be assessed at the most critical combinations of airplane weight, wing flap position and engine power or thrust for the out of trim position being considered.

(d) Stall Warning During Takeoff Speed Tests. The presumption is that if an operational pilot was to make an error in takeoff speeds that resulted in an encounter with stall warning, the likely response would be to recover aggressively to a safe flight condition rather than trying to duplicate the AFM takeoff flight path. Therefore, the activation of any stall warning devices, or the occurrence of airframe buffeting during takeoff speed testing, is unacceptable.

(e) Stick Forces During Takeoff Speed Tests. Per § 25.143(a)(1) and (b), stick forces to initiate rotation and continue the takeoff during takeoff flight testing must comply with the control force limits of § 25.143(d). This includes the mistrim takeoff tests described in paragraphs 10b(9)(c)4(aa) and (bb) to show compliance with § 25.107 (e)(4), which are considered to represent probable operating conditions under § 25.143(b). Stick forces should be those that result from using the takeoff procedures established by the manufacturer for use in operational service in accordance with § 25.101(f) and must comply with § 25.101(h).

(10) Section 25.107(f) - Liftoff Speed (V_{LOF}).

(a) The liftoff speed (V_{LOF}) is defined as the calibrated airspeed at which the airplane first becomes airborne (i.e., no contact with the runway). This allows comparison of liftoff speed with tire limit speed. V_{LOF} differs from V_{MU} in that V_{MU} is the minimum possible V_{LOF} speed for a given configuration, and depending upon landing gear design, V_{MU} liftoff is shown to be the point where all of the airplane weight is being supported by airplane lift and thrust forces and not any portion by the landing gear. For example, after the V_{MU} speed is reached, a truck tilt actuator may force a front or rear wheel set to be in contact with the runway, even though the liftoff is in progress by virtue of lift being greater than weight.

(b) The maximum ground speed at liftoff, considering the entire takeoff operating envelope and taking into account 50 percent of the headwind and 150 percent of the tailwind, in accordance with § 25.105(d)(1), must not exceed the tire speed rating established under § 25.733(a) or (c).

Appendix 8 Topic 12 Steep Approach Landing Final Report

FAA Aviation Rulemaking Advisory Committee
FTHWG Topic 12
Steep Approach Landing

Recommendation Report – Rev A
March, 2017

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Executive Summary

Current airplane certification standards are not harmonized among the U.S., Canadian, Brazilian and European airworthiness authorities, thus leading to an uneven playing field between different applicants for Steep Approach and Landing (SAL) approval.

The latest current standards are defined in

- TCCA : TRANSPORT CANADA ISSUE PAPER IP: FT-06: Steep Approach Landing Capability – Special Conditions – Airworthiness (SCA) (IP number is different from one program to the other but the content is similar)
- FAA : section 231 of Advisory Circular (AC) 25-7C
- ANAC: FCAR EV-27, FCAR EV-28
- EASA : Appendix Q of Certification Specifications (CS) 25

The mandate of this working group was to develop harmonized guidance between agencies to align these various requirements.

There were multiple tasks:

1) Harmonize and clarify the requirements from various agencies
2) Assess Means of Compliances or alternate Means if Compliances for
    - The 2 degrees steeper than normal case
    - FAA go-around
3) Define criteria for expansion of flight test data including operations on wet grooved runways
4) Define the airplane testing required for operation in known icing condition approval
5) Need for additional testing to cover Community noise requirements
6) Identify potential airports for SAL operations (minimum decision height, runway types) to assess if additional requirements are needed

Some of the above "sub-tasks 4, 5, and 6 were cancelled after further discussion, and the focus was put on items 1, 2 and 3 (excluding wet grooved runways) in an attempt to achieve harmonization.

Item 4 is already adequately covered by other regulations and no unique requirements are necessary for SAL operations in icing beyond to what is already included in the regulations.
After further review, Items 5 and 6 were deemed to be outside the scope of this harmonization working group tasks.

The main point of divergence between panel member specialists was the need to do additional flight testing to confirm proper airplane robustness in a SAL role (flare capability demonstration at screen height for a flight path angle steeper than the nominal one). As part of the support to the various discussions, manufacturer's data were reviewed to assess the magnitude of flight path angle deviations at screen height (both flight test and operational data). As no agreement was reached on that topic, a majority position was established.

As a result, the FTHWG recommends to amend AC 25-7C paragraph 231 as proposed in Attachment 12B, and to harmonize TCCA requirements, EASA CS 25 Appendix Q introduced at amendment 13 and other ANAC requirements accordingly.

Background

The objective of this working group was to harmonize the various agency's requirements on Steep Approach and Landing approval (SAL).

The current non-harmonized standards result in some aircraft models being certified by only one authority and in operations for many years (e.g. Airbus A318 certified by EASA and operating in London City since 2007). Due to differing requirements, it is not possible to certify these same models for steep approach operations with all certification authorities. Additionally, this situation does not provide a level playing field between the different applicants.

These new "harmonized" standards are to be such that

- They lead to similar impacts on:
  - Airplane design/modification to support SAL operation:
  - Effort to achieve airplane approval;
- The airplane performance levels are similar from one agency to the other when landing in a steep approach airfield;
- Proper and similar airplane safety standards are achieved and maintained.

The Working Group is to develop and recommend standards in the area of steep approach landing approval between the various agencies. The specific tasking, as published in the Federal Register, is included as Attachment 12A.

The following regulatory differences were identified and were discussed throughout the various meetings:

1. *Screen height definition for SAL*
   - The EASA CS-25 Appendix Q authorizes an applicant to set the screen height for SAL at any value between 35 ft and 60 ft.
   - The FAA and TCCA requirements define the screen height for SAL at 50 ft. If an applicant proposes to use a different height, this must be done through an Equivalent Level of Safety or an exemption process.

2. *Parametric method: touchdown rate for data expansion*
   - FAA AC25-7C §19(b)(3) authorizes applicants to use a parametric analysis to expand landing airborne distances for normal approaches (-3°) with normal landing data expansion (-3.5° slope and a touchdown rate of 8 ft/s). For steep approach, AC25-7C §231(c)(2)(c) requests that, in case that the parametric method is used to collect the flight test data for AFM data expansion, angles appropriate to the steep approach path angle desired and a touchdown sink rate of 6 ft/s be used. One of the panel members requested that 8 fps be used for data expansion for steep approach landing similar to normal landing data expansion.
   - TCCA and EASA requirements do not have such criteria.

3. *Flare capability demonstration at screen height on a flight path angle steeper than nominal.*
   - FAA requires that flare initiation at the screen height on a flight path angle 2° steeper than nominal be demonstrated by flight test complemented by analysis with a touch-down rate not exceeding 3 feet per second;
   - TCCA requires that flare initiation at a screen height on a flight path angle 1° steeper than

nominal be demonstrated by flight test with a touch-down rate not exceeding 3 feet per second;
- EASA does not require any additional steeper than normal flight path angle demonstration with flare at screen height.

4. *Power or Thrust during the 2° steeper than normal angle demonstration*
   - FAA requires that power or thrust remain above flight idle when stabilized on the approach path during the 2° steeper than normal angle demonstration;
   - TCCA and EASA do not have such requirements.

5. *Maximum flare height for the 2° steeper than normal angle demonstration*
   - FAA requirement allows the flare to be initiated "at a reasonable height somewhat higher than the normal steep approach flare height";
   - TCCA and EASA requirements allow the flare to be initiated at a height not exceeding "150% of the normal steep approach flare height".

6. *Guidance for go-around initiating at any height*
   - FAA requires that the airplane can safely transition to a go-around following a failure of the critical engine at any point in the approach and landing;
   - TCCA and EASA requirements do not request that go-around be demonstrated below the landing decision point.

7. *Systems Special Condition*
   - ANAC has proposed Special Conditions to deal with the systems aspects and failure cases of steep approach modes on Embraer fly-by-wire applications;
   - FAA, TCCA and EASA did not require Special Conditions for these systems. Existing regulations, especially §25.1309, were considered sufficient.

8. *AFM wind limitations*
   - EASA CS25 Appendix Q §(SAL)25.6(e) requires that AFM contains *"a statement of headwind and crosswind limitations if they are different from those for non-steep approaches. The tailwind limitation is 5 knots unless test evidence shows that more than 5 knots is acceptable. "* The tests at +2° steeper than nominal are chosen to cover power changes due to head wind and tailwind variability and the ability of the pilot to regain the flight path. The 5 kt tail-wind limitation is linked to the +2° steeper than nominal demonstration. For tail-winds above 5 kts EASA expect additional test substantiation recognising that higher descent rates will result.
   - FAA and TCCA do not have such requirement and the standard 10 kt tailwind limit for landing is considered applicable to steep approaches unless otherwise limited.

9. *Landing distance determination*
   - EASA CS 25 Appendix Q includes a §(SAL)25.3(f) related to devices dependent on operation of an engine for determination of steep approach landing distances, and the need to assume an engine fails during the final stages of an all-engines-operating steep approach, even if one-engine-inoperative steep approach landings are not approved. This comes from an interpretation of §25.125(g).
   - FAA and TCCA do not have such requirement.

As part of the various telecon discussions/meetings, various documents were reviewed and discussed:

1) TCCA Discussion Paper n°5 dated 7 January 1998 and titled "An Analysis of Steep Approach and Landing Capability, and a Review of Current Certification Requirements":

This discussion paper presented an assessment of the effects of various operational parameters on steep approach and landing capability. Based on a simplified analysis, the paper concluded that the maximum flight path angle (FPA) for demonstration could reasonably be as much as 2° steeper than the nominal flight path angle to cover an environmental envelope larger than the envelope demonstrated in flight test. It is therefore believed that this 2° figure could be less if the manufacturer elects to limit the airplane environmental envelope for Steep Approach Landing (SAL) operations.

2) Manufacturer Flight Test data:

Data gathered during the EASA certification of the Airbus A318 for Steep Approach operations (nominal slope of -5.5°) have been reviewed. This exercise represented around 80 certification approaches, involving both flight test and operational pilots. One objective was to assess the magnitude of the FPA deviations at screen height. The maximum FPA deviation observed did not exceed -0.6° (-6.1° FPA).

3) Airline operational data:

3.1 Data from one full year of British Airways A318 operations in London City (around 500 approaches) have been reviewed. One of the main objectives was to assess the magnitude of FPA deviations at screen height really achieved in operations for this aircraft category. The analysis showed that:

- The maximum deviation in terms of ground-based FPA at screen height never exceeded -0.58°(-6.1° FPA).

  Note 1: these points were flown with specific British Airways operational procedures and training.

  Note 2: Tailwind Operations are not permitted and therefore limited as much as possible in London City

- Go-around statistics over the last four years of operations showed a go-around rate due to instability / long flare touchdown point of around 0.1%.

3.2 Embraer ERJ 190-100 operational data have been reviewed. While the overall fleet accumulates more than 50.000 landings in LCY, a sample from one specific operator was used as a case study. It showed a comparison between 899 landings in LCY (short runway, 5.5 degree approach path) and other 899 landings from this same operator on a different airport (long runway, 3 degree approach path). The results indicated that the landing touchdown points in LCY were considerably more concentrated (less dispersion) than the touchdown points on the longer runway with standard 3 degree approach. Embraer concluded that steep approach operations (for this model certified under EASA standards) are as precise as needed and therefore, safe.

Based on the flight data collected over the years, the airplanes certified to the existing EASA standards have shown acceptable safety standards at London City airport.

A. What is the underlying safety issue addressed by the JAR/FAR? Or alternatively (use the alternative in our appendices)

The main safety concern is to confirm that the airplane has proper handling characteristics in the Steep Approach role, i.e. that the airplane is not displaying any hazardous characteristics when operating within the reasonably expected variations in approach speed and path angle envelope.

B. What is the task?

Refer to Appendix 12A.

C. Why is this task needed?

TCCA, FAA, ANAC and EASA standards differ in some significant ways in the areas of flight test demonstration conditions that account for reasonably expected variations in approach speed and path angle. Some other differences were also identified (e.g. screen height difference).

The task is required to harmonize the various agencies' requirements on Steep Approach and Landing approval (SAL).

D. Who has worked the task?

This task has been worked by the Topic 12 sub-team of specialists on Performance and Handling Qualities from the following organizations:

- Certification agencies
  - Transport Canada Certification Agency (TCCA)
  - Federal Aviation Administration (FAA)
  - European Aviation Safety Agency (EASA)
  - National Civil Aviation Agency of Brazil (ANAC)
- Airplane manufacturers
  - Boeing
  - Airbus
  - Embraer
  - Gulfstream
  - Bombardier
  - Dassault
  - Textron
- Airlines
  - American
- Labor Unions
  - ALPA
- Airport authorities (non-voting participants)

E. Any relation with other topics?

No.

Historical Information

This Working group is the first attempt to try to harmonize the steep approach landing regulation in the airplane industry.

A. What are the current regulatory and guidance material CS 25 and FAR 25?

Current regulatory and guidance material are defined in

- FAA : section 231 of Advisory Circular (AC) 25-7C
- EASA : Appendix Q of Certification Specifications (CS) 25

B. What, if any, are the differences in the existing regulatory and guidance material CS 25 and FAR 25?

The following significant differences were identified and were discussed throughout the various meetings (refer to “Background” paragraph above for more details):

1. Screen height definition
2. Parametric method: touchdown rate for data expansion
3. Flare capability at screen height on a flight path angle steeper than nominal
4. Power or Thrust during the 2° steeper than normal angle demonstration
5. Maximum flare height for the 2° steeper than normal angle demonstration
6. Guidance for go-around initiating at any height
7. Systems Special Conditions
8. AFM wind limitations
9. Landing distance determination

C. What are the existing CRIs/IPs (SC and MoC)?

The existing CRIs/IPs are defined in:

- TCCA : TRANSPORT CANADA ISSUE PAPER IP: FT-06: Steep Approach Landing Capability – Special Conditions – Airworthiness (SCA) A
- ANAC: FCAR EV-27 – Embraer EMB-550 Steep Approach – Special Condition
- ANAC: FCAR EV-28 – Embraer EMB-550 Steep Approach – MoC

Please note that EASA has introduced Appendix Q in CS 25 to provide standards for approval of SAL operations that therefore replaces previous existing CRIs.

D. What, if any, are the differences in the Special Conditions (CRIs/IPs) (SC and MoC) and what do these differences result in?

Refer to Background section and paragraph B above for differences between various regulatory and guidance materials.

Consensus

FTHWG recommendations have been established following the review of:

1. Existing regulatory and guidance material: as described in the "BACKGROUND" section of this report, regulatory differences between FAA, TCCA, ANAC and EASA have been established and discussed.

   Acceptable general consensus were found on most of the significant regulatory differences, except for the one dealing with the flare capability at screen height on a steeper flight path angle than nominal and for which a majority position has been determined.

2. TCCA Discussion paper n°5 dated 7 January 1998 and titled "An Analysis of Steep Approach and Landing Capability, and a Review of Current Certification Requirements":

   The 2° variation presented in TCCA Discussion Paper No. 5 could be reduced if the manufacturer elects to reduce the airplane environmental envelope for SAL operations.

3. Manufacturer's Flight Test data: Data gathered during the EASA certification of the Airbus A318 for Steep Approach operations (nominal slope of -5.5°) have been reviewed.

4. Airline's operational data: Data from one full year of British Airways A318 operations in London City (around 500 approaches) have been reviewed.

   The very low numbers of observed go-arounds indicated that the British Airways operational training and procedures have been safe and repeatable.

5. Airline's operational data: Data from one Embraer ERJ 190-100 operator showing around 900 approaches in London City have been reviewed.

   Landing touchdown point showed considerably less dispersion in LCY when compared to operations at a longer runway with a standard 3 degree approach path.

As a reminder, the current regulatory and guidance material is defined in

- Ref. 1; FAA : section 231 of Advisory Circular (AC) 25-7C
- Ref. 2; TCCA : TRANSPORT CANADA ISSUE PAPER IP: FT-06: Steep Approach Landing Capability – Special Conditions – Airworthiness (SCA) (IP number is different from one program to the other but the content is similar);
- Ref. 3; EASA : Appendix Q of Certification Specifications (CS) 25.
- ANAC: FCAR EV-27 – Embraer EMB-550 Steep Approach – Special Condition
- ANAC: FCAR EV-28 – Embraer EMB-550 Steep Approach – MoC

Based on the above, the FTHWG recommendation is to revise the relevant guidance material as follows:

1. *Screen height definition (Ref. 1, Ref. 2 and Ref. 3)*

   Consensus: FTHWG proposes to keep the screen height definition in AC25-7C §231(c)(3) unchanged, and to allow some limited administrative variation relative to the EASA requirement.

   Rationale: Both Ref. 1 and Ref. 2 define the landing screen height as 50 ft. Therefore, for FAA, a change of the SAL Landing Distance definition would also require an amendment of §25.125(a) since AC 25-7C is only guidance material. There is more flexibility for TCCA for the fact that the screen height definition is part of its SAL requirements (Ref. 2). For both agencies, it was agreed that it is not a major issue, as a different screen height value could be requested by an applicant through the ELOS process, in accordance with § 21.21(b)(1), or the exemption process, in accordance with Part 11.
   For EASA (Ref. 3), the SAL screen height definition is provided in Appendix Q of CS25 (any value between 35 ft and 60 ft at the option of the applicant) §(SAL) 25.2 – Definitions.
   The consequence of not harmonizing will be minimal additional administrative work for FAA and TCCA certifications.

2. *Parametric method: touchdown rate for data expansion (Ref. 1)*

   Consensus: FTHWG proposes to keep the criteria of AC25-7C §231(c)(2)(c) unchanged in case of use of the parametric method of AC25-7C §19(b)(3)

   Rationale: Since steep approach landing flare is very time dependent, the use of 8 fps for AFM landing distance expansion is not appropriate.

3. *Flare capability at screen height on a flight path angle steeper than nominal(Ref. 1 and Ref. 2)*

   Majority Position: FTHWG proposes to demonstrate by flight test a flight path angle 1° steeper than nominal, with flare at screen height and a touchdown rate of no more than 6 ft/s, provided there is sufficient control margin.
   A value less than 1° may be used if appropriate substantiation is provided by the applicant (examples that can be used for substantiation: the maximum FPA deviations at screen height from a large number of approaches conducted by a variety of different pilots, environmental factors considerations or system design considerations).
   FTHWG maintains that the 2 deg steeper flare case at 150% screen height may not be reduced in angle with substantiation, such as operational restrictions.

   Rationale: This majority position was considered to be the best acceptable compromise based on the review of existing theoretical analyses, flight test and operational experience. The other positions considered include:

   - Flight test demonstration of a flight path angle 1° steeper than nominal, with flare at screen height and a touchdown rate of no more than 6 ft/s. A value less than 1° may be accepted based on system design considerations;

- No additional flight demonstration of a flight path angle steeper than nominal with flare at screen height;
- No demonstration of a flight path angle steeper than nominal with flare at screen height in case flight tests are performed at the maximum altitude for which certification is sought, or flight test demonstration of a flight path angle 1° steeper than nominal with flare at screen height and 6 ft/s touchdown rate if flight test is performed at an altitude less than the maximum altitude for which certification is sought (limited to TBD ft extrapolation).

EASA opinion to majority position:

Whilst EASA are satisfied with the current standards with respect to the steeper than normal approach demonstration, EASA have no technical objection to adopting the +1°abuse at the screen height. Consequently the EASA position is to abstain.

Dissenting opinions to majority position:

<table>
<tr><td>- FAA:

FAA does not agree that it is appropriate to use flight test data to define the maximum expected operational variation in flight path angle. Flight testing is conducted with controlled conditions and specifically trained pilots, and is not representative of the number of operational variables encountered in service. Therefore, one degree above nominal is considered the minimum acceptable value for the flight test demonstration at screen height, unless mandatory use of enhanced precision guidance systems (e.g. HUD, tuned EGPWS, etc.) is proposed.

-FTHWG answer to FAA dissenting opinion:

The FTHWG recommendation is a compromise obtained through majority position. Reduction below 1 deg is based on possible limitations of operational envelopes or demonstrated variation in glideslope.</td></tr>
<tr><td>- Dassault Aviation:

Dassault considers that the existing requirements of CS SAL 25.5 “Safe operational and flight characteristics”, which already include two different abuse cases (-2° steep with a flare initiated at 150% screen height and Vrefsal-5 kt with flare initiated at screen height) are adequate to demonstrate proper airplane robustness to various extreme variations in a SAL operation and doesn’t see the credit of an extra test point. Indeed Dassault Aviation has no knowledge of any operational feedback from operators of the many Dassault aircraft SAL approved or from SAL airport (up to 6.65°) where these aircraft are operated that would justify the need for an additional criteria to be demonstrated during certification flight test.

- FTHWG answer to Dassault dissenting opinion: The FAA, TCCA, and ANAC policies require an additional demonstration. The FTHWG recommendation was a compromise obtained through majority position.</td></tr>
<tr><td>-Gulfstream:</td></tr>
</table>

Gulfstream disagrees with the majority proposal for AC25-7 Para 231d(1)(a) regarding its allowance for reductions in the glide slope "abuse" angle in subparagraph 3, based upon non-standard operational limitations or design features, while not also allowing similar reduction in the glide slope "abuse" angle in subparagraph 1. The majority position is considered to be inconsistent with group discussions regarding flare evaluations from the 2 deg steeper angle and illogical as explained below:

1) The Note in AC25-7C Para 231d explains that the 2 deg steeper approach angle accounts for tailwinds on the approach and to allow for necessary corrections following inadvertent approach path excursions. The Jim Martin (TCCA) position paper, which was also referenced during topic discussions as noted in the Background section of this report, explains that the 2 deg abuse criteria in the current requirements includes coverage for a 10 kt tailwind on approach, ILS system tolerances, and other operational factors like runway gradient, field elevation and elevated temperature. During the group discussions there was general agreement that some combination of environmental and operational AFM limitations could reduce the abuse angle to as low as 1.5 deg for the flare capability assessment. It is not consistent with these previous discussions nor is it logical to require the same 2 deg steeper flare demonstration for an airplane that is approved without specific steep approach limitations when compared to an airplane that has imposed more restrictive tailwind, field elevation, runway gradient, and/or other operational limitations that would serve to reduce the expected variance from the standard approach angle.

2) The majority proposal has the 2 deg steeper flight test and the 1 deg steeper test (with possible relief to less than 1 deg) as separate conditions. Paragraph (c) says the pilot "may" flare the airplane above the normal screen height for the 2 deg abuse. For small, straight-winged airplanes with Vref in the 90-100 kt range, it is possible the applicant could and would choose to demonstrate landings with flare at a 50 ft screen height at the 2 deg steeper angle with 3 ft/sec touchdown. If so, the additional 1 deg flight test should not be necessary. Yet, the 1 deg steeper test of the majority proposal is permitted to be reduced to less than 1 deg based on non-standard operational restrictions or design features while the 2 deg steeper test is not. If the 2 deg steeper test is demonstrated at the normal screen height, it should be allowed similar relief on the abuse angle as the majority proposed 1 deg steeper test. Moreover, if the non-standard operational limitations and features can be used to substantiate a reduction in the maximum effective glide slope expected during steep approach operations relative to the standard criteria, then that reduction should be realized at the start of the flare regardless of whether the flare is initiated at the normal screen height or up to 150% of the screen height.

Gulfstream submits the following alternative proposal for markup to AC25-7C:

d. Test Conditions For Reasonably Expected Variations In Approach Speed and Path Angle.

(1) The following additional criteria should be applied to show that the airplane is safely controllable and maneuverable during landing (§ 25.143(a)(5)).

(a) Under calm air conditions, demonstrate that it is possible to complete an approach, touchdown, and stop without displaying any hazardous characteristics in the following conditions:

~~1 An approach path angle 2 degrees steeper than the steepest approach path angle for which approval is sought at the V_{REF} established for a steep approach; and~~

1 The steepest approach path angle for which approval is sought at a speed 5 knots lower than the V_{REF} established for a steep approach; and~~.~~

2 An approach path angle 2 degrees steeper than the steepest approach path angle for which approval is sought at the V_{REF} established for a steep approach. A value less than 2 degrees (but not less than 1.5 degrees) may be used only for demonstration of flare and landing characteristics if appropriate substantiation is provided by the applicant (examples include enhanced guidance system design features and/or operational restrictions).

(b) For both conditions above:

1 The airplane should be loaded to the most critical weight and c.g. combination;

2 The airplane should be in the steep approach configuration;

3 The rate of descent should be reduced to no more than 3 feet per second at touchdown;

4 Below a height of 200 feet, no action should be taken by the pilot to increase power or thrust, apart from those small changes needed to maintain an accurate approach;

5 After initiating the flare, the longitudinal control should not be used to depress the nose apart from those small changes necessary to maintain a continuous and consistent flare flight path;

6 The flare, touchdown, and landing should not require exceptional piloting skill, alertness, or strength; and

7 To ensure adequate capability for a go-around or down path adjustment, the engines should remain above flight idle power or thrust when stabilized on the approach path. When conducting the 2 degrees steeper approach path angle test condition of paragraph 231d(1)(a)2, the engines can be periodically at flight idle power or thrust provided the target airspeed and approach path are maintained.

NOTE: The 2 degrees steeper approach path angle demonstration is to account for tailwinds on the approach and to take into account necessary corrections back to the desired approach path after inadvertent excursions. The purpose of the test at V_{REF} minus 5 knots is to account for an unnoticed speed decrease during the approach, hence the requirement in paragraph 231d(1)(b)4 for no power or thrust increase to account for the slower speed.

(c) ~~For flight test safety reasons, w~~When conducting the V_{REF} - 5 knots steep approach test of paragraph 231d(1)(a)1, the flare should not be initiated above the normal steep approach screen height. When conducting the ~~2 degrees~~ steeper approach path angle test condition of paragraph 231d(1)(a)~~1~~2, the pilot may begin to flare the airplane (or reduce the approach angle) at a ~~reasonable~~ height somewhat higher than the normal steep approach screen ~~flare~~ height, not to exceed 150% of the normal steep approach screen height. If this is done, it should be shown by additional tests ~~analysis that there is sufficient pitch control to arrest the descent rate if the flare were to be initiated at the normal steep approach flare height, keeping in mind the criteria in paragraphs 231d(1)(b)3 and 6~~ that the requirements of paragraph 231d(1)(b) are met at an approach angle 1 degree steeper than the steepest approach path angle for which approval is sought at the V_{REF} established for a steep approach. As with paragraph 231d(1)(a)2, a value less than 1 degree may be used if appropriate substantiation is provided by the applicant. During this additional testing:

1 The flare should not be initiated higher than the normal steep approach screen height; and

2 A sink rate at touchdown up to 6 feet per second is acceptable (In lieu of 231d(1)(b)3) if it is achieved without encountering a control or angle of attack limit, and without encountering stall warning.

-FTHWG answer to Gulfstream dissenting opinion:

The FTHWG recommendation is a compromise obtained by majority position.

- The 2° steeper flare case at 150% of screen height is part of all current regulations, and the majority position has been to keep it unchanged as it was not identified as a regulatory difference. This demonstration particularly allows covering power changes due to headwind and tailwind variability and the ability of the pilot to regain the flight path during a steep approach.
- The steeper flare case at screen height was identified as a regulatory difference between EASA, FAA and TCCA, and the compromise obtained by majority position was to consider a 1° steeper flare case, or less upon adequate justification. This demonstration is supposed to cover vertical speed increases due to operational and environmental variations at screen height, and its intent is therefore different from the 2° steeper flare case at 150% of screen height.

4. *Power or Thrust during the 2° steeper than normal angle demonstration*

Consensus: FTHWG proposes to change AC25-7C §231d (1)(b) 7 as follows:

To ensure adequate capability for a go-around or down path adjustment, the engines should remain above flight idle power or thrust when stabilized on the approach path. When conducting the 2 degrees steeper approach path angle test condition of paragraph 231d(1)(a)1, the engines can be periodically at flight idle power or thrust provided the target airspeed and approach path are maintained.

Rationale: FAA is the only agency having specific requirement on thrust for steep approach operations. The other agencies state that:

It must be demonstrated that it is possible to complete a stabilized approach in calm air down to the commencement of the landing flare,

The panel members believe that the conditions of completing a stabilized approach imply that both the target airspeed and approach path are maintained down to the proper screen height therefore meeting the intent of the rule.

5. *Maximum flare height for the 2° steeper than normal angle demonstration*

Consensus: FTHWG proposes to update AC25-7C §231d(1)(c) to state that during the demonstration of a 2° steeper than normal angle the initiation of the flare may not occur above 150% of the screen height.

Rationale: Both the EASA and TCCA require that it must be possible to achieve an approach path angle 2° steeper than the selected approach path angle in all configurations which exist down to the initiation of the flare, which must not occur above 150 % of the screen height. The 150% of the screen height has always been considered as a reasonable height somewhat higher than the normal steep approach flare height to perform the 2° steeper case as per the wording of AC25-7C §231(d)(1) (c) . Therefore, even though not identical, the three agencies' requirements are in fact meeting the same intent.

6. *Guidance for go-around initiating at any height*

Consensus Position: FTHWG proposes to include a note after section d (3) of section 231 of AC 25-7C

NOTE

At least one demonstration should be done to establish height loss. Additional go-arounds are not required if a proper design review is done to assess the impact of transition to go around and confirm that system would not prohibit the airplane to initiate a go-around from any height.

Rationale: The FAA have clarified during the meetings that the intent of the original guidance was to ensure there are no system logics in a steep approach function or feature that would lock the airplane in a "commit to land" mode, preventing the initiation of a go-around below a certain height if the crew decides to do so. The proposed note explains that no additional go-around performance requirement is intended.

7. *Systems Special Conditions*

Consensus: FTHWG proposes to not modify AC25-7C §231 and to not include additional requirements to address system failure cases.

Rationale: Existing regulations, especially §25.1309, are considered sufficient to address system failure cases for SAL operations.

8. *AFM wind limitation*

Consensus Position: FTHWG proposes to include guidance in AC25-7C §231(f)(1)(e) that the AFM contain a statement of headwind and crosswind limitations if different from those for non-steep approaches, and the tailwind limitation is 10 knots unless test evidence shows that more than 10 knots is acceptable.

Results of the non-steep approach wind component testing may be used to establish the safe headwind and crosswind limitation components. If flight test data and/or analysis show that the sideslip angle capability demonstrated is similar to that shown with the non-steep approach airplane, and the flight characteristics (control forces and deflections, for example) are similar, then the non-steep approach airplane crosswind component test result is considered valid for steep approach.

Rationale: FTHWG believes that aligning EASA CS25 Appendix Q §(SAL)25.6(e) with AC 25-7C §231(f)(1)(e) to include a 10 knot tailwind limitation is appropriate.
EASA- Based on the review of TCCA Discussion Paper n°5 dated 7 January 1998 and entitled "An Analysis of Steep Approach and Landing Capability, and a Review of Current Certification Requirements" and with further consideration, EASA agrees to harmonize on a 10 kts tail-wind limitation. EASA would rather keep the reference to a tail wind limitation rather than deleting it completely.
The FTHWG also notes that clarification should be made that analysis may be used to supplement flight test data from non-steep approach.

9. Landing distance determination

Majority Position: FTHWG believes that these requirements are essentially the same and proposes to not modify AC25-7C requirements or remove EASA Appendix Q §(SAL)25.3(f).

Rationale: (SAL) 25.3 (f) reflects the same requirement as in CS25.125(g) which is harmonized with FAR Part 25. The intent of this requirement is to consider any loss in stopping performance arising from an engine failure during the landing at a time when the crew do not have the opportunity to plan ahead accordingly. The main impact is on turbo-propeller designs. This is not the case for turbo-jets which are relatively immune from this requirement. There is currently insufficient basis to justify removal of (SAL) 25.3 (f) or CS25.125(g).

Dissenting opinion to majority position:

- Gulfstream considers steep approach to be a special approval that goes beyond the basic airworthiness criteria of Subpart B. As part of that approval, the applicant can choose to approve OEI steep approach landings or only AEO landings. Clearly, for the standard approach landing performance that is not an option, and the more critical landing distance for OEI vs AEO is to be included in the AFM landing distance (including 25.125(g)) used for dispatch planning (with operational factors). Gulfstream agrees that for an applicant approving OEI steep approach landings, the AFM landing distance for steep approach should cover the more critical of the AEO and OEI conditions. However, where an airplane is approved only for AEO steep approaches, Gulfstream considers it inappropriate to require the same AFM landing distance criteria as the one approved for OEI steep approaches, for the following reasons:
  1) The airplane approved only for AEO steep approaches is required to go-around and divert to an alternate (standard approach angle) airfield if an engine fails at any time of the flight before the final stages of the landing. The dispatch planning should therefore be based on

landing distance data consistent with this operational limitation, including selection of appropriate alternate landing airfields.

2) Safe diversion to a standard approach angle airfield is assured by the standard landing distance data that includes 25.125(g) compliance.

3) The ability to safely land or go-around from any point of the steep approach, should an engine fail in the final stages of the AEO approach, is separately required by para 231d(2) of the existing AC25-7C guidance and this proposal. This can be shown without forcing the engine failure effects into the AFM distance used for dispatch planning. For example, the ability to safely land if an engine fails in the final stages of an AEO steep approach landing can met by showing adequate landing distance margin to a steep approach minimum landing field length AFM limitation, assessed at the maximum field elevation, gradient, temperature and MLW to be approved for steep approach.

FTHWG answer to Gulfstream dissenting opinion:

- The regulatory intent of 25.125(g) and SAL 25.3(f) is to account for failures that are not anticipated or planned for (i.e. assume the engine fails as the landing occurs, and not before). For turbojets, that doesn't typically affect the no-reverse landing distance. If it does, that should be accounted for in the dispatch calculations. It should not be implied that 25.125(g) and SAL 25.3(f) only apply to planned OEI landings.

Recommendation

The FTHWG recommends to amend AC 25-7C paragraph 231 as proposed in Attachment 12B, and to harmonize TCCA requirements, EASA CS 25 Appendix Q introduced at amendment 13 and other ANAC requirements accordingly

A. Rulemaking

1. What is the proposed action?

The FTHWG will recommend changes to section 231 of AC 25-7C and to harmonize TCCA requirements, EASA CS 25 Appendix Q introduced at amendment 13 and ANAC requirements accordingly.

2. What should the harmonized standard be?

As previously stated, full harmonization of the Steep Approach landing standards has not been achieved. EASA is the only agency for which guidance for Steep Approach Landing is covered by part of its certification specifications (Appendix Q) while currently FAA and TCCA do not plan to revise either 14 CFR Part 25 or AWM 525 to include SAL requirements. Nevertheless, the level of harmonization can be improved as per the recommendations, and the primary disagreement is about the additional 1° steeper angle demonstration and the conditions upon which the 1° steeper angle could be reduced.

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

The proposed TCCA/FAA revised standards in addition to the current EASA standards will be sufficient to show proper robustness of an airplane in a Steep Approach Landing role.

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

The level of safety is maintained relative to the current FAA guidance. There is an additional flight test requirement relative to the EASA standards.

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

The level of safety is maintained relative to the current FAA guidance. There is an additional flight test requirement relative to the EASA standards.

6. Who would be affected by the proposed change?

Any applicant that needs to certify their airplane for Steep Approach Landing operations.

7. Does the proposed standard affect other HWG's and what is the result of any consultation with other HWGs?

No

B. Advisory Material

1. Is existing FAA advisory material adequate? If not, what advisory material should be adopted?

The FTHWG believes that the current FAA advisory material is not adequate. Proposed changes to material is attached, see Attachments 12B.

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

The intent is to harmonize the principles of SAL, but not the format of the advisory material. This material includes EASA Appendix Q, FAA AC 25-7C, ANAC guidance and TCCA issue papers.

Economics

A. What is the cost impact of complying with the proposed standard?

There is an additional flight test requirement relative to the EASA standards; however there will be reduced cost for multi-agency certification resulting from the harmonized guidance.

B. Does the HWG want to review the draft NPRM prior to publication in the Federal Register?

Not applicable.

ICAO Standards
How does the proposed standard compare to the current ICAO standard?

There are no current ICAO Annex 8 standards regarding Airworthiness of Aircraft for Large Aeroplanes that specifically address designs with steep approach landing role.

Attachment 12A ARAC Tasking from Federal Register

Work Plan – Steep Approach

1. What is the task?

There are multiple tasks:

1) Harmonize and clarify the requirements from various agencies
2) Assess Means of Compliances or alternate Means of Compliances for
   - the 2 degrees abuse case
   - FAA go-around
3) Define criteria for expansion of flight test data including operations on wet grooved runways
4) Define the airplane testing required for operation in known Icing condition approval
5) Need for additional testing to cover Community noise requirements
6) Identify potential airports for SAL operations (minimum decision height, runway types) to assess if additional requirements are needed

2. Who will work the task?

The Flight Test Harmonization Working Group (FTHWG) will have primary responsibility for this task. The group will seek input from companies having airplane type approved for SAL operations for them to present the areas of high difficulties when approving SAL

3. Why is this task needed? (Background information)

Task 1:

TCCA, FAA and EASA advisory material differs in some significant ways

- FAA requires that "sufficient" glideslope control exist the 2 degrees abuse i.e. the engine is to be operating above idle for the test point
- Screen height definition (different philosophe between EASA/TCCA and FAA)
- Shaker activations for 2 deg abuse case (no implicit requirements for FAA/TCCA)

Tasks 2

- Propose/develop alternate Means Of Compliance (Use of in-flight data demonstration of airplane capabilities, simulation tool for go-around below decision height) to minimize hazardous testing

Tasks 3

- TCCA has the 1 degree abuse case to allow the extrapolation 3000 ft. above test altitude. No guidance from either EASA or FAA
- How can the data gathered on SAL testing (dry smooth) be used for other surface types (wet grooved for instance)?

Tasks 4

- Is there any adjustment to the FAR 25.1419 methodology for the test cases to consider?

Tasks 5

- No covered by FAR 36. Need for any additional requirements?

Task 6:

- To insure that the special requirements of individual airports are covered in the certification material especially for other runway types

4. References (existing regulatory and guidance material, including special conditions, CRIs, etc.)
TCCA 1) AC 5009-6-525 Approval of Steep Approach Landing Capability of Transport Category Aeroplanes 2) IP: FT-06, Steep Approach Landing Capability – Special Conditions - Airworthiness (SCA) 3) TCCA Special Conditions-Airworthiness (SCA), SCA No.: 2007-01, Bombardier Model CL-600-2B16 (604 and 605 Variants) Approval of Steep Approach and Landing Capability **FAA** 1) AC 25-7C, Flight Test Guide For Certification Of Transport Category Airplane, Chapter 8 - Airworthiness: Miscellaneous Items, Section 231, Criteria For Approval Of Steep Approach To Landing. 2) ISSUE PAPER F-15, Steep Approach Certification **EASA** 1) CERTIFICATION REVIEW ITEM CRI B7, STEEP APPROACH LANDING CAPABILITY, Learjet 45 2) CS-25 Amendment 13, Appendix Q, Additional airworthiness requirements for approval of a Steep Approach Landing (SAL) capability
5. Working method
It is envisioned that 2 to 3 face-to-face meetings will be needed to facilitate the discussion needed to complete these tasks. Telecoms and electronic correspondence will be used to the maximum extent possible. Priority is tasks 2, 3 and 4.
6. Preliminary schedule (How long?)
Recommendations to Flight Test Harmonization Working Group within 24 months of the initiation of work on these tasks.
7. Regulations/guidance affected
TCCA AC 5009-6-525 Approval of Steep Approach Landing Capability of Transport Category Aeroplanes **FAA** AC 25-7C, Flight Test Guide For Certification Of Transport Category Airplane, Chapter 8 - Airworthiness: Miscellaneous Items, Section 231, Criteria For Approval Of Steep Approach To Landing. **EASA** CS-25 Amendment 13, Appendix Q, Additional airworthiness requirements for approval of a Steep Approach Landing (SAL) capability
8. Additional information

Attachment 12B Recommended Guidance Material

<u>Update AC 25-7C, Paragraph 231 to include acceptable criteria for Steep Approach and Landing approval (markup are identified in *red italic characters*):</u>

231. Criteria For Approval Of Steep Approach To Landing.

a. <u>Applicable Regulations</u>. Sections 25.119, 25.121, 25.125, and 25.143.

b. <u>Explanation</u>.

(1) Airworthiness Approval. The standard approach angle assumed as part of the type certification of transport category airplanes is 3 degrees, which coincides with the nominal ILS approach angle. Those evaluations are considered adequate to address approach angles of less than 4.5 degrees. The criteria listed below represent FAA policy for airworthiness approval of steep approach landing capability using an approach angle of 4.5 degrees or more. Additions or deletions to these criteria may be needed to address specific design features. It should be noted in the AFM that the presentation of the steep approach limitations, procedures, and performance information reflects the capability of the airplane to perform steep approaches, but does not constitute operational approval.

(2) Operational Approval. Operational approval to conduct steep approaches in the United States is the exclusive responsibility of FAA Flight Standards Service, and cannot be delegated to FAA Aircraft Certification Service employees, designees, or to foreign civil aviation authorities. FAA Flight Standards Service has assigned this responsibility to the Flight Standardization Board (FSB) with oversight for the airplane type in question. Operational approval will, in part, be based on the results of the airworthiness testing described in this section. Additional testing, for operational concerns, may be combined with the airworthiness testing. Ideally, the testing for operational approval would be conducted by the Flight Standardization Board during the test program for airworthiness certification of steep approach capability.

c. <u>General Criteria</u>.

(1) If approval is sought to conduct steep approaches in icing conditions, compliance with the part 25 requirements applicable to steep approach operations identified below should also be shown for icing conditions.

(2) The following criteria apply when showing compliance with § 25.125 for steep approaches:

(a) The airplane should be in the landing configuration used for steep approaches.

(b) Compliance with the requirement that a stable approach be conducted to a height of 50 feet with a speed not less than V_{REF} (§ 25.125(b)(2)) should be shown with an approach path angle not exceeding the maximum for which approval is sought. The V_{REF} used for steep approaches may be different than the V_{REF} used for normal approaches.

(c) If the parametric method of determining the landing distance is used (see paragraph 19b(3) of this AC), approach angles should be appropriate to the steep approach path angle desired, and the touchdown sink rate for data expansion should be limited to 6 feet per second.

(3) The landing distance established under § 25.125(a) begins at a point 50 feet above the landing surface. If an applicant proposes to use a different height for the beginning of the steep approach landing

distance, this must be done through an equivalent level of safety finding, in accordance with § 21.21(b)(1), or an exemption, in accordance with part 11. This has been done in some steep approach certifications to take advantage of precision approach guidance at an airport that guides the airplane to a height over the runway threshold of less than 50 feet.

(4) Compliance with §§ 25.119 and 25.121(d) should be shown using the configurations and speeds established for steep approach operations.

d. Test Conditions For Reasonably Expected Variations In Approach Speed and Path Angle.

(1) The following additional criteria should be applied to show that the airplane is safely controllable and maneuverable during landing (§ 25.143(a)(5)).

(a) Under calm air conditions, demonstrate that it is possible to complete an approach, touchdown, and stop without displaying any hazardous characteristics in the following conditions:

1 An approach path angle 2 degrees steeper than the steepest approach path angle for which approval is sought at the V_{REF} established for a steep approach; and

2 The steepest approach path angle for which approval is sought at a speed 5 knots lower than the V_{REF} established for a steep approach*; and*~~.~~

3 An approach path angle 1 degree steeper than the steepest approach path angle for which approval is sought at the V_{REF} established for a steep approach. A value less than 1° may be used if appropriate substantiation is provided by the applicant (examples that can be used for substantiation: the maximum FPA deviations at screen height from a large number of approaches conducted by a variety of different pilots, environmental factors considerations or system design considerations).

(b) For ~~both~~ *the* conditions above:

1 The airplane should be loaded to the most critical weight and c.g. combination;

2 The airplane should be in the steep approach configuration;

3 The rate of descent should be reduced to no more than:
3 feet per second at touchdown *for conditions 1 and 2 of above §231d (1)(a);*
6 feet per second at touchdown for condition 3 of above §231d (1)(a), provided sufficient control margin is demonstrated and no exceptional pilot skill is required;

4 Below a height of 200 feet, no action should be taken by the pilot to increase power or thrust, apart from those small changes needed to maintain an accurate approach;

5 After initiating the flare, the longitudinal control should not be used to depress the nose apart from those small changes necessary to maintain a continuous and consistent flare flight path;

6 The flare, touchdown, and landing should not require exceptional piloting skill, alertness, or strength; and

7 To ensure adequate capability for a go-around or down path adjustment, the engines should remain above flight idle power or thrust when stabilized on the approach path. *When conducting*

the 2 degrees steeper approach path angle test condition of paragraph 231d(1)(a)1, the engines can be periodically at flight idle power or thrust ~~when stabilized on the approach path~~ *provided the target airspeed and approach path are maintained*.

NOTE: The 2 degrees steeper approach path angle demonstration is to account for tailwinds on the approach and to take into account necessary corrections back to the desired approach path after inadvertent excursions. The purpose of the test at VREF minus 5 knots is to account for an unnoticed speed decrease during the approach, hence the requirement in paragraph 231d(1)(b)4 for no power or thrust increase to account for the slower speed. *The 1 degree steeper approach path angle demonstration is to account for flight path deviations at screen height (for any reason including piloting, guidance instrument accuracy, and environmental conditions).*

(c) ~~For flight test safety reasons, w~~*W*hen conducting the 2 degrees steeper approach path angle test condition of paragraph 231d(1)(a)1, the pilot may begin to flare the airplane (or reduce the approach angle) at a reasonable height somewhat higher than the normal steep approach ~~flare~~ *screen* height*, but not exceeding 150% of the normal steep approach screen height*. ~~If this is done, it should be shown by analysis that there is sufficient pitch control to arrest the descent rate if the flare were to be initiated at the normal steep approach flare height, keeping in mind the criteria in paragraphs 231d(1)(b)3 and 6~~. *When conducting the test conditions of paragraph 231d(1)(a)2 and 231d(1)(a)3, the pilot must not begin to flare the airplane above the normal steep approach screen height.*

(2) Compliance with § 25.143(b)(1) should be assessed as follows: Demonstrate that the airplane can both safely land and safely transition to a go-around following a failure of the critical engine at any point in the approach under the following conditions:

(a) The steepest approach angle for which approval is sought;

(b) The VREF established for a steep approach; and

(c) The most critical combination of weight and c.g.; and

(d) For propeller powered airplanes, the propeller of the inoperative engine should be in the position it would normally assume without any action taken by the pilot following an engine failure.

(3) The height loss experienced during the maneuver described in paragraph 231d(2) should be determined.

NOTE

At least one demonstration should be done to establish height loss. Additional go-arounds are not required if a proper design review is done to assess the impact of transition to go around and confirm that system would not prohibit the airplane to initiate a go-around from any height.

e. One-Engine-Inoperative Steep Approach.

(1) If approval is sought for one-engine inoperative steep approach capability, the following criteria should be met at the most critical weight and c.g. position, using the configuration and speed established for a one-engine-inoperative steep approach:

(a) The demonstrations identified in paragraph 231d(1) above; and

(b) Demonstrate that the airplane can safely transition to a go-around during a one-engine inoperative steep approach.

f. Airplane Flight Manual.

(1) In accordance with §§ 25.1581, 25.1583, 25.1585, and 25.1587, the following information must be provided in the AFM:

(a) Limitations, operating procedures, and performance information necessary for steep approach operations, including the configuration(s), speeds and flight path angle(s) approved for conducting a steep approach; and

(b) Operating limitations prohibiting initiation of a steep approach:

1 With one engine inoperative, unless the airplane is approved for one-engine inoperative steep approaches; and

2 In forecast or known icing conditions unless the airplane is approved for conducting steep approaches in icing conditions.

(c) A statement in the limitations section that the steep approach limitations, procedures, and performance information reflect the capability of the airplane to perform a steep approach, but do not constitute operational approval to conduct steep approach operations.

(d) The height loss determined in accordance with paragraph 231d(3).

(e) A statement of headwind and crosswind limitations if they are different from those for non-steep approaches. The tailwind limitation is 10 knots or less unless test evidence shows that more than 10 knots is acceptable. Results of the non-steep approach wind component testing may be used to establish the safe headwind and crosswind limitation components. If flight test data and/or analysis show that the sideslip angle capability demonstrated is similar to that shown with the non-steep approach airplane, and the flight characteristics (control forces and deflections, for example) are similar, then the non-steep approach airplane crosswind component test result is considered valid for steep approach.

Appendix 9 Topic 13 Out of Trim Final Report

FAA Aviation Rulemaking Advisory Committee
FTHWG Topic 13
Out-of-Trim Characteristics

Recommendation Report
January, 2017

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Executive Summary

Current FAA Part 25 regulations and guidance pertaining to out-of-trim flight characteristics do not account for modern airplane designs equipped with automatic trimming functions, where the pilots don't have direct control over the longitudinal trimming surface(s). Therefore, it might not be possible for these aircraft to directly comply with the application of a "three-second movement of the longitudinal trim system" as specified in the current §25.255(a)(1).

Over the years the certification authorities have treated these kinds of system designs either by modifying the existing §25.255 via Special Conditions, or via the issuance of Equivalent Level of Safety IP's for auto-trim aircraft, or even by waiving §25.255 demonstrations for these aircraft.

It is the recommendation of the majority of the Flight Test Harmonization Working Group voting members, supported by the FAA representatives, that §25.255 and its guidance in AC 25-7 be modified in a manner that would retain the original intent of the regulations while allowing direct compliance (i.e. no need for Special Conditions or ELOS) for airplanes with or without auto-trim functions.

Background

While the use of auto-trim functions has become more commonplace in modern Transport Category airplane designs, apart from the burden of dealing with Special Conditions or Equivalent Levels of Safety, compliance with the original intent of §25.255 has not been consistently required for all applications. Below are a few examples of recent Part 25 applications equipped with auto-trim functions and the method used to show compliance to the original intent of §25.255:

- Boeing 787 → ELOS finding for §25.255 based on the auto-trim system architecture and additional features and protections.
- Bombardier BD 500 → Certification Memorandum modifying §25.255 in the presence of an auto-trim function.
- Gulfstream G650 → compliance with §25.255 with an auto-trim function (with "three-second movement of the longitudinal trim system" applied as a 3-second command of the pitch trim switch).
- Dassault Falcon 7X and Airbus A350 → IP MoC to §25.255 with an auto-trim function, acknowledging that there was no significant mistrim on that aircraft fitted with pitch autotrim but nevertheless requiring the principles of 25.255(b) to (f) to be fulfilled (interpreted as to be demonstrated "in-trim")

Therefore, the main driving need for this ARAC recommendation is the current lack of a standardized manner of dealing with the original intent of §25.255 in the presence of an auto-trim function.

Details of the task have been defined at the working level in the work plan (Topic 13, Out of Trim Characteristics) resulting from the Phase 1 FTHWG Transport Airplane Performance and Handling

Characteristics – New Task Recommendation Report (Revision A, January 30, 2014), included as Attachment 13A.

A. What is the underlying safety issue addressed by the JAR/FAR? Or alternatively (use the alternative in our appendices)

The §25.255 regulation and guidance were originally created as a direct response to a series of accidents in the 1960's involving transport category jets where a combination of nose down trim commanded by the flight crew in the presence of severe atmospheric disturbances, plus the onset of force reversals or force lightening, induced unrecoverable high speed dives. While in the high speed dive the flight crews found there was not enough elevator power to overcome the horizontal stabilizer mistrim condition to initiate a recovery. Additionally, attempts to re-trim the stabilizer surface were also unsuccessful since the stabilizer actuation stalled under those high aerodynamic loads.

Therefore, §25.255 was envisioned to assure that Part 25 aircraft would retain adequate controllability (in terms of force reversal or force lightening) and maneuverability (in terms of minimum recovery load factor capability) when induced to a high speed dive by any reason (e.g. wind gusts) even when combined with some amount of mistrim (e.g. a three second movement of the longitudinal trim surface for conventional trim systems). Additionally, if trim surface movement is required in order to achieve that minimum recovery load factor, it must be shown that the system is capable of operating at the critical aerodynamic loads associated with that scenario.

B. What is the task ?

To recommend a harmonized means of assessing out-of-trim characteristics for airplanes with auto-trim function and/or neutral/augmented stability functions incorporated into the flight control system, e.g. via closed loop fly-by-wire control laws.

C. Why is this task needed ?

Current flight control system design often includes functions such as automatic stabilizer trim, neutral/augmented longitudinal static stability and/or elevator offload. As a consequence of these types of system architecture, in many circumstances the flight crew has no direct control over the horizontal stabilizer position.

However, §25.255 and AC 25-7C require some flight tests to be executed with a pre-determined amount of mistrim. Moreover, the mistrim offset is supposed to be kept constant throughout each flight test point.

In recent programs this conflict between the original means of compliance with §25.255 and the airplane system architecture has been addressed through AMOC or ELOS.

D. Who has worked the task ?

The Flight Test Harmonization Working Group, during Phase 2 activities, has worked the task. Participants in this FTHWG task included:

Airframe Manufacturers:
Airbus, Boeing, Bombardier, Dassault, Embraer, Gulfstream and Textron

Airworthiness Authorities:
FAA, EASA, TCCA (CAAI and JCAB as observers)

Operators:
American Airlines, (Delta Airlines as observer)

Labour Union:
ALPA

E. Any relation with other topics?

The Sidestick Controls – Topic 7 is related to this topic by recommending specific control inceptor force standards applicable to sidestick controls when demonstrating compliance with §25.255(f) and associated guidance for pitch control forces when showing compliance with §25.255(a) and (f). Recommended changes to §25.255 should be integrated with the recommended changes from Topic 7 – Sidestick Controls.

The Envelope Protection – Topic 1 is related to this topic by recommending regulations and criteria for airplanes equipped with a load factor limiting function, a high angle of attack limiting function or a high speed protection function. These functions are mentioned in the recommended revision of §25.255(a) and (e).

The Stability – Topic 6 is related to this topic by defining criteria for airplanes with neutral static stability, which may use auto-trim functions throughout the flight envelope.

Historical Information

A. What are the current regulatory and guidance material in CS-25 and FAR 25?

The current FAA and EASA regulations applicable to this topic are specified in §25.255(a) thru (f). The FAA guidance related to these regulations is specified in AC 25-7C section 33. Out-of-Trim Characteristics - § 25.255. The EASA guidance related to these regulations is specified in CS-25 Book 2 AMC 25.255 - Out-of-trim Characteristics.

B. What, if any, are the differences in the existing regulatory and guidance material CS 25 and FAR 25?

There are no substantive differences between CS-25 and 14 CFR Part 25 regulations, except for an incorrect reference to paragraph "(b)(1)" in §25.255(d) in the FAA regulation (EASA regulation has the correct reference to "(c)(1)" instead).

As for the guidance, AMC 25.255 is more succinct than AC 25-7C section 33, although both achieve the same basic intent. Three notable differences are:

1) The pictorial description of what constitutes acceptable and unacceptable force reversals in AMC 25.255 Figures 1, 2 and 3 is in direct contradiction with AC 25-7C, section 33, Figure 33-1. The FTHWG has concluded that the FAA's Figure is more appropriate.
2) The AMC present specific guidance for dealing with the use of the longitudinal trim system to assist recovery (section 5.1).
3) The AMC present specific guidance for dealing with testing at higher altitudes (section 5.2).

C. What are the existing CRIs/IPs (SC and MoC)?

The list below was taken from the Topic 13 Work Plan written in 2013. Note that the FAA has generated MoC Issue Papers for §25.255 for different projects in the last couple of years.

1) ANAC Issue Paper EV-35 (Project: Embraer, EMB-550 program).
2) TCCA Certification Memorandum CM FT-31 (Project: Bombardier Inc., C-Series program).
3) FAA ELOS Memorandum TC6918SE-T-F-17 (Project: Boeing Company, Model 787-8 program).

D. What, if any, are the differences in the Special Conditions (CRIs/IPs) (SC and MoC) and what do these differences result in?

As discussed in the Background section of this recommendation report, the approaches taken by the various certification authorities were not standardized. They ranged from a waiver from §25.255 based on the system description; to ELOS finding based on compensating safety features; to the complete demonstration of the original §25.255 regardless of the auto-trim function. This lack of harmonized standards resulted in different levels of certification burden to different aircraft manufacturers and authorities. Note that, despite the different certification approaches given to the auto-trim functions, there are no known airworthiness issues with any of the aforementioned applications regarding handling characteristics and maneuvering capability in the high speed regime.

Consensus

During the initial Topic 13 face-to-face meeting (June 2015) and subsequent e-mail exchanges the FTHWG participants discussed three different proposals to accommodate auto-trim equipped aircraft into the existing regulations:

1) Adaptation of existing §25.255(a) thru (f) to require the complete set of demonstrations for airplanes with auto-trim system that could not otherwise directly comply with the three second trim movement specified in §25.255(a)(1). This proposal is similar to TCCA Special Condition to the Bombardier BD 500 project.
2) Inclusion of a new §25.255(g) exempting airplanes with auto-trim and other compensating features from the specific demonstrations of §25.255(a) thru (f). This proposal is similar to the FAA ELOS to the Boeing 787-8 project.
3) Adaptation of existing §25.253(a)(4)(ii) Upset Recovery to supersede §25.255 for auto-trim equipped aircraft. This proposal is similar to the EASA historical approach with Airbus projects.

An intermediate poll was held during a teleconference in January 2016 to decide on the preferable format. Although Airbus, Dassault and Embraer preferred proposal 2 or 3, the majority of the FTHWG voted for proposal 1, including three authorities (FAA, EASA and TCCA) and four OEM's (Boeing, Bombardier, Gulfstream and Textron). At that point in time, no strong dissenting opinion was voiced against proposal 1 format (although a detailed proposal was yet to be discussed). Therefore, the group decided to concentrate the work in detailing proposal 1 for further discussion.

After additional teleconferences and e-mail exchanges the group held a final poll during a face-to-face meeting in December 2016. EASA and ALPA were not present during this voting, and American Airlines abstained. While the majority of the remaining members voted in favor of the final proposal, consensus was not reached, with Airbus and Dassault voicing concerns for potential increase in the certification burden (from their status quo), including increased flight test risk when conducting the test points associated with the proposed modified §25.255(f) (which may lead to high speed flight testing with the high speed protections disabled or modified). The recommendation below contains the FTHWG majority position. These dissenting opinions could not be resolved in the time available.

Dissenting Position	FTHWG Answer to the Dissenting Positions
Airbus dissenting opinion #1 on proposed modified 25.255(f) is related to the increased certification burden which is considered by Airbus as non-justified and not driven by any safety concern with regards to 250 million flight hours accumulated on Airbus Fly–By-Wire aircraft in-service fitted with auto-trim function.	The majority opinion is that, although the Airbus implementation of auto-trim and previous compliance to applicable certification requirements does not create any safety concerns, not all future implementations of auto-trim function may retain the safety level provided by §25.255(f) for airplanes with conventional trim systems without also retaining the requirement of §25.255(f). As Airbus has expressed, the ability to achieve 1.5g as prescribed by §25.255(f) has been previously satisfied while testing other conditions, including those tests conducted for compliance with §25.253(a) based on the assessment that the auto-trim function does not permit development of a mistrim condition. Guidance is proposed for AC 25-7C paragraphs 33.c(1)(c) and 33.d(1)(a) that explains that

	compliance with §25.255(f) can be shown for such an auto-trim design with no specific level of mistrim. As such, for the Airbus auto-trim design, and those like it, that prevent development of mistrim conditions during normal operation, it is not expected that a significant increase in certification burden will result.
Airbus dissenting opinion #2 on proposed modified 25.255(e) "The demonstrations may also be restricted to limits permitted by flight control system characteristics or other system features, including envelope protections, if failure of those features **is not more probable than remote**". According to Airbus, this statement disregards the fact that High Speed Protection (HSP) function has been accepted in the past (through Special Conditions) with a detected loss of the function more probable than remote, based on compensating factors e.g.: dispatch with HSP system inoperative not allowed, adequate Airplane Flight Manual instructions, failure annunciation to the pilots.	The Airbus dissenting opinion is focused solely on the restrictions or limits that High Speed Protection may apply during compliance with §25.255(e). But, this paragraph is more general to envelope protections that restrict the achievable normal acceleration range below that specified in §25.255(c), including Nz limiting, high speed protection, or AOA limiting (as explained in the proposed AC 25-7C paragraph 33.c(6)). As has been the majority position for all FTHWG Phase 2 topic proposals, when an envelope protection function is used to show compliance with a Subpart B regulation, failure of that function is to be shown Improbable (not more probable than remote). This is considered to be consistent with the intent of §25.21(e) and compliance with §25.672(c) for active flight control systems as described in AC 25.672-1, where in paragraph 4.b(1) it states that airplanes having a loss of active control system probability greater than 10^{-5} per flight hour shall meet all applicable Part 25 requirements with the system inoperative. Recent FAA Issue Paper and TCCA Certification Memorandum Special Conditions for use of High Speed Protection when determining the minimum margins between V_C/M_C and V_D/M_D for compliance with §25.335(b), and the minimum margins between V_{MO}/M_{MO} and V_{DF}/M_{DF} indirectly through §25.1505, have allowed credit for High Speed Protection only if failure of the function is shown to be Improbable and annunciation of the failure is provided to the pilots. This proposal is considered to be consistent with the current certification standards applied to new airplane types equipped with a high speed protection function and the permissible failure rate of the function when it is used to show compliance.
Dassault dissenting opinion on proposed 25.255(f) requirement for a demonstration in flight test of the capability to achieve at least 1.5g <u>at</u> VDF/MDF: since reaching such very high Mach number with HS protection active is only achievable as a result of high front wind encounters (as the one defined for 25.335(b)(2)) it appears sufficient to demonstrate the 1.5g capability up to the highest speed achievable through the 25.253 upsets. Requiring the demonstration to be made <u>at</u> VDF/MDF would increase the number of flight test dives up to MDF which would increase flight test risks without significantly increasing the global safety (cf. Airbus 1st dissenting opinion). We acknowledge that minimum HQ (absence of control reversal and ability to safely return to the normal flight envelope) has to be demonstrated, by flight test, up to	The majority opinion is that it is appropriate to apply the §25.255(f) requirement to V_{DF}/M_{DF} even if the only way to reach those speeds with protection systems active is as a result of a large head-on wind encounter or potentially as a result of high altitude upsets more extreme than those defined in AC 25-7C paragraph 32.c for compliance with §25.253. Without application of this existing regulation to airplanes with High Speed Protection and Auto-trim systems, there would be no requirement to demonstrate "at least 1.5g" recovery capability (with or without mistrim) from flight conditions at the applicant's selected V_{DF}/M_{DF} at the most adverse weight and cg in accordance with 25.21(a). Also see the response to the similar Airbus dissenting opinion regarding increased flight test burden.

MDF, which can be done only with high speed protection disabled. Furthermore, the definition of the atmospheric perturbations referred to in new 25.255(a)(2) and in AC §33c(1)(b) is, in our opinion, not really appropriate and the way these perturbations are supposed to be used is too vague and should be further discussed.	The proposed means of compliance for mistrim conditions associated with atmospheric disturbances in §25.255(a)(3) is consistent with that used by Bombardier when showing compliance with similar TCCA certification memorandum for the C-Series. These are well defined gust and shear profiles used to assess margins between V_C/M_C and V_D/M_D. These gusts and shears are identified as an acceptable level of atmospheric disturbance encounter to be assessed by analysis. As this is advisory material, other means of compliance can be proposed by the applicant if considered more appropriate.

Recommendation

It is the recommendation of the majority of the FTHWG that the FAA modifies the existing §25.255(a) thru (f) regulations and their guidance in AC 25-7 section 33 to accommodate the following:

- The demonstration of §25.255 should be required for any type of airplane, including those with auto-trim functions, so that the original intent of the regulation is fully retained.
- Therefore the wording in §25.255(a)(1) should be amended to acknowledge automatic trim system designs where pilots can manually change the longitudinal trim state of the airplane but don't directly command trim surface movement.
- §25.255(a) should be broadened to cover not just an out-of-trim condition encountered during autopilot operation, but also that applied by the automatic trim function during encounters with expected levels of atmospheric disturbance and normal maneuvering in high speed cruising conditions.
- Auto trim and Auto Pilot systems should be assessed for any residual and transient mistrim condition, including those derived from atmospheric disturbances.
- Since certain envelope protections may restrict the range of maneuvering stability testing prescribed by §25.255(a), if credit for these systems is taken when complying with §25.255, a minimum level of reliability of such functions should be mandated.
- The modified §25.255 should also acknowledge the presence of envelope protection features, such as high speed protection, normal load factor protection, high angle of attack protection and pitch attitude protection that may interfere with the required demonstrations.
- In order to retain the intended 1.5g capability at V_{DF}/M_{DF} §25.255(f) guidance should allow disabling or modifying the high speed protections to allow achieving those speeds.

These recommendations will primarily affect Part 25 OEM's with future auto-trim aircraft. The resulting issues for these OEM's will vary according to their respective status quo, in regards to §25.255 compliance. For instance, if an OEM is already showing compliance to Special Conditions similar to those issued by TCCA, there will be no issues. If, on the other hand, an OEM is currently exempted from §25.255 demonstrations (e.g. via an ELOS or waiver) there will be increased burden in certification (reports), analysis (residual mistrim determination), fault tree analysis (reliability of the auto-trim function), flight tests (additional test points on top of §25.253 demonstrations and high speed Subpart C demonstrations) and flight test setup (modified or disabled high speed protections).

A. Rulemaking

1. What is the proposed action?

It is recommended that modifications to the FAA and EASA Part 25 Subpart B regulations be made as contained in Attachment 13B.

2. What should the harmonized standard be?

See Attachment 13B for the recommended changes to current FAA and EASA Part 25 regulations.

3. How does this proposed standard address the underlying safety issue?

This proposal standardizes the way the intent of the original §25.255 is to be applied for auto-trim aircraft as well as conventional aircraft.

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

It maintains the same level of safety. Because auto-trim equipped aircraft cannot directly comply with the current §25.255(a)(1) three second movement of the longitudinal trim system, some of these aircraft have been demonstrating equivalent levels of safety to §25.255, either by formal ELOS finding processes or by the various similarities between the §25.255 maneuvers and the §25.253 maneuvers and Subpart C demonstrations. The proposed rule simply expands the existing standard for aircraft with auto-trim and envelope protections.

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

It maintains the same level of safety. Because auto-trim equipped aircraft cannot directly comply with the current §25.255(a)(1) three second movement of the longitudinal trim system, some of these aircraft have been demonstrating equivalent levels of safety to §25.255, either by formal ELOS finding processes or by the various similarities between the §25.255 maneuvers and the §25.253 maneuvers and Subpart C demonstrations. The proposed rule simply expands the existing standard for aircraft with auto-trim and envelope protections.

6. Who would be affected by the proposed change?

These recommendations will primarily affect Part 25 OEM's with future auto-trim applications, either new aircraft or derivatives.

7. Does the proposed standard affect other HWG's and what is the result of any consultation with other HWGs?

The proposed standard does not affect other HWG.

However, there have been discussions in the FTHWG regarding the precise definitions of V_{DF}/M_{DF} versus V_D/M_D. These discussions were inconclusive and they were triggered by a passage of AC 25-7C section 32a.(6) which presents an interpretation §25.1505 linking the §25.253 demonstrations to the §25.335(b) demonstrations in terms of margins to V_{MO}/M_{MO}. It is recommended that Flight Test Harmonization Working Group and the Structures Harmonization Working Group discuss this issue.

B. Advisory Material

1. Is existing FAA advisory material adequate? If not, what advisory material should be adopted?

The current FAA advisory material is not adequate. The recommended changes to the regulations, including acknowledgement of auto-trim functions and envelope protections that might interfere with the §25.255 demonstrations, calls for advisory material changes to FAA AC 25-7C. Proposed changes to FAA AC25-7C are included in Attachment 13C.

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

FAA AC 25-7C section 33. Out-Of-Trim Characteristics - § 25.255.

EASA CS-25 Book 2 AMC 25.255 - Out-of-trim Characteristics.

Economics

A. What is the cost impact of complying with the proposed standard (it may be necessary to get FAA Economist support to answer this one)?

It is expected that the resulting cost impact for the OEM's will vary according to their respective status quo in regards to §25.255 compliance. For instance, if an OEM is already showing compliance to Special Conditions similar to those issued by TCCA, there will be no significant impact. If, on the other hand, an OEM is currently exempted from §25.255 demonstrations (e.g. via an ELOS or waiver) there will be increased burden in certification (additional reports), analysis (residual mistrim determination), fault tree analysis (reliability of the auto-trim function), flight tests (additional test points on top of §25.253 demonstrations and high speed Subpart C demonstrations) and flight test setup (modified or disabled high speed protections).

B. Does the HWG want to review the draft NPRM prior to publication in the Federal Register?

Yes.

ICAO Standards

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

There are no current ICAO Annex 8 standards regarding Airworthiness of Aircraft for Large Aeroplanes that specifically address designs with auto-trim functions, nor any standards specifically addressing out-of-trim conditions.

Attachment 13A: Phase 1 Final Report

Work Plan – Out-of-Trim Characteristics

1. What is the task?
To recommend a harmonized means of assessing out-of-trim characteristics for airplanes with auto-trim function and/or neutral/augmented stability functions incorporated into the flight control system, e.g. via closed loop fly-by-wire control laws.
2. Who will work the task?
The Flight Test Harmonization Working Group (FTHWG) will have primary responsibility for this task.
3. Why is this task needed? (Background information)
Current flight control system design often includes functions such as automatic stabilizer trim, neutral/augmented longitudinal static stability and/or elevator offload. As a consequence of these types of system architecture, in many circumstances the flight crew have no direct control over the horizontal stabilizer position. However, §25.255 and AC 25-7C require some flight tests to be executed with a pre-determined amount of mistrim. Moreover, the mistrim offset is supposed to be kept constant throughout each flight test point. In recent programs this conflict between the original means of compliance with §25.255 and the airplane system architecture has been addressed through AMOC or ELOS.
4. References (existing regulatory and guidance material, including special conditions, CRIs, etc.)
§ 25.255, AC 25-7C, ANAC Issue Paper EV-35 (Project: Embraer, EMB-550 program), TCCA Issue Paper CM FT-31 (Project: Bombardier Inc., C-Series program), FAA ELOS Memorandum TC6918SE-T-F-17 (Project: Boeing Company, Model 787-8 Program).
5. Working method
It is envisioned that at least 1 face-to-face meeting will be needed to facilitate the discussion needed to complete this task. Telecons and electronic correspondence will be used to the maximum extent possible.
6. Preliminary schedule (How long?)
Recommendations to Transport Airplanes and Engines Subcommittee within 6 months of the initiation of work on these tasks.
7. Regulations/guidance affected
§ 25.255, AC 25-7C
8. Additional information

Attachment 13B: Recommended Rulemaking Text

ORIGINAL	***RECOMMENDED***
§25.255 Out-of-trim characteristics.	**§25.255 Out-of-trim characteristics.**
(a) From an initial condition with the airplane trimmed at cruise speeds up to V_{MO}/M_{MO}, the airplane must have satisfactory maneuvering stability and controllability with the degree of out-of-trim in both the airplane nose-up and nose-down directions, which results from the greater of—	(a) From an initial condition with the airplane trimmed at cruise speeds up to V_{MO}/M_{MO}, the airplane must have satisfactory maneuvering stability and controllability with the degree of out-of-trim in both the airplane nose-up and nose-down directions, ~~which results from the greater of~~ consistent with the design and normal operational characteristics of the longitudinal trim function, including —
(1) A three-second movement of the longitudinal trim system at its normal rate for the particular flight condition with no aerodynamic load (or an equivalent degree of trim for airplanes that do not have a power-operated trim system), except as limited by stops in the trim system, including those required by §25.655(b) for adjustable stabilizers; or	(1) For airplanes with a longitudinal trim function where the pilot directly adjusts the longitudinal trim surface position or otherwise affects the longitudinal trim state, ~~A~~ a three-second ~~movement~~ application of the ~~longitudinal~~ trim ~~system~~ function at its normal rate for the particular flight condition with no aerodynamic load (or an equivalent degree of trim for airplanes that do not have a power-operated trim system), except as limited by stops in the trim system, including those required by § 25.655(b) for adjustable stabilizers, or as limited by other design features in the system; ~~or~~
(2) The maximum mistrim that can be sustained by the autopilot while maintaining level flight in the high speed cruising condition.	(2) The maximum mistrim that can be sustained by the autopilot while maintaining level flight in the high speed cruising condition~~.~~; and (3) For airplanes with a longitudinal trim function where the pilot does not directly adjust the longitudinal trim surface position and the trim surface is controlled by an automatic function, the maximum mistrim must include any position that the longitudinal trim surface could achieve during expected atmospheric disturbances and normal maneuvering while in high speed cruising conditions.
(b) In the out-of-trim condition specified in paragraph (a) of this section, when the normal acceleration is varied from +1 g to the positive and negative values specified in paragraph (c) of this section—	(b) In the out-of-trim condition specified in paragraph (a) of this section, when the normal acceleration is varied from +1g to the positive and negative values specified in paragraph (c) of this section--
(1) The stick force vs. g curve must have a positive slope at any speed up to and including V_{FC}/M_{FC}; and	(1) The stick force vs. g curve must have a positive slope at any speed up to and including V_{FC}/M_{FC}; and
(2) At speeds between V_{FC}/M_{FC} and V_{DF}/M_{DF} the direction of the primary longitudinal control force may not reverse.	(2) At speeds between V_{FC}/M_{FC} and any achievable speed (under normal flight control system operation) up to V_{DF}/M_{DF} the direction of the primary longitudinal control force may not reverse.

(c) Except as provided in paragraphs (d) and (e) of this section, compliance with the provisions of paragraph (a) of this section must be demonstrated in flight over the acceleration range—	(c) Except as provided in paragraphs (d) and (e) of this section, compliance with the provisions of paragraph (a) of this section must be demonstrated in flight over the acceleration range--
(1) −1 g to +2.5 g; or	(1) -1g to +2.5g; or
(2) 0 g to 2.0 g, and extrapolating by an acceptable method to −1 g and +2.5 g.	(2) 0 g to 2.0 g, and extrapolating by an acceptable method to -1g and +2.5g
(d) If the procedure set forth in paragraph (c)(2) of this section is used to demonstrate compliance and marginal conditions exist during flight test with regard to reversal of primary longitudinal control force, flight tests must be accomplished from the normal acceleration at which a marginal condition is found to exist to the applicable limit specified in paragraph (b)(1) of this section.	(d) If the procedure set forth in paragraph (c)(2) of this section is used to demonstrate compliance and marginal conditions exist during flight test with regard to reversal of primary longitudinal control force, flight tests must be accomplished from the normal acceleration at which a marginal condition is found to exist to the applicable limit specified in paragraph ~~(b)~~(c)(1) of this section.
(e) During flight tests required by paragraph (a) of this section, the limit maneuvering load factors prescribed in §§25.333(b) and 25.337, and the maneuvering load factors associated with probable inadvertent excursions beyond the boundaries of the buffet onset envelopes determined under §25.251(e), need not be exceeded. In addition, the entry speeds for flight test demonstrations at normal acceleration values less than 1 g must be limited to the extent necessary to accomplish a recovery without exceeding V_{DF}/M_{DF}.	(e) During flight tests required by paragraph (a) of this section, the limit maneuvering load factors prescribed in Secs. 25.333(b) and 25.337, and the maneuvering load factors associated with probable inadvertent excursions beyond the boundaries of the buffet onset envelopes determined under Sec. 25.251(e), need not be exceeded. The demonstrations may also be restricted to limits permitted by flight control system characteristics or other system features, including envelope protections, if failure of those features is not more probable than remote. In addition, the entry speeds for flight test demonstrations at normal acceleration values less than 1 g must be limited to the extent necessary to accomplish a recovery, without exceeding V_{DF}/M_{DF}.
(f) In the out-of-trim condition specified in paragraph (a) of this section, it must be possible from an overspeed condition at V_{DF}/M_{DF} to produce at least 1.5 g for recovery by applying not more than 125 pounds of longitudinal control force using either the primary longitudinal control alone or the primary longitudinal control and the longitudinal trim system. If the longitudinal trim is used to assist in producing the required load factor, it must be shown at V_{DF}/M_{DF} that the longitudinal trim can be actuated in the airplane nose-up direction with the primary surface loaded to correspond to the least of the following airplane nose-up control forces:	(f) In the out-of-trim condition specified in paragraph (a) of this section, it must be possible from an overspeed condition at V_{DF}/M_{DF} to produce at least 1.5g for recovery by applying not more than 125 pounds of longitudinal control force using either the primary longitudinal control system alone or the primary longitudinal control and the longitudinal trim system. If the longitudinal trim system is used to assist in producing the required load factor, it must be shown at V_{DF}/M_{DF}, that the longitudinal trim surface can be actuated in the airplane nose-up direction with primary surface loaded to correspond to the least of the following airplane nose-up control forces:
(1) The maximum control forces expected in service as specified in §§25.301 and 25.397.	(1) The maximum control forces expected in service as specified in Secs. 25.301 and 25.397.
(2) The control force required to produce 1.5 g.	(2) The control ~~force~~input required to produce 1.5g with elevator deflection alone, or as limited by elevator control system characteristics.
(3) The control force corresponding to	(3) The control ~~force~~input corresponding to buffeting or other

buffeting or other phenomena of such intensity that it is a strong deterrent to further application of primary longitudinal control force.	phenomena of such intensity that it is a strong deterrent to further application of primary longitudinal control force.

Attachment 13C: Recommended Guidance Material

AC 25-7 section 33. Out-Of-Trim Characteristics - § 25.255.

a. Explanation. Certain early, trimmable stabilizer equipped jet transports experienced "jet upsets" that resulted in high speed dives. When the airplane was mistrimmed in the nose-down direction and allowed to accelerate to a high airspeed, it was found that there was insufficient elevator power to recover. Also, the stabilizer could not be trimmed in the nose-up direction, because the stabilizer motor stalled due to excessive airloads imposed on the horizontal stabilizer. As a result, a special condition was developed and applied to most part 25 airplanes with trimmable stabilizers. With certain substantive changes, it was adopted as § 25.255, effective with Amendment 25-2. While these earlier problems seem to be generally associated with airplanes having trimmable stabilizers, it is clear from the preamble discussions to Amendment 25-42 that § 25.255 applies "regardless of the type of trim system used in the airplane." Section 25.255 is structured to give protection against the following unsatisfactory characteristics during mistrimmed flight in the higher speed regimes:

(1) Changes in maneuvering stability leading to overcontrolling in pitch.

(2) Inability to achieve at least l.5 g for recovery from upset due to excessive control forces.

(3) Inability of the flightcrew to apply the control forces necessary to achieve recovery.

(4) Inability of the pitch-trim system to provide necessary control force relief when high control force inputs are present.

With the advent of Electronic Flight Control Systems ("Fly-By-Wire"), some airplanes have included automatic longitudinal trim systems whereby the trim surface position is automatically adjusted without direct command from the pilot. Such systems have the ability to minimize or eliminate the potential mistrim of the trimming surface under normal operation. However, depending on the design of the automatic trim system, some level of mistrim may exist at high speed cruise conditions under normal maneuvering conditions or atmospheric disturbances, including those leading to the "jet upsets" described above. It is the intent of this regulation to demonstrate the required maneuvering characteristics in any achievable high speed condition up to V_{DF}/M_{DF} and minimum controllability at V_{DF}/M_{DF} with the level of mistrim that can be expected in service, including any automatic movement, in response to normal maneuvering and atmospheric disturbances expected in the cruise phase of flight.

The maximum achievable speed for maneuvering characteristics demonstration, referred to in sec. 25.255(b)(2), is the maximum speed reached during maneuvers specified for compliance with 25.253(a)(1) in paragraph 32.c. of this AC, conducted with the flight control system and envelope protections operating normally. This speed may be lower than or equal to V_{DF}/M_{DF} at some or all altitudes in the envelope to be approved depending on the criteria used to establish V_{DF}/M_{DF}.

b. Reference Regulation. Section 25.255.

c. Discussion of the Regulation.

(1) Section 25.255(a) is the general statement of purpose. Maneuvering stability may be shown by a plot of applied control force versus normal acceleration at the airplane c.g.. Characteristics need only be

shown for critical out of trim positions, including in trim, where applicable. Mistrim must be set within the design and operational constraints of the longitudinal trim system to the greater of the following:

(a) Section 25.255(a)(l). For airplanes with longitudinal trim systems where the pilot directly adjusts the trim surface position, a 3-second movement of the longitudinal trim system at its normal rate for the particular flight condition with no aerodynamic load, unless otherwise limited by system stops or other design features that restrict trim movement under certain conditions. Since many modern trim systems are variable rate systems, this subsection requires that the maneuver condition be defined and that the no-load trim rate for that condition be used to set the degree of mistrim required. For airplanes that do not have power-operated trim systems, experience has shown a suitable amount of longitudinal mistrim to be applied is that necessary to produce a 30 pound control force, or reach the trim limit, whichever occurs first.

(b) Section 25.255(a)(2). The maximum mistrim that can be sustained by the autopilot while maintaining level flight in the high speed cruising condition. The high speed cruising condition corresponds to the speed resulting from maximum continuous power or thrust, or V_{MO}/M_{MO}, whichever occurs first. Maximum autopilot mistrim may be a function of several variables, and the degree of mistrim should therefore correspond to the conditions of test. In establishing the maximum mistrim that can be sustained by the autopilot, the normal operation of the autopilot and associated systems should be taken into consideration. If the autopilot is equipped with an auto-trim function, then the amount of mistrim that can be sustained, if any, will generally be small. If there is no auto-trim, consideration should be given to the maximum amount of out-of-trim that can be sustained by the elevator servo without causing autopilot disconnect.

(c) Section 25.255(a)(3). For airplanes with a longitudinal trim function where the pilot does not directly adjust the longitudinal trim surface position and the trim surface is controlled by an automatic function, the amount of mistrim should be determined by analysis, accounting for system design, thresholds for automatic trimming, capability of the trim system to move the trim surfaces during the demonstrations and system tolerances. It must also account for any mistrim that may result from normal maneuvering or atmospheric disturbances expected in cruise flight. Maneuvering to normal load factors ranging from 0.8g to 1.3g are considered acceptable in this assessment (Reference: Figure 5 of Appendix 5 of this AC). The gusts and shears of § 25.335(b) and AC 25.335-1A are considered acceptable levels of atmospheric disturbances to assess the maximum out-of-trim condition. If the amount of possible mistrim from paragraphs (a)(2) and (a)(3) is considered negligible and paragraph (a)(1) is not applicable, the testing required by paragraphs (b) through (f) can be conducted with no specific level of mistrim (see paragraph d.(1)(a) below for details).

(2) Section 25.255(b) establishes the basic requirement to show positive maneuvering stability throughout a specified normal acceleration envelope at all speeds to V_{FC}/M_{FC}, and the absence of longitudinal control force reversals throughout that normal acceleration envelope at speeds between V_{FC}/M_{FC} and any achievable speed up to V_{DF}/M_{DF} with the flight control system (including envelope protections) operating normally. (Later subsections (d) and (e) recognize that buffet boundary, envelope protections or other limiting features, and control force limits will limit the normal acceleration actually reached; this does not account for Mach trim gain, etc.)

(a) The out-of-trim condition for which compliance must be shown with § 25.255(b) is specified in § 25.255(a). For the initial trimmed condition before applying the mistrim criteria, the airplane should be trimmed at:

1 For speeds up to V_{MO}/M_{MO}, the particular speed at which the demonstration is being made; and

2 For speeds higher than V_{MO}/M_{MO}, V_{MO}/M_{MO}.

(b) Section 25.255(b)(2) appears to indicate that unstable airplane characteristics would be satisfactory, regardless of the character of the primary longitudinal control force as load factor is increased, as long as the force did not reverse (e.g., from a pull to a push). While such criteria may have merit for evaluating airplanes when starting the maneuver from a trimmed condition, it can be shown that this provides a poor specification for evaluating an airplane's maneuvering characteristics when starting the test from the specified mistrimmed condition. For example, an airplane would be deemed to have unacceptable characteristics with a nose-up mistrim, if while relaxing the large initial elevator push force to increase the load factor to the specified value, the elevator force just happened to cross through zero to a slight pull force at one load factor, and then back through zero to a push force at a higher load factor. Such an airplane's characteristics are clearly superior to one that has a severe elevator force slope reversal, during the same maneuver, but never reaches a zero elevator force condition as the load factor is increased. A literal interpretation of § 25.255(b)(2) would find this airplane to be compliant, while finding the preceding airplane non-compliant because it had a slight reversal of the primary longitudinal control force.

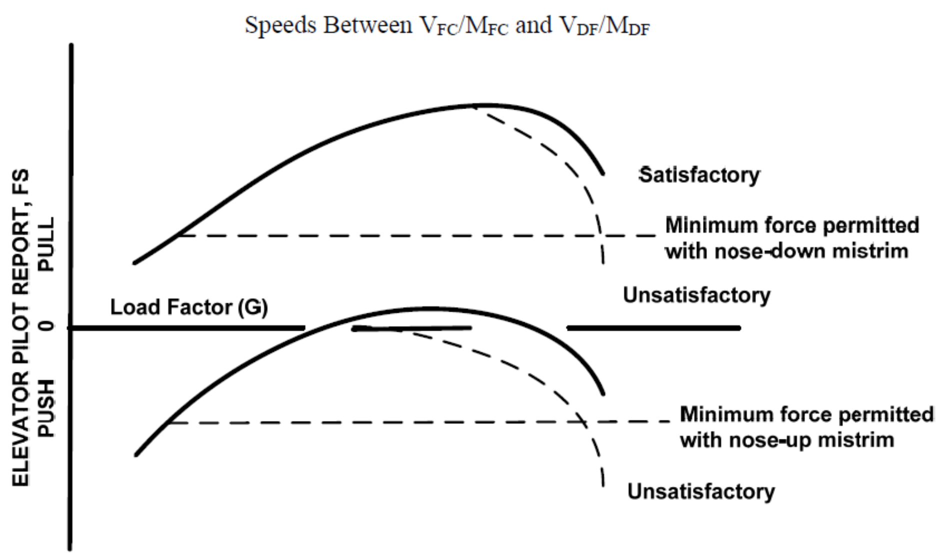
(c) Section 25.255(b)(2) should be interpreted to mean that the primary longitudinal control force, for load factors greater than 1.0, may not be less than that used to obtain the initial 1g flight condition. This is illustrated in Figure 33-1. Slight control force reversals as discussed in paragraph (a), above, will be permitted for speeds above ~~between~~ V_{FC}/M_{FC} ~~and V_{DF}/M_{DF}~~ only if:

1 No severe longitudinal control force slope reversals exist;

2 Any pitching tendency (uncommanded changes in load factor) should be mild and readily controllable; and

3 The airplane's pitch response to primary longitudinal control should be predictable to the pilot.

Figure 33-1. Mistrimmed Maneuvering Characteristics



(3) Section 25.255(c) requires that the investigation of maneuvering stability (§ 25.255(b)) include all attainable normal acceleration values between –l g and +2.5 g. Sections 25.333(b) and 25.337, to which it refers, limit the negative g maximum to 0 g at VD. Section 25.251 further limits the g to that occurring in probable inadvertent excursions beyond the buffet onset boundary at those altitudes where buffet is a factor.

(4) Section 25.255(c)(2) allows for extrapolation of flight test data by an acceptable method. For example, if the stick force gradient between 0 and +2 g agrees with predicted data, extrapolation to -1 g and 2.5 g should be allowed. As described in § 25.255(e), the maneuvering tests may be restricted by flight control system characteristics or features. Likewise, the extrapolation need not extend beyond the limits established by such features.

(5) Section 25.255(d) requires flight tests to be accomplished from the normal acceleration at which any marginal stick force reversal conditions are found to exist to the applicable limits of § 25.255~~(b)~~(c)(1). This requirement takes precedence over the extrapolation allowance described in paragraph (4), above. However, the exceptions described in § 25.255(e) may still restrict the maneuvering tests.

(6) Section 25.255(e), limits the investigation to the required structural strength limits of the airplane and maneuvering load factors associated with probable inadvertent excursions beyond the boundary of the buffet onset envelope. Additionally, it allows the maneuvering demonstrations to be restricted to the limits permitted by flight control system characteristics or features (for example, Nz limiting, high speed protection systems or AOA limiting), if failure of those features is shown to be at least improbable (not more probable than remote). It also accounts for the fact that speed may increase substantially during test conditions in the -1 g to +1 g range. It limits the entry speed to avoid exceeding VDF/MDF.

(7) Section 25.255(f) requires that in the out-of-trim condition specified in § 25.255(a), it must be possible to produce at least 1.5 g during recovery from the overspeed condition of VDF/MDF. For this demonstration, flight envelope protections may be disabled or modified to allow reaching VDF/MDF. The objective of this test is to demonstrate that the airplane and its flight control system are capable of producing 1.5 g during recovery from an overspeed condition, even if a protection system would normally act to deter or prevent such an overspeed encountered due to upsets similar to those used for compliance with Section 25.253(a). This could include more extreme upsets or large horizontal wind shear or gusts that result in momentary exceedences of the normally achievable airspeed with the protections operating normally. If adverse flight characteristics preclude the attainment of this load factor at the highest altitude reasonably expected for recovery to be initiated at VDF/MDF following an upset at high altitude, the flight envelope (c.g., VDF/MDF, altitude, etc.) of the airplane should be restricted to a value where 1.5 g is attainable. Inability to attain 1.5g due to encountering deterrent buffet or envelope protection is not considered an adverse flight characteristic. Although a pilot commanded trim input may be used to assist in producing the required normal acceleration of 1.5 g, it is not acceptable for recovery to be completely dependent upon the pilot commanded trim input. It should be possible to produce at least 1.2 g by applying not more than 125 pounds of longitudinal control force for a conventional control wheel or 50 pounds for a side stick using the primary longitudinal control alone. If trim surface movement must be used for the purpose of obtaining 1.5 g, whether commanded by manual pilot trim inputs or by the automatic trim system, it must be shown to operate with the primary control surface loaded to the least of three specified values.

(a) The force resulting from application of the pilot limit loads of § 25.397. ~~(300 lbs.)~~

(b) The control input ~~force~~ required to produce 1.5 g with elevator deflection alone, or as limited by elevator control system characteristics, including elevator command limits or actuator hinge moment capability. ~~(between 125 and 300 lbs.)~~

(c) The control input ~~force~~ corresponding to buffeting or other phenomena of such intensity that it is a strong deterrent to further application of primary longitudinal control force.

d. Procedures.

(1) Compliance is determined by the characteristics of Fs/g (normally a plot). Any standard flight test procedure that yields an accurate evaluation of Fs/g data in the specified range of speeds and acceleration should be considered for acceptance. Bounds of investigation and acceptability are set forth in the rule and in discussion material above, and broad pilot discretion is allowed in the selection of maneuvers.

(a) For airplanes that include a design that provides automatic trimming under all cruise flight conditions (including auto-flight), the amount of mistrim should be determined by analysis, accounting for system design, thresholds for automatic trimming, and system tolerances. It must also account for any mistrim that may result from normal maneuvering or atmospheric disturbance expected in cruise flight. If the possible mistrim is considered negligible (and paragraph (a)(1) is not applicable) the testing required by paragraphs (b) through (f) can be conducted with no specific level of mistrim. Alternatively, if the amount of mistrim is not negligible, it would be considered acceptable to conduct the flight testing with no specific mistrim if it can be shown by analysis that, (1) the level of mistrim does not affect the maneuvering characteristics (Fs vs g) of the airplane (e.g., a maneuver demand control system) and (2) the maneuvering capability of 1.5g demonstrated during flight tests for §25.255(f) would still be possible if the mistrim was present at the start of the recovery (this could be shown by demonstrating controllability beyond 1.5g during flight test and adjusting the peak Nz achieved by the effect of the mistrim on pitching moment, or by showing sufficient margin in elevator authority during the flight tested recovery at 1.5g to offset the possible level of mistrim and still generate 1.5g).

(b) The flight testing for § 25.255(b) is required at achievable airspeeds up to V_{DF}/M_{DF} (established in accordance with §25.253(a)), with the flight control system (including envelope protections) operating normally. While conducting these tests, the airplane should be accelerated from a level flight condition at V_{MO}/M_{MO} (or any lower initial airspeed with the level of mistrim established with paragraph (a) above) using up to Maximum Continuous Thrust to the target airspeed. Testing should be conducted with the flight control system operating normally to accurately present the airplane's maneuvering characteristics. Upset maneuvers similar to those used to establish the achievable overspeed conditions during certification tests for § 25.253(a) may be necessary to achieve the airspeed for the maneuvering characteristics demonstration. If full forward pitch control input is required to maintain the target airspeed after it is achieved, no pushover maneuver is possible. A wings-level pull-up or constant speed/Mach wind-up turn maneuver to the extent required for the maneuver should be accomplished from this condition with the control system operating normally, including any automatic trim surface movement.

(c) The flight testing for § 25.255(f) is required at V_{DF}/M_{DF} with the flight control system operating normally, except that flight envelope protections may be disabled or modified if necessary to allow reaching V_{DF}/M_{DF}. While conducting these tests, the airplane should be accelerated from a level flight condition at V_{MO}/M_{MO} (or any lower initial airspeed with the level of mistrim established with paragraph (a) above) using up to Maximum Continuous Thrust until V_{DF}/M_{DF} is achieved. A wings-level pull-up maneuver to at least 1.5g should be accomplished from this condition with the control system operating normally, including any automatic trim surface movement. Recovery capability is generally critical at altitudes where airspeed (V_{DF}) is limiting. If at the highest altitude reasonably expected for recovery to be initiated at V_{DF}/M_{DF} following an upset the maneuver capability is limited by buffeting of such an intensity that it is a strong deterrent to further increase in normal acceleration or an AOA Limit imposed by a High Angle of Attack Limiting Function is reached, some reduction of maneuver capability will be acceptable, provided that it does not reduce to below 1.3 g and that 1.5 g is possible at lower altitudes. The entry speed for flight test demonstrations of compliance with this requirement should be limited to the extent necessary to accomplish a recovery without exceeding V_{DF}/M_{DF}, and the normal acceleration should be measured as near to V_{DF}/M_{DF} as is practical.

(d) In accordance with § 25.255(e), the maneuvering characteristics tests for § 25.255(b) and any extrapolation of Nz in accordance with § 25.255(c)(2) need only extend to the lesser of

(i) The levels defined in § 25.255(c);

(ii) The positive load factors associated with probable inadvertent excursions beyond the boundaries of the buffet onset envelopes determined under § 25.251(e); and

(iii) The +/- load factors achievable at the test airspeed with the flight control system operating normally, including high speed protections, AOA limiting, Nz limiting, or other control system limitations.

(2) Investigation Range. Out-of-trim testing should be done at the most adverse loading for both high and low control forces, and the most adverse for the controllability test for §25.255(f). Testing should be accomplished both at the dynamic pressure (q) and Mach limits.

(3) The ability to move the primary controls (including trim), when loaded, should be considered prior to the tests.

Appendix 10 Topic 14 Tailwind/Crosswind Final Report

FAA Aviation Rulemaking Advisory Committee
FTHWG Topic 14
Crosswind & Tailwind

Recommendation Report

19 January, 2017

Table of Contents

Executive Summary

No changes to the regulations are recommended for crosswind and tailwind compliance. An update of guidance is proposed and accepted by a large majority of the FTHWG with some dissenting opinions presented in this report. Despite these dissenting opinions, significant improvements have been achieved by the group towards a clearer and better harmonized guidance.

Background

In-service experience has shown that crosswind and related gusts may be a contributing factor to reduced safety margins if not properly handled by the crew. Following a particular accident where crosswind gusts (and more specifically mountain waves) were identified as a contributing factor, FAA has assigned and ARAC has accepted a tasking which would use the existing Flight Test Harmonization Working Group (FTHWG) to develop and recommend standards of compliance demonstration for Crosswind. Taking the opportunity of this crosswind activity, Tailwind was also added to the scope of work.

Details of the task has been defined at the working level in the work plan (Topic 14, crosswind / Tailwind) resulting from Phase 1.

A. What is the underlying safety issue addressed by the JAR/FAR?

EASA and FAA standards define a minimum of crosswind capability to certify an airplane. This minimum value of 0.2VSR0 (not required to exceed 25 knots) is sufficient to cover a large proportion of operations but current certification practices do not mandate an evaluation of the effects of gusts on airplane handling characteristics during crosswind take-off and landing.

For tailwind above 10 knots, EASA and FAA guidance both consider, although in a different way, occurrences of tailwind gusts above the tailwind limit as defined in the Airplane Flight Manual (AFM).

B. What is the task ?

1) Propose a compliance methodology for Crosswind and Tailwind airplane capability i.e.
- Review current rules and standards for manual T/O and landing
- Harmonize test analysis methodology
- Assess means complementary to flight tests

2) Propose a way to present wind limitations in AFM according to operational practices.

3) If considered relevant, propose an adaptation of the standard ICAO practices applied by airports to communicate wind values to the crews

C. Why is this task needed ?

For crosswind, because the regulation is quite general and only specifies a minimum crosswind value, information on demonstrated crosswind in the AFM very much depends on OEM choice. This variety in OEM choices generates confusion among operators on how to handle practical cases with crosswind involved. The Task is therefore mainly needed to harmonize the presentation of crosswind information in the AFM and to remove risks of different interpretations.

For tailwind above 10 knots, despite both EASA and FAA have a similar intent (i.e. coverage of an airplane experiencing tailwind beyond the tailwind limit), the compliance itself significantly differs, generating concerns for OEM's. The task is therefore needed to harmonize compliance methodology.

D. Who has worked the task ?

This task has been worked with representatives from the following organisations :

- Authorities : FAA, EASA, TCCA, JCAB*, CAAI*
- Manufacturers : Airbus, Boeing, Bombardier, Dassault, Embraer, Gulfstream, Textron
- Airlines : American Airlines, Delta Airlines*
- Labour Union: ALPA

(*) non-voting members

E. Any relation with other topics?

This topic has no direct relation with other FTHWG topics in phase 2.

Historical Information

Refer to Background

A. What are the current regulatory and guidance material CS 25 and FAR 25?

The main regulatory paragraphs concerned by Topic 14 are the following

- 25.21(f)
- 25.233(a)
- 25.237
- 25.1581 to 25.1587

They exist in both CS25 and FAR25

Guidance for crosswind in AFM (25.1581) exists for both CS25 and FAR25

Guidance for crosswind demonstration only exists in FAA Flight Test Guide AC25-7C

Nothing exists in the regulation connected to Tailwind.

Guidance for Tailwind in AFM (25.1581) exists for both CS25 and FAR25.

Guidance for Tailwind demonstration exists only in FAA Flight Test Guide AC25-7C

B. What, if any, are the differences in the existing regulatory and guidance material CS 25 and FAR 25?

When both CS25 and FAR25 regulatory and associated guidance materials exist, they are harmonised. Even if some editorial differences may exist, the technical implications are the same.

C. What are the existing CRIs/IPs (SC and MoC)?

No CRI or IP exist for crosswind.

For Tailwind, an EASA CRI and a TCCA AC (525-008) exist. Both are Interpretative Material describing the process for demonstration of take-off and landing operations with tailwind greater than 10 knots, up to 15 knots included. A FAA IP – MoC – was issued for two manufacturers (Airbus, Bombardier) seeking 15kt tailwind approval.

D. What, if any, are the differences in the Special Conditions (CRIs/IPs) (SC and MoC) and what do these differences result in?

As explained in Background, the intent of tailwind demonstration for getting approval above 10 knots up to 15 knots included is similar between authorities but compliance standards are different. The main differences are summarized in the table below, assuming a 15kt tailwind approval

	FAA	EASA	TCCA
Average tailwind	22.5kt	15kt	15kt
Gusts	No criteria	22.5kt	22.5kt
Glideslope recovery	Qualitative criteria	Glideslope+1.146° (+2% gradient)	No criteria

The FAA standard is considered by some manufacturers as too stringent and not commensurate with the few extra knots claimed above 10kt when no particular demonstration is required up to 10kt of Tailwind. Some concerns about testing an intentionally high Tailwind of 22.5kt average were expressed, due to the gusts above the average of 22.5kt that cannot be avoided during such tests.
Regarding the fact that no particular demonstration is requested up to 10kt of tailwind, the FAA has stated that it anticipates that a normal airplane flight test program will experience tailwinds up to 10 knots. Therefore, an additional specific demonstration of operation in tailwind conditions up to 10kt is normally not necessary.

Consensus

All participants concluded that the existing rules need not be modified and that update of guidance adequately covers the FAA expectations for crosswind and tailwind. Additionally, the group's consensus was that requiring an AFM Crosswind Limitation for all airplanes was not appropriate (except for airplane where limiting conditions were encountered in flight test).

Recommendation

FAA should adopt the proposed harmonized guidance that consists of an update of relevant AC25-7 parts. In particular, FAA should make sure that the proposed standard, established for an airplane control perspective is acceptable for evaluation of engine operations in tailwind conditions. Further, the FAA should liaise with other regulatory authorities to ensure consistent implementation in their jurisdictions.

A. Rulemaking

1. What is the proposed action?

No changes to the regulations are proposed.

2. What should the harmonized standard be?

N/A

3. **How does this proposed standard address the underlying safety issue (identified under #1)?**

N/A

4. **Relative to the current FAR, does the proposed standard increase, decrease, or maintain the same level of safety?**

N/A

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

N/A

6. **Who would be affected by the proposed change?**

N/A

7. **Does the proposed standard affect other HWG's and what is the result of any consultation with other HWGs?**

N/A

B. Advisory Material

1. Is existing FAA advisory material adequate? If not, what advisory material should be adopted?

FTHWG recommends an update of existing guidance to improve clarity and consistency regarding compliance demonstration for tailwind beyond 10 knots and crosswind.

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

N/A

Economics

A. What is the cost impact of complying with the proposed standard ?

N/A

B. Does the HWG want to review the draft NPRM prior to publication in the Federal Register?

N/A

ICAO Standards

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

ICAO Annex 8 for Airworthiness of Aircraft, Part III for Large Aeroplanes includes Flight standards in Chapter 2, including flying qualities standards in Section 2.3. These ICAO standards are qualitative in nature and do not specifically address crosswind or tailwind standards or demonstrations. The proposed guidance changes associated with this task are not considered to be in conflict with the ICAO standard.

Attachment 1A Recommended Rulemaking Text

As previously expressed, FTHWG agreed that updating or enriching existing rules is not needed.

Rationale for not changing the rule

- Existing rules governing crosswind demonstration - 25.21(f), 25.233 & 25.237– should remain unchanged. Demonstrating a crosswind capability of 0.2VSR0 (and not more than 25kt) on a dry runway is sufficient for certifying an airplane. The rule indeed provides a minimum for certifying an airplane. It constitutes a reasonable balance between a value of crosswind representative of a large proportion of airplane operations and the difficulty for an OEM to find a suitable crosswind for performing representative compliance tests in time for certification.

- Existing rules governing AFM – 25.1581 to 25.1587 – and guidance associated to 25.1581 are suitable : if the crosswind demonstrated as per 25.237 is not limiting, the demonstrated crosswind needs not be presented in the limitation section of the AFM. As the residual airplane control authority can still be large when showing compliance to the minimum crosswind specified in 25.237, imposing the demonstrated crosswind as limiting would unduly penalise OEM's not able to test their airplane with strong crosswind above 25.237 requirement up to a value considered limiting.
  An OEM can nevertheless still decide to declare the demonstrated crosswind in the limitation part of the AFM and declare it limiting.

- It is not necessary to impose that an approved part of the AFM provides a crosswind limitation, unless the actual crosswind limit was reached in flight tests because :

  - Among the known safety cases, none would have been appropriately mitigated by providing a limitation

  - In order not to unduly penalise OEM's that have not been successful in finding a strong crosswind for TC, providing a limiting crosswind value in AFM may require large extrapolations beyond the demonstrated crosswind. This may necessitate the use of simulation and analysis, but simulation capability is different in between OEM's : this would therefore introduce competitive disadvantage for no obvious safety benefit.
    Furthermore, simulation is not considered by some authorities – FAA, TCCA – as a valid MoC for establishing a demonstrated crosswind value beyond what was experienced in flight, not even speaking about defining a limitation.

- Current status for tailwind was considered acceptable. The challenges are not due to the absence of rule but to differences in guidance.

Attachment 1B Recommended Guidance Material

FTHWG has worked on an update of the guidance for both crosswind and tailwind whose rationale is summarized hereafter.

Rationale for crosswind guidance update

The fact that 0.2VSR0 is an averaged value is clearly stated for the sake of clarity.

The averaged value is clearly expressed as a mathematical value to avoid misinterpretations.

The data processing and associated rationale is explained in the guidance itself.

In order to answer the primary reason for which FTHWG was tasked, the guidance is updated to specify that OEM's need to assess how airplane handling characteristics in crosswind are affected by gusts when documenting the maximum demonstrated crosswind.

Rationale for tailwind guidance update

The proposed update represents a compromise in between two diverging standards for a comparable intent that is to cover occurrences of gusts beyond the tailwind limit defined in AFM.

With the proposal of guidance update, the coverage of gusts is preserved but is now translated into a reasonable amount of gusts (5 knot) instead of being previously expressed as a factor of the tailwind limit. To account for these gusts, OEM will have to conduct tests at an average wind 5 knot above the foreseen tailwind limit (hence 20 knot for 15 knot tailwind approval). For the purpose of harmonization, this was accepted by all parties except for the FAA who noted that compliance to a related engine-operating regulation (25.939) will require coordination with propulsion specialists from industry and authorities.

In the harmonisation effort made by all parties, the glideslope recovery requirement will be quantified in AC25-7 while it was only qualitative up to now.

Group position on the guidance update

There is globally a large consensus on the update but few dissenting opinions have been expressed

- Embraer, Bombardier and Airbus expressed a dissenting opinion on the fact that the tailwind to be considered for the glideslope recovery criteria also has to consider a 5kt margin in addition to the foreseen tailwind limit. They all consider that to evaluate the glideslope recovery, using a wind equal to the foreseen limit is sufficient, especially now that the glideslope recovery will be harmonized and quantified (while it was not quantified, so far, in AC25-7).
    - FTHWG answer : FTHWG considers the 5 kt margin during the glideslope recovery criteria is reasonable due to the fact that operationally glideslope recovery will not be performed near 10m, where the tailwind is reported. The increased altitude where a glideslope recovery action is expected to occur will also mean that the actual tailwind experienced during the glideslope recovery will also be greater than the 10m height tailwind. An additional 5 kt margin is an acceptable way to account for this difference.

- FAA expressed a dissenting opinion on the modification of tailwind requirement for engine operations : FAA Flight cannot accept the proposed modification without crosschecking it will still satisfy the expectations of FAA propulsion as far as engine operations in tailwind conditions are concerned.
    - FTHWG answer : FTHWG considers the modification from 150% to 5kt as a reasonable compromise satisfying at the same time AA's and OEM's when covering, by flight tests, the aircraft handling during T/O and LDG in tailwind condition. The 5kt are there to account for gusts and make sure that an average wind of at least 20kt will be experienced in flight. The engines will therefore be exposed to similar conditions considered, for the aircraft, as sufficient to clear a 15kt approval. Furthermore, when exposed to 20kt average, the engines will most likely experience peaks of wind of at least 22,5kt.

- TCCA expressed a dissenting opinion on permitting the presentation of the maximum demonstrated crosswind as a set of two values "Average + Gusts" : "TCCA disagrees with the wording proposed in para (c)(3) of the advisory material which allows an "average plus gust" presentation in the AFM. The TCCA position is based on clear feedback from the operators that an "average plus gust" presentation is confusing as operators have different views on how the numbers should be used and whether the average or the gust value is overriding. It is considered that this solution does not meet task 2 of this topic which was to "Propose a way to present wind limitation in the AFM according to operational practices."
    - FTHWG answer : FTHWG considers that an "average plus gust" format, although not the preferred format, can be used. First of all, the "average plus gust" format describes the physical phenomena experienced during the demonstrations, giving indications on the magnitude of the gusts actually encountered. Then, it provides information about gusts in the AFM and as such, can be recognized as a possible answer to one of the NTSB issues. Finally, this format is also comparable to the format of ATIS or tower reports. The confusion it may create, if any, can be mitigated by additional explanations in the AFM on the way to use this format.

The proposed guidance together with the original AC25-7C text is provided here below.

Guidance update for Tail-wind

Current AC25-7C	Proposed update
(9) Tailwind Takeoff and Landing. (a) Wind Velocities of 10 Knots or Less - Approval may be given for performance, controllability, and engine operating characteristics for operations in reported tailwind velocities up to 10 knots without conducting additional flight tests at specific wind speeds. (b) Wind Velocities Greater than 10 Knots. 1 Performance. It is considered that takeoff, rejected takeoff, and landing distances, measured in tailwind conditions greater than 10 knots, are unreliable for use in determining airplane performance. Wind conditions of such magnitude are generally not sufficiently consistent over the length of the runway or over the time period required to perform the test maneuver. The 150 percent operational tailwind factor, required by §§ 25.105(d)(1) and 25.125(f), provides a satisfactory level of safety for operation in tailwinds up to 15 knots when using AFM data based on flight tests in nominally calm wind conditions. **NOTE:** The design requirements of § 25.479 (Level landing conditions) also require the effects of increased contact speeds to be investigated if approval for landings with tailwinds greater than 10 knots is desired.	(9) Tailwind Takeoff and Landing. (a) Tailwind Velocities of 10 Knots or Less - Approval may be given for performance, controllability, and engine operating characteristics for operations in reported tailwind velocities up to 10 knots without conducting additional flight tests at specific wind speeds. (b) Tailwind Velocities Greater than 10 Knots, up to 15 knots. 1 Performance. It is considered that takeoff, rejected takeoff, and landing distances, measured in tailwind conditions greater than 10 knots, are unreliable for use in determining airplane performance. Wind conditions of such magnitude are generally not sufficiently consistent over the length of the runway or over the time period required to perform the test maneuver. The 150 percent operational tailwind factor, required by §§ 25.105(d)(1) and 25.125(f), provides a satisfactory level of safety for operation in tailwinds up to 15 knots when using AFM data based on flight tests in nominally calm wind conditions. **NOTE:** The design requirements of § 25.479 (Level landing conditions) also require the effects of increased contact speeds to be investigated if approval for landings with tailwinds greater than 10 knots is desired.

Small modification

2 <u>Control Characteristics</u>. The test tailwind velocity for demonstrating handling qualities should be equal to the proposed limit tailwind **factored by 150 percent**. The intent of the **150 percent factor** is to provide adequate margin for wind variability in operations, including currency of the wind data, averaging of the data by the measuring and reporting method, and the highly variable nature of higher wind conditions. Therefore, the test wind condition **of 150 percent of** the proposed tailwind limit should be an averaged or smoothed wind speed, not a peak wind speed. Airplane control characteristics should be evaluated under the following conditions with the c.g. at the aft limit and the test mean tailwind velocity equal to the proposed limit tailwind **factored by 150 percent**: (aa) Takeoff. Both all-engines-operating and one-engine-inoperative (i.e., with a simulated failure of the critical engine at the engine failure speed, V_{EF}) takeoffs should be evaluated at a light weight with maximum approved takeoff flap deflection. (bb) Landing. Approach and landing at light weight with maximum approved landing flap deflection. (cc) Determination of the increased ground speed effect on gear vibration or shimmy, and flight director, or autopilot instrument landing system (ILS) approaches, terrain awareness warning system (TAWS) sink rate modes, etc. (dd) **If engine idle power or thrust is increased to account for the increased tailwind velocity, ensure that deviations above the glideslope are recoverable.**	2 <u>Control Characteristics</u>. The test tailwind velocity for demonstrating handling qualities should be equal to the proposed limit tailwind increased by 5 knots. The intent of the 5 knots increase is to provide adequate margin for wind variability in operations, including currency of the wind data, averaging of the data by the measuring and reporting method, and the highly variable nature of higher wind conditions. Therefore, the test wind condition 5 knots higher than the proposed tailwind limit should be an averaged or smoothed wind speed, not a peak wind speed (Refer to Section 7. 30. e. (c) 7 - Guidance to 25.237 for explanation on averaged crosswind speed, to be adapted to tailwind). Airplane control characteristics should be evaluated under the following conditions with the c.g. at the aft limit and the test mean tailwind velocity equal to the proposed limit tailwind increased by 5 knots : (aa) Takeoff. Both all-engines-operating and one-engine-inoperative (i.e., with a simulated failure of the critical engine at the engine failure speed, V_{EF}) takeoffs should be evaluated at a light weight with maximum approved takeoff flap deflection. (bb) Landing. Approach and landing at light weight with maximum approved landing flap deflection. (cc) Determination of the increased ground speed effect on gear vibration or shimmy, and flight director, or autopilot instrument landing system (ILS) approaches, terrain awareness warning system (TAWS) sink rate modes, etc. (dd) It should be demonstrated that deviations above the glideslope are recoverable. In particular, it should be demonstrated that the approach speed can be maintained, in tailwind conditions, on a glide path that is 1° steeper than a typical 3° glideslope. This can be shown by analysis. Whatever method is used for the glideslope recovery demonstration, the actual tailwind (i.e. without correction to 10 meters height) need not be higher than the proposed tailwind limit increased by 5 knots.

Large modification

3 Weight Limits. Consistent with the requirements of §§ 25.105(d)(1) and 25.125(f), the maximum takeoff and maximum quick turnaround weights should be determined using brake energies and tire speeds, as appropriate, calculated with the limit tailwind velocity factored by 150 percent. 4 Engine Operating Characteristics. Satisfactory engine operation should be demonstrated at the limit tailwind velocity **factored by 150 percent**. The demonstrations should include: (aa) Zero groundspeed operation. (bb) Takeoff power or thrust setting procedure used for AFM performance (typically completed by approximately 80 knots), both manually and automatically (autothrottle). (cc) Reverse thrust operations. 5 Airplane Flight Manual. The AFM should contain a statement that the limitation for tailwinds greater than 10 knots reflects the capability of the airplane as evaluated in terms of airworthiness but does not constitute approval for operation in tailwinds exceeding 10 knots.	3 Weight Limits. Consistent with the requirements of §§ 25.105(d)(1) and 25.125(f), the maximum takeoff and maximum quick turnaround weights should be determined using brake energies and tire speeds, as appropriate, calculated with the limit tailwind velocity factored by 150 percent. 4 Engine Operating Characteristics. Satisfactory engine operation should be demonstrated at the limit tailwind velocity increased by 5 knots. The demonstrations should include: (aa) Zero groundspeed operation. (bb) Takeoff power or thrust setting procedure used for AFM performance (typically completed by approximately 80 knots), both manually and automatically (autothrottle). (cc) Reverse thrust operations. 5 Airplane Flight Manual. The AFM should contain a statement that the limitation for tailwinds greater than 10 knots reflects the capability of the airplane as evaluated in terms of airworthiness but does not constitute approval for operation in tailwinds exceeding 10 knots.

Large modification

Guidance update for crosswind

Current AC25-7C	Proposed update
Directional Stability and Control - § 25.233. (1) Explanation. None. (2) Procedures. Taxi, takeoff, and landing should be conducted in all configurations under normal operating conditions. (a) There may be no uncontrollable ground-looping tendency in 90-degree crosswinds, up to a wind velocity of 20 knots or 0.2 V_{SR0}, whichever is greater (except that the wind velocity need not exceed 25 knots) at any speed at which the airplane may be expected to be operated on the ground. This may be shown while establishing the 90-degree crosswind component required by § 25.237. (b) Landplanes must be satisfactorily controllable, without exceptional piloting skill or alertness in power-off landings at normal landing speed, without using brakes or engine power or thrust to maintain a straight path. This may be shown during power-off landings made in conjunction with other tests. (c) The airplane must have adequate directional control during taxiing. This may be shown during taxiing prior to takeoffs made in conjunction with other tests.	Directional Stability and Control - § 25.233. (1) Explanation. None. (2) Procedures. Taxi, takeoff, and landing should be conducted in all configurations under normal operating conditions. (a) There may be no uncontrollable ground-looping tendency in 90-degree crosswinds, up to an averaged wind velocity of 20 knots or 0.2 V_{SR0}, whichever is greater (except that the wind velocity need not exceed 25 knots) at any speed at which the airplane may be expected to be operated on the ground. This may be shown while establishing the 90-degree crosswind component required by § 25.237. (b) Landplanes must be satisfactorily controllable, without exceptional piloting skill or alertness in power-off landings at normal landing speed, without using brakes or engine power or thrust to maintain a straight path. This may be shown during power-off landings made in conjunction with other tests. (c) The airplane must have adequate directional control during taxiing. This may be shown during taxiing prior to takeoffs made in conjunction with other tests.

Medium modification

e. <u>Wind Velocities -§ 25.237</u>. (1) <u>Explanation</u>. (a) Landplanes. 1 There must be a 90-degree crosswind component established that is shown to be safe for takeoff and landing on dry runways. 2 The airplane must exhibit satisfactory controllability and handling characteristics in 90-degree crosswinds at any ground speed at which the airplane is expected to operate. (b) Seaplanes and Amphibians. 1 There must be a 90-degree crosswind component established that is shown to be safe for takeoff and landing in all water conditions that may reasonably be expected in normal operation. 2 There must be a wind velocity established for which taxiing is safe in any direction under all water conditions that may reasonably be expected in normal operation.	e. <u>Wind Velocities -§ 25.237</u>. (1) <u>Explanation</u>. (a) Landplanes. 1 There must be a 90-degree crosswind component established that is shown to be safe for takeoff and landing on dry runways. 2 The airplane must exhibit satisfactory controllability and handling characteristics in 90-degree crosswinds at any ground speed at which the airplane is expected to operate. (b) Seaplanes and Amphibians. 1 There must be a 90-degree crosswind component established that is shown to be safe for takeoff and landing in all water conditions that may reasonably be expected in normal operation. 2 There must be a wind velocity established for which taxiing is safe in any direction under all water conditions that may reasonably be expected in normal operation.

No modification

(c) Crosswind Demonstration. A 90-degree crosswind component at 10 meters (as required by § 25.21(f)) of at least 20 knots or 0.2 V_{SR0} (where V_{SR0} is for the maximum design landing weight), whichever is greater, except that it need not exceed 25 knots, must be demonstrated during type certification tests. There are two results possible: 1 A crosswind component value may be established that meets the minimum requirements but is not considered to be a limiting value for airplane handling characteristics. This demonstrated value should be included as information in the AFM. 2 A crosswind component value may be established that is considered to be a maximum limiting value up to which it is safe to operate for takeoff and landing. This limiting value should be shown in the operating limitations section of the AFM	(c) Crosswind Demonstration. An averaged 90-degree crosswind component at 10 meters (as required by § 25.21(f)) of at least 20 knots or 0.2 V_{SR0} (where V_{SR0} is for the maximum design landing weight), whichever is greater, except that it need not exceed 25 knots, must be demonstrated during type certification tests. At the same time, the maximum gusts encountered should be established and their effect on airplane handling characteristics in crosswind assessed. There are two results possible: 1 A crosswind component value may be established that meets the minimum requirements but is not considered to be a limiting value for airplane handling characteristics. This demonstrated value should be included as information in the AFM. 2 A crosswind component value may be established that is considered to be a maximum limiting value up to which it is safe to operate for takeoff and landing. This limiting value should be shown in the operating limitations section of the AFM (d) The crosswind component included in AFM, whether limiting or not, should be provided as a single gust included value i.e."XX kt (Gust included)". A set of two values, such as " Average XX kt with gusts up to YYkt", is acceptable although not preferred. Other formats, in particular those not providing information related to gusts, should not be used.

Large modification

(2) Procedures. (a) Configuration. These tests should be conducted in the following configurations: 1 At light weight and aft c.g. (This is desirable; however, flexibility should be permitted.) 2 Normal takeoff and landing flap configurations using the recommended procedures. 3 Normal usage of thrust reversers. Particular attention should be paid to any degradation of rudder effectiveness due to thrust reverser airflow effects. 4 Yaw dampers/turn coordinator On, or Off, whichever is applicable. (b) Test Procedures. Three takeoffs and 3 landings, with at least one landing to a full stop, should be conducted in a 90-degree crosswind component of at least 20 knots or 0.2 V_{SR0}, whichever is greater, except that it need not exceed 25 knots. For each test condition, a qualitative evaluation by the pilot of airplane control capability, forces, airplane dynamic reaction in gusty crosswinds (if available), and general handling characteristics should be conducted. The airplane should be satisfactorily controllable without requiring exceptional piloting skill or strength. If thrust reversers are installed, these landings should be conducted with the thrust reversers deployed as per normal procedures and additional landings should be conducted at the critical reverse thrust/power level to verify that there are no unsatisfactory handling characteristics.	(2) Procedures. (a) Configuration. These tests should be conducted in the following configurations: 1 At light weight and aft c.g. (This is desirable; however, flexibility should be permitted.) 2 Normal takeoff and landing flap configurations using the recommended procedures. 3 Normal usage of thrust reversers. Particular attention should be paid to any degradation of rudder effectiveness due to thrust reverser airflow effects. 4 Yaw dampers/turn coordinator On, or Off, whichever is applicable. (b) Test Procedures. Three takeoffs and 3 landings, with at least one landing to a full stop, should be conducted in a 90-degree crosswind component of at least 20 knots or 0.2 V_{SR0}, whichever is greater, except that it need not exceed 25 knots. For each test condition, a qualitative evaluation by the pilot of airplane control capability, forces, airplane dynamic reaction in gusty crosswinds (if available), and general handling characteristics should be conducted. The airplane should be satisfactorily controllable without requiring exceptional piloting skill or strength. If thrust reversers are installed, these landings should be conducted with the thrust reversers deployed as per normal procedures and additional landings should be conducted at the critical reverse thrust/power level to verify that there are no unsatisfactory handling characteristics.

No modification

(c) Test data. Crosswind data may be obtained from a calibrated flight test wind measurement station, from an airfield wind reporting device, or from any other method acceptable to the FAA. 1 A calibrated flight test wind measurement station located in the vicinity of the liftoff or touchdown point generally provides the most accurate data and is preferable. 2 An airport wind reporting device may also be acceptable provided the device has been calibrated and is located near the runway being used for testing. 3 Crosswind data taken directly from a commercially available inertial or differential GPS based reference system may not be accurate in sideslips and is not accurate on the ground. During landing, filtering may introduce lags making the data incorrect due to wind shear with altitude (i.e., a higher wind value at altitude is “remembered”). Hence this method is considered unsuitable for accurately determining the crosswind during takeoff and landing. 4 Other methods based on the computation of the actual crosswind encountered by the airplane based on on-board measurements are also acceptable. For example, the crosswind can be computed by resolving the difference between true airspeed (from an ADC) and an accurate ground speed measurement (e.g., derived from IRS groundspeed) into the along runway and across runway heading taking into account the airplane heading, track angle and sideslip. 5 No matter which method is used, the wind should be continuously time-recorded throughout the takeoff from brake release (or any low speed above which all data necessary to the computation are available and of sufficient accuracy) to a height of 50 ft, and throughout the landing from a height of 50 ft to termination of the test event (e.g., full stop, touch-and-go, go-around) or any low speed above which all data necessary to the computation are available and of sufficient accuracy. The measured crosswind component should be corrected from the height of the measurement device to a height of 10 meters. The average crosswind at 90 degrees to the runway heading should then be calculated for the above time span. The maximum gust could also be derived during this process, based on the same time span.	(c) Test data. Crosswind data may be obtained from a calibrated flight test wind measurement station, from an airfield wind reporting device, or from any other method acceptable to the FAA. 1 A calibrated flight test wind measurement station located in the vicinity of the liftoff or touchdown point generally provides the most accurate data and is preferable. 2 An airport wind reporting device may also be acceptable provided the device has been calibrated and is located near the runway being used for testing. 3 Crosswind data taken directly from a commercially available inertial or differential GPS based reference system may not be accurate in sideslips and is not accurate on the ground. During landing, filtering may introduce lags making the data incorrect due to wind shear with altitude (i.e., a higher wind value at altitude is “remembered”). Hence this method is considered unsuitable for accurately determining the crosswind during takeoff and landing. 4 Other methods based on the computation of the actual crosswind encountered by the airplane based on on-board measurements are also acceptable. For example, the crosswind can be computed by resolving the difference between true airspeed (from an ADC) and an accurate ground speed measurement (e.g., derived from IRS groundspeed) into the along runway and across runway heading taking into account the airplane heading, track angle and sideslip. 5 No matter which method is used, the wind should be continuously time-recorded throughout the takeoff from brake release (or any low speed above which all data necessary to the computation are available and of sufficient accuracy) to a height of 50 ft, and throughout the landing from a height of 50 ft to termination of the test event (e.g., full stop, touch-and-go, go-around) or any low speed above which all data necessary to the computation are available and of sufficient accuracy. The measured crosswind component should be corrected from the height of the measurement device to a height of 10 meters. The average crosswind at 90 degrees to the runway heading should then be calculated for the above time span. The maximum gust could also be derived during this process, based on the same time span.

No modification

6 With prior agreement from the FAA, it may also be permissible to obtain crosswind data from tower wind reports. However the use of this method should be carefully reviewed to ensure that the measurement sensor is properly calibrated to establish the measurement sensor reference height, to establish that the smoothing characteristics do not produce unacceptable filtering, and that the location of the measurement sensor is appropriate for the takeoff and landing runway(s). Such a method has the disadvantage of not being able to provide the gust value during takeoff and landing.	6 With prior agreement from the FAA, it may also be permissible to obtain crosswind data from tower wind reports. However the use of this method should be carefully reviewed to ensure that the measurement sensor is properly calibrated to establish the measurement sensor reference height, to establish that the smoothing characteristics do not produce unacceptable filtering, and that the location of the measurement sensor is appropriate for the takeoff and landing runway(s). Such a method has the disadvantage of not being able to provide the gust value during takeoff and landing. 7 With the exception of the method described in 6 where the following is not applicable : - the averaged value of wind should be understood as a mathematical average obtained from : Landing: $\frac{\int_{t_{50ft}}^{t_{last\_valid\_data}} Vw_y.dt}{t_{last\_valid\_data} - t_{50ft}}$ Take-off: $\frac{\int_{t_{first\_valid\_data}}^{t_{50ft}} Vw_y.dt}{t_{50ft} - t_{first\_valid\_data}}$ where Vwy is the wind component corrected to 10m height as per 25.21(f) and perpendicular to the runway axis. - the maximum gust derived from test analysis should be of a duration sufficient to interfere with airplane handling characteristics in crosswind. It should be obtained from a centered moving average applied to the test data. The centered moving average should not be of less than 3 seconds in order to be consistent with the filtering standard applied by airports to communicate the gust value. Note however that a 3 second moving average applied on the data collected during the tests may not necessarily provide the same result as airport reported gusts due to differences in data acquisition and reduction methodologies in between flight tests systems and airport system. This filtering also introduces some conservatism in the gust determination to account for the variability of gusts profiles as compared to the ones encountered in flight tests. - If an applicant wants to use a centered moving average below 3 seconds, this should be substantiated on a case by case basis. The moving average should not go below 1 second. 8 If demonstrated crosswind is not considered limiting, an applicant may use a separate and distinctively identified portion of the AFM to provide “unapproved” data regarding airplane crosswind capability beyond the demonstrated level.

Large modification