

Avionics Systems Harmonization Working Group Report - Low Airspeed Alerting Systems for Part 25 Aircraft (Final Report)

Contents

Background	2
Discussion	4
Phase 1 Activity - Working Group Summary	5
Question 1: How much time is needed to alert the crew in order to avoid stall warning or excessive deviation below the intended operating speed?	6
Question 2: What would make the alerting instantly recognizable, clear, and unambiguous to the flightcrew?	8
Question 3: How could nuisance alerts be minimized?	9
Question 4: Could the alerting operate under all operating conditions, configurations, and phases of flight, including icing conditions?	11
Question 5: Could the alerting operate during manual and auto flight?	12
Question 6: Could the system reliability be made consistent with existing regulations and guidance for stall warning systems?	13
Question 7: Are there any regulations or guidance material that might conflict with New Standards?	14
Question 8: What recommended guidance material is needed?	16
Question 9: After reviewing airworthiness, safety, cost, benefit, and other relevant factors, including recent certification and fleet experience, are there any additional considerations that should be taken into account?	18
Appendix 1: Low Airspeed Awareness/Alerting Examples	21
Appendix 2: Expanded Considerations List	22
Appendix 3: Text from Related Requirements and Guidance Material	23
Appendix 4: Relevant Guidance and Regulatory Material	26

Background

The FAA established the Aviation Rulemaking and Advisory Committee (ARAC) to provide advice and recommendations to the FAA administrator on the FAA's rulemaking activities with respect to aviation-related issues.

With respect to low airspeed alerting, the FAA previously revised regulations in the area of flight guidance (autopilot/autothrottle) and performance and handling qualities in icing conditions to improve transport airplane standards for low airspeed protection. Performance and Handling Qualities in Icing Conditions (Amendment 25-121, issued Oct 9, 2007) address handling and low speed protection requirements in icing conditions. In addition:

- In June 2007 the FAA revised Advisory Circular AC 25-11A which includes guidance for low airspeed awareness
- In November 2010 the FAA published the revised rule 25.1322 for flightcrew alerting.

However, as a result of several recent loss-of-control accidents and incidents, the FAA has identified a need for additional low airspeed safeguards, in addition to the regulatory actions that have already been taken.

This report addresses the first task. Under the Transport Airplane and Engine Issues Group (TAEIG), the existing Avionics Systems Harmonization Working Group was assigned to provide information that will be used to develop standards and guidance material for low airspeed alerting systems (LAS). This information may result in standards that complement existing stall warning requirements.

This working group report addresses the following ten (10) low-airspeed alerting technical questions relative to new aircraft designs (Phase 1 — new Part 25 standards), and provides the rationale for their responses.

- (1) How much time is needed to alert the crew in order to avoid stall warning or excessive deviation below the intended operating speed?
- (2) What would make the alerting instantly recognizable, clear, and unambiguous to the flight crew?
- (3) How could nuisance alerts be minimized?
- (4) Could the alerting operate under all operating conditions, configurations, and phases of flight, including icing conditions?
- (5) Could the alerting operate during manual and auto flight?
- (6) Could the system reliability be made consistent with existing regulations and guidance for stall warning systems?
- (7) Are there any regulations or guidance material that might conflict with new standards?
- (8) What recommended guidance material is needed?

- (9) After reviewing airworthiness, safety, cost, benefit, and other relevant factors, including recent certification and fleet experience, are there any additional considerations that should be taken into account?
- (10) Is coordination necessary with other harmonization working groups (e.g., Human Factors, Flight Test)? (If yes, coordinate and report on that coordination.)

A future report from the working group will address similar low airspeed alerting technical questions, relative to existing aircraft designs (Phase 2 activity—retrofit standards). Phase 2 activity will consider, where practical all in-service airplanes engaged in commercial operations under 14 CFR Part 121, 135, or 91. Safety Recommendation A-10-12 from the National Transportation Safety Board (NTSB) recommends requiring these airplanes to have Low Airspeed Alert Systems (LAS) installed that provide redundant aural and visual warnings of an impending hazardous low-speed condition.

Discussion

Previous NTSB investigations resulted in two Safety Recommendations to the FAA; A-10-11 to address Low Airspeed Awareness, and A-10-12, to address Low Airspeed Alert Systems (LAS).

- A-10-11 recommends that the airspeed indicator depict a yellow/amber cautionary band above the low-airspeed cue or airspeed indicator digits that changes from white to yellow/amber as the airspeed approaches the low-airspeed cue per Advisory Circular (AC) 25-11A section 2.3 *Electronic Flight Displays*. Many 14 CFR part 25 aircraft equipped with electronic flight displays currently provide pilots with an amber band on the airspeed display above the low-airspeed cue.
- A-10-12 recommends that for all airplanes engaged in commercial operations under 14CFR Parts 121, 135 and 91K, require the installation of low airspeed alert systems that provide pilots with redundant aural and visual warnings of an impending hazardous low-airspeed condition.

Based on the working group task, the scope of this report is relevant to A-10-12 for low-airspeed Alert Systems (LAS). The release of AC/AMC 25-11A (reference text contained in Appendix 3) provides additional guidance material relevant to low airspeed awareness (A-10-11).

In drafting this report, the working group assumed that the updates to AC 25-1322 would be released before any additional changes to low-airspeed alerting regulations or advisory material are generated. The objective of this report is to be consistent with the draft AC 25-1322, where an “alert” is defined as “a generic term used to describe a flight deck indication meant to attract the attention of and identify to the flight crew a non-normal operational or airplane system condition.”

The group also assumes that similar requirements and advisory material have been or will be generated by the European Aviation Safety Agency (EASA), since this task was assigned to a working group that includes both U.S. and Foreign based regulatory and industry personnel.

Although the group was not tasked with recommending a rule, the group believes that any new rule should consider relevant accidents/incidents, and those should be evaluated with all of the relevant facts and data relating to the contribution of that accident/incident. These should include not only accidents/incidents resulting from the aircraft inadvertent entry into a low-airspeed state, but also incidents in which the aircraft entered a low-airspeed state but the crew successfully recovered using existing systems and procedures to avoid a departure from controlled flight. To support Safety Recommendation A-10-12, the group recommends a thorough analysis of relevant transport category accidents and incidents and whether low airspeed alerting systems played a role, or would have played a role if installed. Consideration of recent recommendations from the FAA-Industry Stall/Stick Pusher Working Group should be taken into account, i.e. “a low airspeed alert may have helped pilots prevent or avoid conditions that can lead to stalls.”

Phase 1 Activity - Working Group Summary

In order to answer the 10 questions tasked to the ARAC, the working group used a combination of knowledge and experience, as well as specific examples of low-airspeed awareness and low-airspeed alerting designs for aircraft certified under 14 CFR Part 25 airworthiness requirements. These examples can be found in Appendix 1, System Descriptions.

Question 8 includes information for consideration when writing new guidance material. As new guidance material is generated from this Phase 1 information, it should be coordinated with the ASHWG and the FTHWG.

Additional related comment from Airbus, regarding proposed guidance material for low airspeed alerting: Airbus opinion is that additional guidance material on low speed alerting, as written in Question 8, is not necessary. See Airbus minority position on Question 8.

Question 1: How much time is needed to alert the crew in order to avoid stall warning or excessive deviation below the intended operating speed?

There is no standardized systematic practice or analytical method currently accepted by industry that determines how “timely” the alert must be for the pilot to intervene and avoid a stall warning and safely recover the airplane. While there is not a clear answer to “how much time,” at least one manufacturer proposes that the alert should be timed such that when slowing at approximately 1 knot per second, following a Low Airspeed Alert and allowing one second recognition for pilot flying or three seconds for autopilot engaged, the pilot can take corrective action to recover airspeed without causing activation of the shaker or disconnect of the autopilot. Additional variables beyond rates of deceleration need to be considered as discussed below.

In addition the assumptions surrounding the indication of a certain margin above stall speed (Ref AC/AMC 25-11A, Paragraph 1.1, 2.1, and 2.3) may not always provide the flight crew with a timely indication of approaching a stall condition, when considering corner conditions (sudden upsets for example), higher than normal flightcrew workload, fatigue, flightcrew confusion, lack of attention and distractions such as multiple alerts that can all contribute to slowed flightcrew response. Most envelope protection systems consider the rate of approaching stall, but the systems in service typically do not consider the slow response of the engine after idling for a long duration. These variables can be listed and analyzed via timeline analysis to identify and determine the assumptions behind timeliness of the alert. Both Appendix 1 and Appendix 2 in this report provide data on the industry approach to rate and trend cueing and alerting.

For an alert to meet its intended function (14 CFR Part 25.1301(a)), and allow the flight crew to respond with an appropriate effect on the airplane, the alert must be timely enough to account for the interval of time needed to attract the flightcrew to the alert, the time for the flightcrew to identify the alert, the time to determine the appropriate actions (if any), the time to respond to the alert, and the aircraft response time to the flightcrew’s control inputs..

14 Code of Federal Regulations (CFR) Part/ Certification Specification 25.1322 (Flightcrew Alerting) requires that alerts be provided in a timely manner. Both 14 CFR Part/CS 25.1322 and CS 25.1302 discuss urgency of alerts and information. Other 14 CFR Part 25 regulations pose similar requirements for timely alerting. Question 7 in this report provides additional information regarding regulations and guidance.

The present assumption is that low airspeed alerting should be timely enough for the flightcrew to take corrective action to recover airspeed without causing a stall warning or excessive speed deviation. However these existing airspeed awareness cues and low airspeed alerts will not provide the desired timeliness in all cases. A review of these design features and how they are triggered in combination with the examination of other timeline variables discussed below will help in determining an appropriate alerting time. Appendix 2 of this document provides examples of trigger events to including the use of predictive airspeed trend/rate information.

The time needed to alert the crew to avoid stall warning or prevent an excessive deviation below the intended operating speed will vary as a function of the specific scenario (e.g., phase of flight), effectiveness of the alerting, state of the flightcrew (workload) and the energy state of the airplane when the alert is needed. A simple time line analysis should be used to help the applicant determine a timely alert, considering both airplane and flightcrew processing and response times. In particular:

- The time line analysis for the airplane should include the time for the alert to be generated, and the time for the airplane to respond to flightcrew actions (e.g. engine spool up time, airplane speed, airplane energy state, and airplane attitude).
- The time line analysis for the flightcrew to detect that an alert has occurred should include: identification of the specific alert, determination of the appropriate action, and the time needed to take the appropriate action. For those conditions where an alert cannot be timely for flightcrew response other mitigations should be considered.

Additional comment from EASA: The timeliness of any alert other than stall warning is debatable, whereas timeliness and adequacy of stall warning is looked at according to deceleration rates required by regulation (14 CFR Part 25.207). The purpose of 14 CFR Part 25.207 is to protect against inadvertent stall.

Additional comment from Boeing: This question implies a specific intended function, asking for the ‘time needed to avoid stall warning’. The purpose of 25.207 is to protect against inadvertent stall, and crew procedures are established to support that. A new alert prior to stall warning may not be designed to alert far in advance to avoid stall warning in all cases, but may only have the intent of informing the flight crew of the low speed condition sooner than stall warning does and getting them to begin recovery actions prior to stall warning. Additionally, the typical small margins between operational speeds and minimum speeds do not provide the luxury of extra time, so designs typically push the alerts away from the operational speeds to avoid nuisances which then yields less ‘time’ for the crew to take action. Tradeoffs between nuisance and timeliness will need to be made in any design.

Question 2: What would make the alerting instantly recognizable, clear, and unambiguous to the flightcrew?

By compliance with the new 14 CFR Part 25.1322 rule and proposed CS 25.1322 alerting must be readily and easily detectable and intelligible by the flightcrew under all foreseeable operating conditions, including conditions where multiple alerts are provided. This theme (instantly recognizable, clear, and unambiguous) is supported throughout the rule language by requirements for alert priority, distinctive symbol coding (e.g. color), limiting the use of alerting colors for non-alerting functions that can interfere with the recognition of actual alerts, minimizing nuisance alerting, and importantly requiring timely attention-getting cues through at least two different senses by a combination of aural, visual, or tactile indications. In addition, other systems which are used in conjunction with alerting may be beneficial to help avoid the stall condition (e.g. Autothrottle Wakeup, Alpha Floor, Tactile Sensory Inputs), AC/AMC 25.1322 describes an acceptable means, but not the only means, for showing compliance with the requirements for transport category airplanes. The FAA will consider other methods of showing compliance that an applicant may elect to present.

Question 3: How could nuisance alerts be minimized?

Per 14 CFR Part 25 25.1322 and CS 25.1322 the alert function must be designed to minimize the effects of nuisance alerts. In particular, it must be designed to prevent the presentation of an alert that is inappropriate or unnecessary.

Per AC/AMC 25.1322 a nuisance alert is defined as “an alert generated by a system that is functioning as designed but which is inappropriate or unnecessary for the particular condition”

Considerations surrounding present methods of minimizing nuisance alerts can be found in Appendix 1 and Appendix 2.

Nuisance alerts can be minimized in several ways:

- Large Margin - Establish a large margin between the normal operating condition and the alert trip point. Example - Setting the speed or angle of attack (AOA) trip point further away from the normal operating condition. However, this also minimizes the margin between alert and stall warning.
- Dynamic Margin - Margins could be changed (made dynamic) in certain conditions.
- Change Input Parameter - Use a different input to set the alert. Example – If an AOA near wings-level stick shaker were used as the trip point, but, that AOA could be reached at normal operating speeds under ‘g’ load, another parameter such as airspeed may need to be used instead (or in addition to). Using body AoA instead of AoA may also be helpful in minimizing nuisance alerts.
- Combination of Input Parameters (“Smart” Alerting) - Use a combination of input parameters to set the alert (e.g., speed, deceleration rate, alpha, alpha rate). Use of a combination may allow better confirmation of the alert trip point, however, this drives more logic, complexity and cost into the design.
- Alert Inhibit - The alert may be inhibited under certain conditions and/or configurations.

There are tradeoffs between minimizing nuisance alerts and providing ‘sufficient’ alert margin to stall warning. In general, the earlier the alert is set, the higher the false alarm rate. And the later the alert is set, the less time the pilot has to recover. The potential for multiplicity of alerts during a low energy state should also be considered.

A given design is developed to provide an alert for a particular scenario or set of scenarios. The design has to be analyzed against these scenarios to determine if the alert is set as expected, not set, or set when not expected (potential nuisance). In the scenario(s) where the alert is set when not expected, a few things must be answered: Is the risk of the nuisance acceptable? Is the alert accurate or inaccurate? Would it lead a flight crew to respond in a manner that could or would make the situation worse? Would the flight crew ignore the alert based on their experience from prior nuisance alerts?

Nuisance alerts can be caught earlier in a new design with thorough analysis. Design scenarios should consider all operating conditions, airplane configurations, phases of flight, and the errors or conditions that will drive the airplane to the alert trip point or those that will drive the stick shaker up toward the operational speed.

What may drive the airplane speed down toward stall warning:

- Normal operational approach speeds. Operational speeds are set with specific regulatory margins.
- Thrust mismanagement, including mismanagement of autoflight modes by the flight crew. Deceleration rates – should the 1 and 3kt/sec rates used in stall warning regulations be considered for low airspeed alerting?
- Turbulence/windshear – what magnitude and duration should be considered?
- Non-normal operations closer to stall warning than usual. e.g., flying V2 speed with engine failure after takeoff
- Icing conditions
- System failure conditions (e.g. air data system failures)
- Scenarios where the flight crew could mis-manage information or other inputs that impact thrust parameters (e.g. improper initialization of the Flight Management System, incorrect speed bug settings)
- System malfunction (e.g. system does not operate as designed or does not operate correctly to pilot input). Example could be where autothrottle inadvertently disconnects without warning or being commanded.
- Partial system failure undetected by pilots.
- Un-commanded autothrust mode change
- Scenarios such as high-altitude flight where the flight envelope is very narrow and the margin between Mmo and Vs is small.

What may drive the stall warning speed up toward current speed:

- Banked turns, pull-up (increased positive g load)
- Icing increments
- Flap/slat or speedbrake operation
- Non-normal airplane configurations (higher angle of attack than usual)
- System malfunction, including erroneous airspeed display

Question 4: Could the alerting operate under all operating conditions, configurations, and phases of flight, including icing conditions?

Yes. A review of the low airspeed awareness, low airspeed alerting, and low energy alerting systems described in Appendix 1 and 2 shows that in general, they operate under most operating conditions, configurations, and phases of flight, including icing conditions. Manufacturers choosing to incorporate such systems have employed a variety of design solutions that reflect their flight deck design philosophy, as well as the applicable regulatory requirements and guidance.

A variety of low airspeed awareness and alerting systems either already exist or are under development for certain fleets of 14 CFR Part 25 airplanes with electronic flight instrument systems. These systems provide low speed awareness and alerting under (to a greater or lesser extent) a variety of operating conditions, configurations, and phases of flight, including icing conditions. For these systems the initial answer to Question 4 is already a qualified “yes”, but there are some conditions where it may be better to inhibit the alert (e.g. takeoff, some commanded avoidance maneuvers), and of course this does not address future systems. In order to provide the final answer a table was developed that identifies a more detailed set of “expanded considerations” related to those listed in the question above was developed. A number of manufacturers have provided information for one or more of their airplane models consistent with the expanded considerations list. This information is presented in Appendix 2, Tables 1 and 2.

Information Received: Airbus, Boeing, Bombardier, Embraer, Beechcraft, Dassault, Gulfstream, Cessna, and Mitsubishi provided the system information shown in Appendix 1. Several of these companies also provided detailed inputs for the tables in Appendix 2. The Appendices indicate that low speed cues, low airspeed alerting, or low energy alerting information are provided via a wide range of methods to flight crews. It should be noted that some existing low airspeed cues do not meet other criteria, such as cueing through at least two different senses by a combination of aural, visual, or tactile attention getting indications. The Bombardier CRJ models provide low speed awareness via a “green line” and low speed cue (barber pole) on the airspeed tape. Boeing provides a comprehensive low speed alerting system in all production models. Airbus provides for the whole flight envelope, a speed scale with an overview of the low speed thresholds based on several layers of automatic high AOA protection. In addition, a low energy aural alert is generated at low altitudes. The EMB Legacy 500 system (in development) will provide low speed aural alerting with consideration of inertial deceleration and flight path angle near the ground. The system information shown in Appendix 1 provides additional details for these and several other airplane models. As noted above, the extent to which several of the systems take into account the various expanded considerations is provided in Appendix 2.

Question 5: Could the alerting operate during manual and auto flight?

Yes. The availability and level of effectiveness of the low-speed alerting system could be the same for manual and auto flight, whether the flight guidance is based on visual or is machine-generated, and it should be independent of visual or instrument flight rules. Thus, the alerting system should be functionally independent of the equipment available to the flightcrew for manual or automatic control. To achieve this independence, the method of detecting an impending low airspeed or low energy hazard must be based on the observed or measured state and or state trajectory of the airplane (i.e., the airplane performance and or performance trend). To the extent this can be achieved, the hazard detection and alerting can be independent of the means of flight control.

The intended function of the low-speed alert is to preclude a stall warning; but the flightcrew must take appropriate action after an alert to change the state of the airplane or to avoid the stall event. Thus, proper crew training to recognize a low airspeed alert and respond appropriately is critical, and should be considered in both the design and the corresponding flight crew operations manual.

If an alert occurs while automatic control is selected, a transducer fault, a system error, or erroneous use of the automation is the most probable cause of the non-normal condition. Additionally, during cruise at high altitudes, it is possible that due to changing weather conditions (increasing temperature, mountain wave, windshear, etc.) or inadequate planning, an airplane could be thrust limited and not be able to maintain the desired altitude and/or airspeed in automatic control. Thus, the crew must be properly trained to understand and use the automation without risk to flight safety; to monitor the system operation for anomalous behavior; and to correct or disarm the automation to address a problem.

Consequently, the means of detecting and resolving the source of an alert will depend on the capability of the equipment available to the crew for manual and automatic control. However, the best design practice includes rigorous safety engineering and human factors in accordance with industry practices and recommendations as stated in question 8 (or existing Certification Review Items / Issue Papers set for specific designs) and the specific guidance set forth in the other sections of this report.

Question 6: Could the system reliability be made consistent with existing regulations and guidance for stall warning systems?

Yes. At the system level 14 CFR Part/CS 25.1309 would apply to the reliability of a Low Airspeed Alerting (LAS) system. This recommendation assumes that a low airspeed alert comes prior to Stall Warning/Flight Envelope Protection/Speed Protection functions and for some cases the Stick Pusher and that these systems have their own SSA in accordance with 14 CFR Part 25.1309. 14 CFR Part/CS 25.1322 requires that the alerts be designed to be reliable and prevent the presentation of an low airspeed alert that is inappropriate or unnecessary.

COMMENT: In this context, the term “reliability” is defined as the conditional probability of a hazard caused by erroneous operation or loss of the Low Airspeed Alerting function (i.e., malfunction or loss-of-function). Integrity and availability are figures of merit commonly used to characterize the probability of undetected errors and continuity-of-function, respectively.

The safety analysis should address the following failure conditions:

- Total loss of the LAS function
- Malfunctioning of the LAS function
 - The low airspeed alert is triggered when not required (nuisance alert)
 - The low airspeed alert does not operate adequately when required (applies to all components of the alerting function, e.g. aural, visual, tactile)

The safety analysis should consider phase of flight, a/c configuration, environmental conditions, and non-normal operating conditions.

The safety objective for the LAS function should be determined in conjunction with the other protection functions (i.e. envelope protection, stall warning etc.). Generally, the safety objective of the LAS function would mainly be driven by the alerting system (including aural/visual attention getters, CAS messages etc.). A minimum safety level for the LAS function should be considered in the system safety assessment.

Nuisance alerts need to be minimized and addressed as part of the analysis.

Question 7: Are there any regulations or guidance material that might conflict with New Standards?

No. Existing standards (see figure 7-1), regulations or guidance material (Appendix 4) do not appear to conflict with the proposed addition of low airspeed alerting in new transport category aircraft. Many current production 14 CFR part 25 aircraft provide low airspeed awareness in the form of an amber band on the airspeed display above the stall warning speed. Some aircraft also provide low airspeed alerting. However, EASA certification memo FT-01 issue 3 Rev A prohibits the display of amber on the airspeed indicator scale for normal and non-normal operations.

The FAA previously revised regulations in the area of flight guidance (autopilot) and performance and handling qualities in icing conditions to improve transport airplane standards for low airspeed protection (in the case of icing, stall warning standards were enhanced).

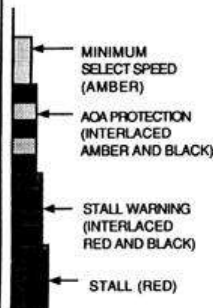
The proposed Low Airspeed Alert functionality is a requirement not addressed by current regulation. AC25-11A provides guidance material addressing display of low airspeed awareness but not alerting. TSO c113 defines display requirements for display of airspeed information on airborne electronic flight displays. Current regulations require equipage of airspeed indicators (14 CFR Part 25.1303(b1)) and stall warning systems (14 CFR Part 25.207(a),(b)). The existing stall warning regulation (14 CFR 25.207) and maneuvering capability free of stall warning (14 CFR Part 25.143(h)) still appear to be adequate relative to stall warning, but may be complemented by additional low airspeed alert requirements.

14 CFR Part 25.1322 meets the intent of NTSB Safety Recommendation A-10-11, requiring that alerting systems provide pilots with redundant attention-getting cues (e.g. aural and visual) of an impending hazardous condition. Also 14 CFR Part 25.1329 (h) Flight Guidance System Rule (11 May 2006) and AC25.1329-1B 17 (July 2006) Para 45b Speed Protection Alerts and Para 57 Speed Protection may partially meet the intent of NTSB Safety Recommendation A-10-12 (the 25.1329 requirements only apply when the airplane's flight guidance system is in use). 14 CFR Part 25.1322 also helps meet the intent by requiring that the flightcrew be alerted using two senses for alerts requiring "immediate awareness." New regulatory or guidance material must be aligned with CFR 25.1322.

Figure 7-1

ASHWG Low Airspeed Alerting Draft Task 7 attachment 1
SAE ARP4102-7 Appendix A Electronic Display Symbolology for EADI/PFD

EADI/PFD

NAME	RECOMMENDED SYMBOL	ACCEPTABLE ALTERNATIVES	REMARKS
27. REFERENCE SPEED			
28. CONFIGURATION LIMIT SPEED			• MAX SPEED FOR CURRENT CONFIGURATION (GEAR AND FLAPS) INCLUDING ABNORMAL CONFIGURATIONS WHENEVER POSSIBLE • THIS SYMBOL SHOULD LOOK THE SAME AS THE STALL WARNING SPEED SYMBOL
29. ENGINE-OUT OPERATING SPEED-CLEAN			• CIRCLE ON THE VERTICAL LINE OF THE SPEED TAPE • BEST LIFT TO DRAG RATIO • "GREEN DOT" SPEED
30. LOW SPEED INDICATIONS			• SYMBOL IS INVERTED IF ORIENTATION OF AIRSPEED SCALE/TAPE HAS LOW NUMBERS AT THE TOP • MINIMUM SELECT SPEED AREA MAY BE FILLED OR AN AMBER OUTLINE • THE FOUR REGIONS OF LOW SPEED INDICATIONS ARE SHOWN GROUPED AS ONE SYMBOL FOR CLARITY. MANUFACTURERS SHOULD ONLY USE THE REGIONS APPROPRIATE TO THE AIRCRAFT DESIGN AND OPERATING PHILOSOPHY.

Question 8: What recommended guidance material is needed?

Many current transport category aircraft already incorporate an alert before stall warning. Some aircraft use high angle of attack instead of low airspeed as a means to identify the approach to stall warning. These may be titled “low energy alert” or “low airspeed alert” – this recommended guidance material applies to both types of alerts.

If a low airspeed (or low energy) alert is provided, the guidance contained in AC/AMC 25.1322 should apply. Any new guidance material should consider the following:

- (i) Considerations should be given to all operating conditions, configurations (e.g., flap, slat, speedbrakes, weight, cg), manual and autoflight combinations, all phases of flight, including icing conditions and engine state (e.g., all engine, engine-out, derated thrust).
- (ii) The alert should be timely enough to allow recovery to a stabilized flight condition before a stall warning.
- (iii) Nuisance alerts should be minimized. For example, alerts should not be triggered during normal operation, including operation in moderate turbulence for recommended maneuvers at recommended speeds.
- (iv) In order to show compliance with 14 CFR Part 25.1322, two senses (e.g. both visual and aural) will be required to provide sufficient attention-getting for the low airspeed alert.

NOTE: The new 14 CFR Part 25.1322 rule applies only to type certificate applications for transport category airplanes submitted after the rule’s effective date and to certain amended type certificate (TC) and supplemental TC (STC) applications submitted after that date.

The Phase 2 tasking will address low airspeed alerting as applied to retrofit. The FAA expects that the requirements of § 21.101 will determine which future design changes would need to have the certification bases updated to include the requirements in this final rule.

Some aircraft incorporate attention-getting using a single sense implementation.

Task 2 will consider LAS for aircraft already in service.

- (vi) The alert should be consistent with the low airspeed awareness cueing as identified in AC/AMC 25-11A

Low/airspeed or low energy alerting should be evaluated by simulator and/or flight tests for all appropriate operating conditions.

Airbus minority position: As exposed in appendix 1 paragraphs 3 and 4 of this report, Airbus FBW aircraft present a set of high incidence protection layers associated with specific CRIs and

IPs, including those addressing low speed/energy alert near the ground. Airbus opinion is that an additional guidance material, on low speed alerting, as written in Question 8, is not necessary. Actually this proposed guidance material does not address properly flight envelope protected aircraft specific features and may conflict with the existing dedicated CRIs/IPs, which have proven to be ensuring an adequate level of safety for this type of aircraft.

Question 9: After reviewing airworthiness, safety, cost, benefit, and other relevant factors, including recent certification and fleet experience, are there any additional considerations that should be taken into account?

Yes.

Scope: The scope of Question 9 is limited to low airspeed *alerting* for aircraft to be certified under 14 CFR Part 25.

Airworthiness Considerations: To support Safety Recommendation A-10-11, the group recommends an assessment of existing low airspeed awareness designs compared to current EASA and FAA and airworthiness standards (i.e., CS 25.207 and 14 CFR Part 25.207; include TSO-C54) as well as AC/AMC 25-11A. System descriptions from aircraft manufacturers for aircraft certified under 14 CFR Part 25 should be used, where available (reference Appendix 1 and Appendix 2). Compare systems to: applicable certification bases; any deviation from existing standards; any difference from guidance in AC 25-11A and AMC 25.207, and should consider all relevant phases of flight and flight conditions.

Safety Considerations: To support Safety Recommendation A-10-12, the group recommends a thorough analysis of relevant transport category accidents and incidents and whether low airspeed alerting systems played a role, or would have played a role if installed. Assessments of A-10-11, existing cues and other relevant systems (e.g. were aircraft equipped with a low-air-speed awareness function) should be included. Additional considerations should be taken into account for airplanes with envelope protection systems that make it harder to stall, but may get into low energy states from which crew awareness may be necessary to allow the pilot to take appropriate recovery action.

Any potential causal deficiency in the interface with respect to other factors assessed in this report (i.e. Questions (bullets) 1 through 6) should be considered. Consider use of SAE ARP 4761, Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment, and in coordination with Question 8, review the recommended draft advisory material for possible resolution to any identified deficiency.

Cost Considerations: If a rule is developed, the FAA should solicit aircraft manufacturers assessments of any necessary changes of new design and new production aircraft meet any standards developed. By model, there is also a need to develop estimates of the unit cost of those changes and projected deliveries through 2021.

Benefit Considerations: The FAA should also develop an estimate of the value that any proposed changes in airworthiness requirements would have had in the relevant accidents. Using FAA APO methodology, there is also a need to quantify the benefit-cost analysis (BCA) ratio projected through 2021.

Relevant Factors:

- Recent Certification - Use certification basis data obtained to perform a sensitivity analysis of the BCA developed.
- Fleet Experience - Gather data on other low-air-speed events and similar warning systems, and assess their relevance to this review.
- Other - Assess the potential role of training, value of angle-of-attack indicators, compatibility of night vision systems, or other factors that may have surfaced in working group discussions.
- Additional Considerations. Review and assess any additional considerations that should be taken into account, including synergies with other initiatives focusing on low-air-speed events.

Question 10: Is coordination necessary with other harmonization working groups (e.g. Human Factors, Flight Test)? (If yes, coordinate and report on that coordination)

Yes. Coordination was necessary with the Flight Test Harmonization Working Group (FTHWG). The FTHWG provided the response to question #4. Some FTHWG group members participated in this activity directly, and were responsible for overall comments from the FTHWG.

There is Human Factors representation on the group so there is no need to have additional coordination with the Human Factors Working Group.

The group provided a draft report to individuals from the Special Committee #220 for Automatic Flight Guidance and Control. This committee is currently working on ACs 23.1329, 25.1329 and 27.1329.

One of the group members participates on the Airplane state awareness Joint Safety Analysis Team (JSAT) of the Commercial Aviation Safety Team (CAST). The JSAT is currently investigating accidents and incidents, and the AVHWG recommends that they include in their activity an assessment of whether low airspeed alerting would have helped mitigate those accidents/incidents.

Appendix 1: Low Airspeed Awareness/Alerting Examples



Appendix 1 (Oct 22
2010).pdf

Appendix 2: Expanded Considerations List



Appendix 2 Update
(Feb_8_2011).pdf

Appendix 3: Text from Related Requirements and Guidance Material

New aircraft should follow the new AC 25.1329, Flight Guidance Systems, and AC 25.11A, Appendix 1. This would also assume a fully integrated AOA system. In this assessment there are 2 categories worth discussion.

- Aircraft with autothrottles and how they are used to provide speed protection
- Aircraft without autothrottles and how the flight guidance system provides speed protection

AC 25-11A, Appendix 1, Para. 2.3. states:

The preferred colors to be used are amber or yellow to indicate that the airspeed has decreased below a reference speed that provides adequate maneuver margin, changing to red at the stall warning speed. The speeds at which the low speed awareness bands start should be chosen as appropriate to the airplane configuration and operational flight regime. For example, low airspeed awareness cues for approach and landing should be shown starting at VREF with a tolerance of +0 and –5 knots. Some FAA approved systems use a pilot selectable operating speed “bug” at VREF supplemented by system-computed low airspeed cues that vary in color as airspeed decreases below certain multiples of the appropriate stall speed (for example, white below 1.3VS, amber below 1.2 VS, and red below 1.1 VS). Consider the specific operating needs of other flight regimes when developing the criteria for the associated visual cue.

Basically, this paragraph describes where the color bands are positioned on the airspeed tape, specifically:

- The red band has to be from stall warning speed to the stall speed
- The yellow band should be from the top of red band to a speed which provides adequate maneuver margins below the reference speeds (Vref).

Appendix 1, Para. 2.3 also states:

Low airspeed awareness displays should be sensitive to load factor (g-sensitive) to enable the pilot to maintain adequate maneuver margins above stall warning in all phases of flight.

From the latest version of AC 25.1329, Section 45b, Speed Protection Alerts.

(1) Alerts to Crew. To assure crew awareness, an alert should be provided when a sustained speed protection condition is detected. This is in addition to any annunciations associated with mode reversions that occur as a consequence of invoking speed protection (See Chapter 5, Performance of Function, paragraph 57, Speed Protection).

(2) Alert Specifications.

(a) Low Speed Protection. Low speed protection alerts should include both an aural and a visual component.

(b) High Speed Protection. High-speed protection alerts need include only

a visual alert component because of existing high-speed aural alert requirements. However, giving an alert prior to that required aural alert is not precluded. [Refer to § 25.1303(c)(1) for overspeed alerting regulations.]

(3) Consistency. Alerts for speed protection should be consistent with the protection provided and with the other alerts in the flight deck.

(4) Nuisance Alerts. Care should be taken to set appropriate values for indicating speed protection that would not be considered a nuisance for the flightcrew.

From the latest version of AC 25.1329, Section 57, Speed protection methods of compliance state:

(1) Speed Excursions. The requirement for speed protection is based on the premise that reliance on flight crew attentiveness to airspeed indications alone during [Flight Guidance System] FGS operation is not adequate to avoid unacceptable speed excursions outside the speed range of the normal flight envelope. Many existing FGS systems have no provisions to avoid speed excursions outside the normal flight envelope. Some FGSs will remain engaged until the aircraft slows to stall conditions and also to speeds well above maximum operating limit speed/maximum operating limit Mach (VMO/MMO).

(2) Compliance with § 25.1329(h). Standard stall warning and high-speed alerts are not always timely enough for the flight crew to intervene to prevent unacceptable speed excursions during FGS operation. The intent of § 25.1329(h) is for the FGS to provide a speed protection function for all operating modes, so that the airspeed can be safely maintained within an acceptable margin of the speed range of the normal flight envelope.

The FGS design may use any of the following ways or a combination of ways to provide acceptable speed protection:

(a) The FGS Provides Speed Protection. In this case, the following are acceptable means to comply with this rule:

1. The FGS may detect the speed protection condition, alert the flightcrew, and provide speed protection control or guidance.
2. The FGS may detect the speed protection condition, alert the flightcrew, and then disengage the FGS.
3. The FGS may detect the speed protection condition, alert the flightcrew, and remain engaged in the active mode without providing speed protection control or guidance.

(b) Other Systems Provide Speed Protection. Other systems, such as the primary flight control system or the FMS (when in a vertical navigation (VNAV) mode) may be used to provide equivalent speed protection.

NOTE: If compliance with this requirement is based on use of alerting alone, the alerts should be shown to be appropriate and timely to ensure flight crew awareness and enable the pilot to keep the airplane within an acceptable margin from the speed range of the normal flight envelope. See Chapter 4, Controls, Indications, and Alerts, paragraph 45b, Speed Protection Alerts, for additional discussion of speed protection alerting.

For aircraft predating the speed protection requirements of 25.1329.

Aircraft with a fully integrated AOA system – These aircraft must comply fully with AC-25-11A

Aircraft without an integrated AOA system – These aircraft must comply with AC25-11A , and the TAD issue paper for an alternate Means of compliance. These “classic” aircraft have displays and systems that won’t support “g” compensation and cannot support all configurations, weights, or c.g. locations related to the positioning of the airspeed scales for the entire flight duration. Using pilot generated speed inputs before takeoff and before landing to position the scales, and using alternate color schemes of red and amber required by AC 25-11A for the speed scales, has been accepted to be an alternate means of compliance.

Appendix 4: Relevant Guidance and Regulatory Material

Guidance Material	Issue Date	Section	Paragraph	
AC25-7A Chg 1	3-Jun-99	29	f: Stall Warning	(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. (2) Background: To be acceptable, a stall warning must have the following features: (i) Distinctiveness. The stall warning indication must be clear and distinct to a degree that will ensure positive pilot recognition of an impending stall. (ii) Timeliness. The stall warning should normally begin at a speed not less than 7 percent above the stall speed. A lesser margin may be acceptable, depending on the probability of an inadvertent stall following stall warning recognition, and how much difference there is between the speed at which the airplane stalls (stall identification), and the minimum speed allowed under § 25.103(a). (iii) Consistency. The stall warning must be reliable and repeatable. The warning must occur with flaps and gear in all normally used positions in both straight and turning flight. 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, and continue throughout the stall until the angle of attack is reduced to approximately that at which stall warning was initiated. (iv) An artificial stall warning indication that is a solely visual device which requires attention in the cockpit,

Guidance Material	Issue Date	Section	Paragraph
			inhibits cockpit conversation or, in the event of malfunction, causes distraction that would interfere with safe operation of the airplane, is not acceptable. (v) 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 of the FAR. (3) Procedures. Stall warning tests are normally conducted in conjunction with the stall testing required by §§ 25.103 (stall speeds) and 25.203 (stall characteristics). (4) Data Acquisition and Reduction. The stall warning speed and type and quality of warning should be noted. The speed at which acceptable stall warning begins should then be compared to the stall speed as defined in paragraph (3) above to determine if the required margin exists. The applicant should determine that adequate stall warning occurs in turning flight under expected conditions of flight for takeoff, en route, and approach/landing configurations at aft c.g. and heavy weight. It should be demonstrated in slowdown turns at 1.5g normal load factor, with entry rates of at least 2 knots per second, that sufficient stall warning is provided to prevent stalling when the pilot takes recovery action not less than one second after recognition of stall warning. When stall warning is provided by an artificial system, that system's activation point should be set to the high side of its angle of attack tolerance band for this testing.
			g. Accelerated Stall Warning

Guidance Material	Issue Date	Section	Paragraph
		Chapter 8: Airworthiness: Miscellaneous Items	h. Maneuver Margins 228. DESIGN AND FUNCTION OF ARTIFICIAL STALL WARNING AND IDENTIFICATION SYSTEMS The applicant should determine that adequate maneuvering capability exists prior to stall warning at V₂, all-engines-operating takeoff speed (typically defined as V₂+XX kts.), final takeoff speed (§ 25.121(c)), and V_{REF} at forward c.g. and heavy weight for each appropriate flap setting. When stall warning is provided by an artificial system, that system's activation point should be set to the low side of its angle of attack tolerance band for this testing. NOTE: If it can be shown that the angle of attack tolerance band of an artificial stall warning system results in no more than a ± 1.0 knot variation about the stall warning speed obtained at the nominal AOA setting, that nominal setting may be used for the maneuver margin testing specified in paragraph 29h, above. a. Applicable Regulations. Sections 25.103, 25.201, 25.203, and 25.207 of the Federal Aviation Regulations (FAR). b. Explanation. Some airplanes require artificial stall warning systems, such as stick shakers, to compensate for a lack of clearly identifiable natural stall warning to show compliance with the stall warning requirements of § 25.207. Similarly, some airplanes require a stall identification device or system (e.g., stick pusher, automatic inboard slat segment retraction, auto-trim, etc.) to compensate for an inability to meet the stalling definitions of § 25.201 or the stall characteristics requirements of § 25.203. In addition to compliance with the flight test requirements prescribed in Paragraph 29 of this AC, certain system design and function criteria should also be addressed during the certification process of these airplanes. Included are system arming and

Guidance Material	Issue Date	Section	Paragraph
			disarming, preflight checks, failure indications and warnings, and system reliability and safety. The reliability of these systems can be evaluated in terms of the probability of the system not operating when required, and the safety aspects in terms of the probability of the system operating inadvertently. The required reliability and safety of stall warning and identification systems should be defined as a function of how critical their respective functioning. c. Arming and Disarming. (1) Stall warning systems should be armed any time the airplane is in flight. (i) Arming of stall warning systems has typically been accomplished by a ground/air logic circuit, which requires the nose and/or main gear squat switches to sense air mode before the system is armed. A pitch angle threshold during rotation has also been used to arm the stall warning system. These types of system arming schemes provide stall warning protection during liftoff and initial climb, where a stall would most probably have catastrophic consequences. They also provide protection against nuisance warnings during the takeoff roll, where the angle of attack (AOA) sensor vanes may be misaligned. Service history, however, has shown that systems armed around the liftoff point have caused pilots to abort takeoffs due to false alerts resulting from stall warning system faults or failures. In some cases, these high-energy rejected takeoffs have resulted in overruns. Therefore, system faults and failures that would lead to a false stall warning near liftoff should be made evident as early in the takeoff as practicable. (ii) In accordance with the requirements of § 25.207(b), if a stall warning system is required for any normal combination of flap and landing gear position, it must be used for all combinations of flap and landing gear positions. The purpose of this requirement is to provide a

Guidance Material	Issue Date	Section	Paragraph
			standard, consistent warning to the flightcrew of an operational flight envelope limit. (2) Stall identification systems should be armed any time the airplane is in flight. (i) The arming should take place automatically and may be provided by the same ground/air sensing system used for arming the stall warning system. The stall identification system may be inhibited during the takeoff rotation, but should become functional immediately after main gear liftoff. For airplanes with both stall warning and stall identification systems, it is permissible to have the stall identification system armed by operation of the stall warning system, provided the resulting probability of the stall identification not to operate when required is not greater than that specified in paragraph 228e, below. (ii) Stall identification systems may incorporate automatic disarming in flight regimes where the risk of stalling is extremely remote or where their unwanted operation would pose a threat to continued safe flight; examples of such inhibits would be high airspeed, and "g" cutouts (typically 0.5g), and while the pilot is following windshear recovery Flight Director guidance. (iii) A means to quickly deactivate the stall identification system should be provided and be made readily available to the pilots. It should be effective at all times, and should be capable of preventing the system from making any input to the longitudinal control system. It should also be capable of canceling any input that has already been applied, from either normal operation or from a failure condition.

Guidance Material	Issue Date	Section	Paragraph
			(iv) If a stall identification system is required to show compliance with the stall requirements of Part 25 in one (or some) airplane configuration(s), it does not have to be used for stall identification in configurations where compliance can be demonstrated without it. Unlike stall warning, the stall point, be it aerodynamic or artificially induced, represents an end-point outside the in-service operational envelope of the airplane, and, therefore, does not need to be provided by the same means for all flap and landing gear configurations. Additionally, the added system complexity, and increased exposure to malfunctions and failures, would not warrant the use of a stall identification system for configurations where it is not required. d. Indicating and Warning Devices. (1) A method should be provided to adequately ascertain the proper operation of the stall warning and stall identification systems prior to takeoff. This method should be described in the operating procedures section of the Airplane Flight Manual (AFM). (2) Warning that the associated systems for operating the stall warning or stall identification devices has failed should be provided. As far as is practicable, this warning should cover all system failure modes. (3) A clear and distinctive cockpit indication should be given when the stall identification system has been deactivated by the flightcrew (see paragraph 228c(2)(iii), above). This indication should be present as long as the system is deactivated. (4) Any related limitations, and normal and emergency operating procedures, together with any information found necessary for safety during operation of the stall warning and identification systems, should be included in the AFM and supplemented by such markings and placards as deemed necessary.

Guidance Material	Issue Date	Section	Paragraph	
				e. System Reliability and Safety. When stall warning and/or stall identification systems are installed to show compliance with the stalling requirements of §§ 25.201, 25.203, and 25.207 of the FAR, engineering data must be supplied to satisfy the following criteria, determined in accordance with the procedures of Advisory Circular 25.1309-1A, "System Design Analysis," dated June 21, 1988, where appropriate. . . . 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., stick pushers), should be such that it is unlikely that a member of the flightcrew will prevent or delay their operation. (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.
AC25-11A	21-Jun-07	Appendix 1 Primary Flight Information	1.1 Attitude	There should be a means to determine the margin to stall and to display that information when necessary. For example, a pitch limit indication is acceptable. There Should be a means to identify excessive bank angle condition prior to stall buffet.

Guidance Material	Issue Date	Section	Paragraph	
AC25-11A	21-Jun-07	Appendix 1 Primary Flight Information	2.1 Airspeed and Altitude	Airspeed scale markings such as stall warning, maximum operation speed/maximum operating mach number, or flap limits, should be displayed to provide the flightcrew a quick-glance sense of speed relative to key targets or limits. The markings should be predominant enough to confer the quick-glance sense information, but not so predominant as to be distracting when operating normally near those speeds (for example, stabilized approach operating between stall warning and flap limit speeds).
AC25-11A	21-Jun-07	Appendix 1 Primary Flight Information	2.2 Airspeed & Altitude for HUD	The compensating features for HUD formats that provide an alphanumeric-only display of airspeed and altitude is that the information display should also provide clear and distinct alerts to the flightcrew when these and any other required parameters exceed well defined tolerances around the nominal approach range , and when these alerts have associated procedures that require the termination of the approach. Previously accepted display formats also included effective cues for acceleration and speed deviation so that the pilot could manually achieve tight speed control to preclude unintended proximity to low speed limits. When an alphanumeric-only indication of airspeed and altitude HUD format is displayed, there should still remain an overall awareness of the following indications: • Airspeed/altitude, • Airspeed/altitude trends, • Deviations from selected airspeed/altitude targets, • Low and high airspeed limits, and • Selected airspeed/altitude setting changes.

Guidance Material	Issue Date	Section	Paragraph	
AC25-11A	21-Jun-07	Appendix 1 Primary Flight Information	2.3 Low and High Speed Awareness	Section 25.1541(a)(2) states: “The airplane must contain – Any additional information, instrument markings, and placards required for the safe operation if there are unusual design, operating, or handling characteristics.” The part 25 regulations related to instrument systems and their markings were not developed with modern day electronic displays in mind; consequently, these electronic displays are considered an “unusual design characteristic” per § 25.1541(a)(2), and may require additional marking to warrant safe operation. In particular, it is considered necessary to incorporate additional markings on electronic airspeed displays in the form of low and high speed awareness cues to provide pilots the same type of “quick glance” airspeed awareness that was an intrinsic feature of round dial instruments. Low speed awareness cues should provide adequate visual cues to the pilot that the airspeed is below the reference operating speed for the airplane configuration (that is, weight, flap setting, landing gear position, etc.); similarly, high speed awareness cues should provide adequate visual cues to the pilot that the airspeed is approaching an established upper limit that may result in a hazardous operating condition. Consider the following guidance when developing airspeed awareness cues: • Take into account all independent parameters that may affect the speed against which protection is being provided. This is most important in the low speed regime where all transport category airplanes have a wide range of stall speeds due to multiple flap/slat configurations and potentially large variations in gross weight.

Guidance Material	Issue Date	Section	Paragraph
			• The cues should be readily distinguishable from other markings such as V-speeds and speed targets (bugs). The cues should indicate not only the boundary value of the speed limit, but must clearly distinguish between the normal speed range and the unsafe speed range beyond those limiting values (§ 25.1545). Since the moving scale display does not provide any inherent visual cue of the relationship of present airspeed to low or high airspeed limits, many electronic displays utilize an amber and red bar adjacent to the airspeed tape to provide this quick-glance low/high speed awareness. The preferred colors to be used are amber or yellow to indicate that the airspeed has decreased below a reference speed that provides adequate maneuver margin, changing to red at the stall warning speed. The speeds at which the low speed awareness bands start should be chosen as appropriate to the airplane configuration and operational flight regime. For example, low speed awareness cues for approach and landing should be shown starting at VREF with a tolerance of +0 and –5 knots. Some FAA approved systems use a pilot selectable operating speed “bug” at VREF supplemented by system-computed low speed cues that vary in color as airspeed decreases below certain multiples of the appropriate stall speed (for example, white below 1.3VS, amber below 1.2 VS, and red below 1.1 VS). Consider the specific operating needs of other flight regimes when developing the criteria for the associated visual cue. • Low speed awareness displays should be sensitive to load factor (g-sensitive) to enable the pilot to maintain adequate maneuver margins above stall warning in all phases of flight. The accuracy of this g-sensitivity function should be verified by flight tests. Flight tests should also be conducted in maneuvering flight and expected levels of turbulence to evaluate proper functioning of any damping routines incorporated into the low speed awareness software; the level of damping

Guidance Material	Issue Date	Section	Paragraph	
				should preclude nuisance/erratic movement of the low speed cues during operation in turbulence but not be so high that it inhibits adequate response to accurately reflect changes in margins to stall warning and stall during maneuvering flight.
AC25-11A	12-Mar-10	Draft HUD Appendix	4.1.3 AirSpeed Consideration	Low speed awareness cues presented on the HUD should provide adequate visual cues to the pilot that the airspeed is below the reference operating speed for the airplane configuration (i.e., weight, flap setting, landing gear position, etc.); similarly, high speed awareness cues should provide adequate visual cues to the pilot that the airspeed is approaching an established upper limit that may result in a hazardous operating condition. The cues should be readily distinguishable from other markings such as V-speeds and speed targets (bugs). The cues should not only indicate the boundary value of speed limit, but also clearly distinguish between the normal speed range and the unsafe speed range beyond those limiting values. Cross-hatching may be acceptable to provide delineation between zones of different meaning.
AC25-25	10-Sep-07	Performance & Handling Characteristics in Icing Conditions Specified in Part 25 Appd C	1h(2)(e)(2) Airplane Flight Manual 3r Stall Warning	2 Stall and stall warning speed margins are considered adequate if the stall speed does not increase by more than 3 knots calibrated airspeed (CAS) or 3 percent of VSR and compliance with § 25.207(e) and (f) can be shown with residual ice contamination on the wing leading edge and upper surface. Potential means for increasing stall and stall warning speed margins , if necessary, include reducing the peak angle of attack reached during the takeoff by using increased rotation and V2 takeoff speeds, reducing the takeoff rotation pitch rate, or reducing the target pitch attitude. (1) To show compliance with § 25.207, stall warning should be assessed in conjunction with stall speed testing and stall demonstration/characteristics testing (§§

Guidance Material	Issue Date	Section	Paragraph
			25.103, 25.201, and 25.203, and paragraphs 3b and 3q of this AC, respectively), and in tests with faster entry rates. (2) Normal Ice Protection System Operation. The following represents 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: (a) Holding ice. (b) Medium to light weight, aft center-of-gravity position, symmetric fuel loading. (c) Normal stall test altitude. (d) In the configurations listed below, trim the airplane at 1.3 VSR with the power or thrust necessary to maintain straight level flight. Maintain the trim power or thrust during the test demonstrations. Increase speed as necessary prior to establishing at least 1.5 g and a deceleration of at least 2 knots per second. Decrease speed until 1 second after stall warning and recover using the same recovery maneuver as for the non-contaminated airplane. 1 High lift devices retracted configuration; 2 Lowest lift takeoff configuration; and 3 Highest lift landing configuration. (3) Ice Accretion Prior to Activation and Operation of the Ice Protection System. The following represents acceptable means for evaluating stall warning margin for flight in icing conditions before the ice protection system has been activated and is performing its intended function. (a) If activation of the ice protection system depends on visual recognition of a specified amount of ice (not just the first indication of icing) accreted on a reference surface (for example, an ice accretion probe or the wing leading edge), the test program for normal ice protection system operation given in the preceding paragraph continues to apply, but with the ice accretion prior to

Guidance Material	Issue Date	Section	Paragraph	
				normal system operation. (b) If activation of the ice protection system depends on means of recognition other than that defined in paragraph (a) above, it is acceptable to demonstrate adequate stall warning with the ice accretion prior to normal system operation as follows: 1 In the configurations listed in paragraphs (aa) and (bb), below, trim the airplane at 1.3 VSR. (aa) High lift devices retracted configuration: Straight/Power Off. (bb) Landing configuration: Straight/Power Off. 2 At deceleration rates of up to 1 knot per second, reduce the speed to 1 second past stall warning, and demonstrate that stalling can be prevented using the same recovery maneuver as for the non-contaminated airplane, without encountering any adverse characteristics (for example, rapid wing roll-off). Where stall warning is provided by a different means than for the airplane without ice accretion, § 25.207(i)(2)(ii) requires a demonstration of satisfactory stall characteristics as well as the capability to prevent a stall if the pilot does not take any recovery action for at least 3 seconds after stall warning.
AMC 25.1322	5/8/2010	Alerting Systems		This AMC gives general guidance on the design and certification of alerting systems. The term “alerting system” is meant to include all the Warnings, Cautions and Advisories (see paragraph 3 below) on the flight deck whether they are provided by a single system or not. It includes both the means used to draw the attention of the crew to the existence of an abnormality or an aircraft condition and the means of identifying it. In

Guidance Material	Issue Date	Section	Paragraph	
				any case where the guidance appears to conflict with a specific CS-25 requirement the requirement must take priority.
AC25.1329-1B	17-Jul-06	Ch 4: Controls, Indications, and Alerts; Para 45: FGS ALERTING, WARNING, CAUTION, ADVISORY, and STATUS	b. Speed Protection Alerts	(1) Alerts to Crew. To assure crew awareness, an alert should be provided when a sustained speed protection condition is detected. This is in addition to any annunciations associated with mode reversions that occur as a consequence of invoking speed protection (See Chapter 5, Performance of Function, paragraph 57, Speed Protection). (2) Alert Specifications. (a) Low Speed Protection. Low speed protection alerts should include both an aural and a visual component. (b) High Speed Protection. High-speed protection alerts need include only a visual alert component because of existing high-speed aural alert requirements. However, giving an alert prior to that required aural alert is not precluded. [Refer to § 25.1303(c)(1) for overspeed alerting regulations.] (3) Consistency. Alerts for speed protection should be consistent with the protection provided and with the other alerts in the flight deck. (4) Nuisance Alerts. Care should be taken to set appropriate values for indicating speed protection that would not be considered a nuisance for the flightcrew.

Guidance Material	Issue Date	Section	Paragraph	
AC25.1329-1B	17-Jul-06	Ch 5: Performance of Function; Para 57: Speed Protection	a. General	(1) Speed Excursions. The requirement for speed protection is based on the premise that reliance on flightcrew attentiveness to airspeed indications alone during FGS operation is not adequate to avoid unacceptable speed excursions outside the speed range of the normal flight envelope. Many existing FGS systems have no provisions to avoid speed excursions outside the normal flight envelope. Some FGSs will remain engaged until the aircraft slows to stall conditions and also to speeds well above maximum operating limit speed/maximum operating limit Mach (VMO/MMO). (2) Compliance with § 25.1329(h). Standard stall warning and high-speed alerts are not always timely enough for the flightcrew to intervene to prevent unacceptable speed excursions during FGS operation. The intent of § 25.1329(h) is for the FGS to provide a speed protection function for all operating modes, so that the airspeed can be safely maintained within an acceptable margin of the speed range of the normal flight envelope. The FGS design may use any of the following ways or a combination of ways to provide acceptable speed protection: (a) The FGS Provides Speed Protection. In this case, the following are acceptable means to comply with this rule: 1 The FGS may detect the speed protection condition, alert the flightcrew, and provide speed protection control or guidance. 2 The FGS may detect the speed protection condition, alert the flightcrew, and then disengage the FGS. 3 The FGS may detect the speed protection condition, alert the flightcrew, and remain engaged in the active mode without providing speed protection control or guidance.

Guidance Material	Issue Date	Section	Paragraph
			(b) Other Systems Provide Speed Protection. Other systems, such as the primary flight control system or the FMS (when in a vertical navigation (VNAV) mode) may be used to provide equivalent speed protection. NOTE: If compliance with this requirement is based on use of alerting alone, the alerts should be shown to be appropriate and timely to ensure flightcrew awareness and enable the pilot to keep the airplane within an acceptable margin from the speed range of the normal flight envelope. See Chapter 4, Controls, Indications, and Alerts, paragraph 45b, Speed Protection Alerts, for additional discussion of speed protection alerting. (3) Design Standard. (a) Interaction of FGS Elements. The design should consider how and when the speed protection is provided for combinations of autopilot, FDs, and autothrust operation. Care should be taken to set appropriate values for transitioning into and out of speed protection such that the flightcrew does not consider the transitions a nuisance. (b) Integration of Pitch and Thrust Control. The speed protection function should integrate pitch and thrust control. Consideration should be given to automatically activating the autothrust function when speed protection is invoked. If an autothrust function is either not provided or is unavailable, speed protection should be provided through pitch control alone. (c) Interaction of Systems. The role and interaction of autothrust with elements of the FMS, the primary flight control system, and the propulsion system, as applicable, should be accounted for in the design for speed protection. (d) Engine Inoperative. Consideration should be given to the effects of an engine inoperative condition on the performance of speed protection.

Guidance Material	Issue Date	Section	Paragraph
			b. Low Speed Protection (1) General. When the FGS is engaged in any modes (with the possible exception of Approach, as discussed in paragraph (3) below) for which the available thrust is insufficient to maintain a safe operating speed, the low speed protection function should be invoked to avoid unsafe speed excursions. (2) Factors to Consider. Activation of speed protection should take into account such factors as the phase of flight, turbulence and gusty wind conditions, and compatibility with the speed schedules. The low speed protection function should activate at a suitable margin to stall warning that will not result in nuisance alerts. Consider the operational speeds, as specified in the AFM, for all-engine and engine-inoperative cases during the following phases of flight: (a) Takeoff. (b) Departure, climb, cruise, descent, and terminal area operations. During these flight phases, airplanes are normally operated at or above the minimum maneuvering speed for the given flap configuration. NOTE: For high altitude operations, it may be desirable to incorporate low speed protection at the appropriate engine out drift-down speed schedule, if the FGS (or other integrated sensors/systems) can determine that the thrust deficiency is due to an engine failure. (c) Approach. (d) Transition from approach to go-around and go-around climb. NOTE: A low speed alert and a transition to the Speed Protection mode at approximately 1.13 VSR (reference stall speed) for the landing flap configuration has been found to be acceptable.

Guidance Material	Issue Date	Section	Paragraph
			(3) Low Speed Protection During Approach Operations. (a) Non–Interference. Speed protection should not interfere with the approach and landing phases of flight. (b) Autothrust Operation. It is assumed that with autothrust operating normally, the combination of thrust control and pitch control during the approach will be sufficient to maintain speed and desired vertical flight path. In cases where it is not sufficient, an alert should be provided in time for the flightcrew to take appropriate corrective action. (c) Defined Vertical Path. For approach operations with a defined vertical path (for example, ILS, microwave landing system (MLS), GNSS landing system (GLS), Lateral Navigation (LNAV) mode, VNAV mode), if the thrust is insufficient to maintain both the desired flight path and the desired approach speed, there are several ways to meet the intent of low speed protection: 1 The FGS may maintain the defined vertical path as the airplane decelerates below the desired approach speed until the airspeed reaches the low speed protection value. At that time, the FGS would provide guidance to maintain the low speed protection value as the airplane departs the defined vertical path. The FGS mode reversion and low speed alert should be activated to ensure pilot awareness. NOTE: The pilot is expected to take corrective action to add thrust and return the airplane to the defined vertical path or go–around, as necessary. 2 The FGS may maintain the defined vertical path as the airplane decelerates below the desired approach speed to the low speed protection value. The FGS will then provide a low speed alert while remaining in the existing FGS approach mode. NOTE: The pilot is expected to take corrective action to add thrust to cause the airplane to accelerate back to the desired approach speed while maintaining the defined vertical path or go–around, as necessary.

Guidance Material	Issue Date	Section	Paragraph
			3 The FGS may maintain the defined vertical path as the airplane decelerates below the desired approach speed until the airspeed reaches the low speed protection value. The FGS will then provide a low speed alert and disengage. NOTE: The pilot is expected to take corrective action when alerted to the low speed condition and the disengagement of the autopilot, to add thrust, and to manually return the airplane to the desired vertical path or go-around. (d) Vertical Flight Path Not Protected. If the speed protection is invoked during approach such that vertical flight path is not protected, the subsequent behavior of the FGS after speed protection should be carefully considered. Activating low speed protection during the approach, resuming the Approach mode, and re-acquiring the defined vertical path may be an acceptable response, if the activation is sufficiently brief and not accompanied by large speed or path deviations. This response is considered consistent with criteria for Category III automatic landing systems in AC 120-28D, Criteria for Approval of Category III Weather Minima for Takeoff, Landing, and Rollout, appendix 3, section 8.1, Automatic Flight Control Systems, which states that it should not be possible to change the flight path of the airplane with the autopilot(s) engaged, except by initiating an automatic go-around. (1) General. Section 25.1329(h) states that means must be provided to avoid excursions beyond an acceptable margin from the speed range of the normal flight envelope. VMO and MMO mark the upper speed/Mach limit of the normal flight envelope. This is not intended to
			c. High Speed Protection

Guidance Material	Issue Date	Section	Paragraph
			require or preclude high speed protection based on airplane configurations (for example, flaps extended). (2) Factors to Consider. (a) Duration of Airspeed Excursions, Rate of Airspeed Change, Turbulence, and Gust Characteristics: 1 Operations at or near VMO/MMO in routine atmospheric conditions (for example, light turbulence) are safe. Small, brief excursions above VMO/MMO by themselves are not unsafe. 2 The FGS design should strive to strike a balance between providing adequate speed protection margin and avoiding nuisance activation of high-speed protection. NOTE: The following factors apply only to designs that provide highspeed protection through FGS control of airspeed. (b) High Speed Protection While in Altitude Hold Mode: 1 Climbing to control airspeed is not desirable, because departing an assigned altitude can be disruptive to air traffic control (ATC) and potentially hazardous (for example, in RVSM airspace). As long as the speed does not exceed a certain margin beyond VMO/MMO (for example, six knots), it is better that the FGS remain in Altitude Hold mode. 2 The autothrust function, if operating normally, should effect highspeed protection by limiting its speed reference to the normal speed envelope (that is, at or below VMO/MMO). 3 The basic airplane high-speed alert should be sufficient for the pilot to recognize the overspeed condition and take corrective action to reduce thrust. However, if the airspeed exceeds a margin beyond VMO/MMO (for example, six knots), the FGS may transition from Altitude Hold to the Overspeed Protection mode and depart (that is, climb above) the selected

Guidance Material	Issue Date	Section	Paragraph	
				altitude.
				(c) High Speed Protection During Climbs and Descents. 1 When the elevator channel of the FGS is not controlling airspeed, the autothrust function, if engaged, should reduce thrust, as needed to prevent sustained airspeed excursions beyond VMO/MMO (for example, six knots) down to the minimum appropriate value. 2 When thrust is already the minimum appropriate value or the autothrust function is not operating, the FGS should begin using pitch control, as needed, for high-speed protection. 3 If conditions are encountered that result in airspeed excursions above VMO/MMO, it is preferable for the FGS to smoothly and positively guide or control the airplane back to within the speed range of the normal flight envelope.
AMC 25.1329	25-Aug-10	AMC 25.1329	9.3.1	Alerting for Speed Protection: To assure crew awareness, an alert should be provided when a sustained speed protection condition is detected. This is in addition to any annunciations associated with mode reversions that occur as a consequence of invoking speed protection (see Section 10.4, Speed Protection). Low speed protection alerting should include both an aural and a visual component. High-speed protection alerts need only include a visual alert component because of existing high-speed aural alert requirements, but does not preclude giving an earlier alert.

Guidance Material	Issue Date	Section	Paragraph
			Alerting for speed protection should be consistent with the protection provided and with the other alerts in the flight deck. Care should be taken to set appropriate values for indicating speed protection that would not be considered a nuisance for the flight crew.
			Low Speed Protection: When the FGS is engaged in any modes (with the possible exception of approach as discussed in Section 10.4.1.1) for which the available thrust is insufficient to maintain a safe operating speed, the low speed protection function should be invoked to avoid unsafe speed excursions. Activation of speed protection should take into account the phase of flight, factors such as turbulence and gusty wind conditions, and be compatible with the speed schedules. The low speed protection function should activate at a suitable margin to stall warning consistent with values that will not result in nuisance alerts. Consider the operational speeds, as specified in the Aeroplane Flight Manual (AFM), for all-engine and engine-inoperative cases during the following phases of flight: · Takeoff. · During departure, climb, cruise, descent and terminal area operations aeroplanes are normally operated at or above the minimum manoeuvring speed for the given flap configuration. NOTE: For high altitude operations, it may be desirable to incorporate low speed protection at the appropriate engine out drift-down speed schedule if the FGS (or other integrated sensors/systems) can determine that the cause of the thrust deficiency is due to an engine failure. · Approach.
			10.4.1

Guidance Material	Issue Date	Section	Paragraph	
				NOTE: A low speed alert and a transition to the speed protection mode at approximately 1.2VS, or an equivalent speed defined in terms of VSR, for the landing flap configuration has been found to be acceptable. · The transition from approach to go-around and go-around climb.

Guidance Material	Issue Date	Section	Paragraph
			Low Speed Protection during Approach Operations: Speed protection should not interfere with the landing phase of flight. It is assumed that with autothrust operating normally, the combination of thrust control and pitch control during the approach will be sufficient to maintain speed and desired vertical flight path. In cases where it is not, an alert should be provided in time for the flight crew to take appropriate corrective action. For approach operations with a defined vertical path (e.g., ILS, MLS, GLS, LNAV/VNAV), if the thrust is insufficient to maintain both the desired flight path and the desired approach speed, there are several ways to meet the intent of low speed protection: a) The FGS may maintain the defined vertical path as the aeroplane decelerates below the desired approach speed until the airspeed reaches the low speed protection value. At that time the FGS would provide guidance to maintain the low speed protection value as the aeroplane departs the defined vertical path. The FGS mode reversion and low speed alert should be activated to ensure pilot awareness. NOTE: The pilot is expected to take corrective action to add thrust and return the aeroplane to the defined vertical path or go-around as necessary. b) The FGS may maintain the defined vertical path as the aeroplane decelerates below the desired approach speed to the low speed protection value. The FGS will then provide a low speed alert while remaining in the existing FGS approach mode. NOTE: The pilot is expected to take corrective action to add thrust to cause the aeroplane to accelerate back to the desired approach speed while maintaining the defined vertical path or go-around as necessary. c) The FGS may maintain the defined vertical path as the aeroplane decelerates below the desired approach speed until the airspeed reaches the low speed
			10.4.1.1

Guidance Material	Issue Date	Section	Paragraph	
				protection value. The FGS will then provide a low speed alert and disengage. NOTE: The pilot is expected to take corrective action when alerted to the low speed condition and the disengagement of the autopilot, to add thrust and manually return the aeroplane to the desired vertical path or go-around as necessary. The FGS design may use any one or a combination of these ways to provide acceptable low speed protection. If the speed protection is invoked during approach such that vertical flight path is not protected, the subsequent behaviour of the FGS after speed protection should be carefully considered. Activation of low speed protection during the approach, resuming the approach mode and reacquiring the defined vertical path, may be an acceptable response if the activation is sufficiently brief and not accompanied by large speed or path deviations.
AC90-106	2-Feb-10	Appendix 4: Guidance on AW Cert for Installation of EFVS HUD	e. HUD aispeed indications	(1) FAA policy states that the airspeed indications provide pilots the equivalent “quick-glance” airspeed awareness that has been intrinsic on traditional mechanical round dial indicators. For part 25 applications, see FAA policy memoranda PS-ANM100-1992-00057, dated February 25, 1992, and PS-ANM100-1996-00056, dated September 12, 1996. (2) Low speed awareness cues must provide adequate warning to the pilot that the airspeed is below the reference operating speed for the aircraft configuration (i.e., weight, flap setting, landing gear position, etc.); similarly, high speed awareness cues must provide adequate warning to the pilot that the airspeed is approaching an established upper limit that may result in a hazardous operating condition.

Guidance Material	Issue Date	Section	Paragraph
			(3) The cues should be readily distinguishable from other markings such as V-speeds and speed targets (bugs). The cues must indicate not only the boundary value of speed limit, but must clearly distinguish between the normal speed range and the unsafe speed range beyond those limiting values. Cross-hatching may be acceptable to provide delineation between zones of different meaning. (4) The display requirements for airspeed awareness cues are in addition to other alerts associated with exceeding high and low speed limits, such as the stick shaker and aural overspeed warning.

Table 7-2 Relevant Regulations

Regulation	Description	Paragraph	Paragraph	Change Required Y/N				
25.103	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: where: V_{CLMAX}= Calibrated airspeed obtained when the load factor-corrected lift coefficient 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.	N				
		(b)	(1) Engines idling, or, if that resultant thrust causes an appreciable decrease in stall speed, not more than zero thrust at the stall speed;	N				
			(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 $1.3V_{SR}$.					
		(c)	Starting from the stabilized trim condition, apply the longitudinal control to decelerate the airplane so that the speed reduction does not exceed one knot per second.	N				
		(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., 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	N				
25.143	General	(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:	Y				
			<table><tr><th>Configuration</th><th>Speed</th><th>Maneuvering bank angle in a coordinated turn</th><th>Thrust/power setting</th></tr></table>	Configuration	Speed	Maneuvering bank angle in a coordinated turn	Thrust/power setting	
Configuration	Speed	Maneuvering bank angle in a coordinated turn	Thrust/power setting					

Regulation	Description	Paragraph	Paragraph				Change Required Y/N	
			Takeoff	V2	30°	Asymmetric WAT-Limited. ¹		
			Takeoff	² V2 + XX	40°	All-engines-operating climb. ³		
			En route	VFTO	40°	Asymmetric WAT-Limited. ¹		
			Landing	VREF	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.					
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.					N
		(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 showing compliance with the stall warning margin prescribed in paragraph (h)(3)(ii) of this section, stall warning for flight in icing conditions must be provided by the same means as stall warning for flight in non-icing conditions.					N
		(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.					N
		(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.					N
		(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—					N
			(1) The more critical of the takeoff ice and final takeoff ice accretions defined in appendix C for each configuration used in the takeoff phase of flight;					

Regulation	Description	Paragraph	Paragraph	Change Required Y/N
			(2) The en route ice accretion defined in appendix C for the en route configuration;	
			(3) The holding ice accretion defined in appendix C for the holding configuration(s);	
			(4) The approach ice accretion defined in appendix C for the approach configuration(s); and	
			(5) The landing ice accretion defined in appendix C for the landing and go-around configuration(s).	
		(f)	The stall warning margin must be sufficient in both non-icing and icing conditions to allow the pilot to prevent stalling when the pilot starts a recovery maneuver not less than one second after the onset of stall warning in slow-down turns with at least 1.5 g load factor normal to the flight path and airspeed deceleration rates of at least 2 knots per second. When demonstrating compliance with this paragraph for icing conditions, the pilot must perform the recovery maneuver in the same way as for the airplane in non-icing conditions. Compliance with this requirement must be demonstrated in flight with—	N
			(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).	N
		(h)	For flight in icing conditions before the ice protection system has been activated and is performing its intended function, with the ice accretion defined in appendix C, part II(e) of this part, 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:	N
			(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.	N
25.251	Vibration and buffeting	(d)	There may be no perceptible buffeting condition in the cruise configuration in straight flight at any speed up to V_{MO}/M_{MO} , except that stall warning buffeting is allowable .	N

Regulation	Description	Paragraph	Paragraph	Change Required Y/N
CS 25.1302	Installed systems and equipment for use by the flight crew			N
		(b)	(b) Flight deck controls and information intended for flight crew use must: (1) Be presented in a clear and unambiguous form, at resolution and precision appropriate to the task. (2) Be accessible and usable by the flight crew in a manner consistent with the urgency, frequency, and duration of their tasks, and (3) Enable flight crew awareness, if awareness is required for safe operation, of the effects on the aeroplane or systems resulting from flight crew actions.	N
		(c)	(c) Operationally-relevant behaviour of the installed equipment must be: (1) Predictable and unambiguous, and (2) Designed to enable the flight crew to intervene in a manner appropriate to the task.	N
		(d)	(d) To the extent practicable, installed equipment must enable the flight crew to manage errors resulting from the kinds of flight crew interactions with the equipment that can be reasonably expected in service, assuming the flight crew is acting in good faith. This sub-paragraph (d) does not apply to skill-related errors associated with manual control of the aeroplane.	N
25.1303	Flight and Navigation Instruments			N
		(c)(1)	(1) A speed warning device is required for turbine engine powered airplanes and for airplanes with VMO/MMO greater than 0.8 VDF/MDF or 0.8 VD/MD. The speed warning device must give effective aural warning (differing distinctively from aural warnings used for other purposes) to the pilots, whenever the speed exceeds VMO, plus 6 knots or MMO +0.01. The upper limit of the production tolerance for the warning device may not exceed the prescribed warning speed.	N
25.1322	Warning, caution, and advisory lights			
		(a)	(a) Red, for warning lights (lights indicating a hazard which may require immediate corrective action);	N
		(b)	(b) Amber, for caution lights (lights indicating the possible need for future corrective action);	N
		(c)	(c) Green for safe operation lights; and	N
		(d)	(d) Any other color, including white, for lights not described in paragraphs (a) through (c) of this section, provided the color differs sufficiently from the colors prescribed in paragraphs (a) through (c) of this section to avoid possible confusion.	N
CS 25.1322	Alerting			N

Regulation	Description	Paragraph	Paragraph	Change Required Y/N
	Systems			
Draft FAR/CS 25.1322	Flight Crew Alerting	(a)	(a) When flight crew alerts are provided they must: 1) Provide timely attention-getting cues through at least two different senses by combination of aural, visual, or tactile indications, for crew alerts requiring immediate flight crew awareness. 2) Provide the flight crew with the information needed to identify the alert and determine correct action, if any. 3) Be readily and easily detectable and intelligible by the flight crew under all foreseeable operating conditions including conditions where multiple alerts are provided.	N
		(b)	(b) Alerts must conform to the following prioritization hierarchy based upon urgency of flight crew awareness and urgency of flight crew response. 1) Warning: For conditions that require immediate flight crew awareness and immediate flight crew response. If warnings are time critical to maintain the immediate safe operation of the airplane, they must be prioritized higher than other warnings. 2) Caution: For conditions that require immediate flight crew awareness and subsequent flight crew response. 3) Advisory: For conditions that require flight crew awareness and may require subsequent flight crew response.	N
		(c)	(c) Alert presentation means must be designed to minimize nuisance effects. In particular a crew alerting system must: 1) Permit each occurrence of attention getting cues, if provided, to be acknowledged and suppressed unless they are otherwise required to be continuous. 2) Prevent the presentation of an alert that is inappropriate or unnecessary for the particular phase of operation. 3) Remove the presentation of the alert when the condition no longer exists 4) Provide a means to suppress an attention getting component of an alert caused by a failure of the alerting system, and/or the sensors, which interfere with the flight crew's ability to safely operate the aircraft. This means must not be readily available to the flight crew such that it could be operated inadvertently, or by habitual reflexive action. In this case, there must be a clear and unmistakable annunciation to the flight crew that the alert has been suppressed.	N
		(d)	(d) Alerts must conform to the following color convention for visual alert indications: 1) Red for Warning alert indications. 2) Amber/yellow for Caution alert indications. 3) Any color except red or green for Advisory alert indications.	N
		(e)	(e) The colors red and amber/yellow are normally reserved for alerting functions. The use of these colors for functions other than crew alerting must be limited and must not adversely affect crew alerting.	N

Regulation	Description	Paragraph	Paragraph	Change Required Y/N
25.1323	Airspeed Indicating System			
CS 25.1323			Ref AMC 25.1323	N
25.1329	Flight guidance system			N
25.1503	Airspeed limitations: general			N
25.1505	Maximum operating limit speed			N

