failure condition unless substantiated as meriting a lower failure condition classification.

For the identification of conditions conducive to airframe icing in the frame of CS 25.1419(e)(3), the temperature cue used in combination with visible moisture has to be considered as a primary parameter, and the display of erroneous too high temperature to the flight crew, which potentially leads to non-activation of the IPS, should be considered as a catastrophic failure condition, unless substantiated as meriting a lower failure condition classification.

1.2 Visual cues

Visual cues can be either direct observation of ice accretions on the aeroplane's protected surfaces or observation of ice accretions on reference surfaces. The first indications of any of the following are examples of what could potentially be used as visual cues:

— Accretions forming on the windshield wiper posts (bolt or blade).

— Accretions forming on propeller spinner.

— Accretions forming on radome.

— Accretions on the protected surfaces.

If accretions on protected surfaces cannot be observed, a reference system would be necessary if compliance with CS 25.1419(e)(2) is sought. The applicant should consider providing a reference surface that can be periodically de-iced to allow the flight crew to determine if the airframe is continuing to accumulate ice.

Without a means to de-ice the reference surface, as long as ice is present on the reference surface:

— The IPS should operate in presence of conditions conducive to icing (AFM procedure based on visible moisture and temperature); the IPS may be switched off after leaving conditions conducive to icing, even though ice may still be present on the reference surface; or

— The IPS should operate continuously, even if additional ice is not accumulating.

When ice accretion is no longer present on the reference surface, the next activation of the IPS can again be triggered by the presence of ice accreting on this reference surface.

As the freezing fraction drops below 1, although some reference surfaces may not build up ice, ice may begin to accumulate on protected surfaces of the aeroplane. The applicant should substantiate, for all the icing conditions defined in the relevant icing environment, that the reference surface accumulates ice at the same time as or prior to ice accumulating on the protected surfaces.

1.2.1 Field of view

Visual cues should be developed with the following considerations:

a. Visual cues should be within the flight crew's primary field of view, if possible. If cues are outside the primary field of view, they should be visible from the design eye point and easily incorporated into the flight crew's vision scan with a minimum of head movement while seated and performing their normal duties.

b. Visual cues should be visible during all modes of operation (day, night, and in cloud).

1.2.2 Verification

During the certification process, the applicant should verify the ability of the crew to observe the visual cues. Visibility of the visual cues should be evaluated from the most adverse flight crew seat locations in combination with the range of flight crew heights, within the approved range of eye reference point locations, if available. A visual cue is required for both the left and right seats. If a single visual cue is used, it should be visible from each seat. The adequacy of the visual cue should be evaluated in all expected flight conditions, and in particular the capability of detecting clear ice should be verified. The applicant may carry out night evaluations with artificial accretions to assess visibility in and out of cloud. Visual cues should be substantiated by tests and analysis, including tests in measured natural icing.

2. Compliance With CS 25.1419(e)(3)

This subparagraph of CS 25.1419 provides an alternative to the PIDS and visual cues plus the AIDS as defined in CS 25.1419(e)(1) and (e)(2). This alternative requires operation of the IPS when the aeroplane is in conditions conducive to airframe icing during all phases of flight.

2.1 Temperature cue.

The temperature cue used in combination with visible moisture should consider static temperature variations due to local pressure variations on the airframe. If the engine IPS and the airframe IPS are both activated based on visible moisture and temperature, a common conservative temperature for operation of both systems should be used. For example, if the engine IPS is activated at + 5 ºC static air temperature or less, the airframe IPS should be activated at the same temperature, even if it is substantiated that the airframe will not accrete ice above + 2 ºC static air temperature. This would ease the flight crew workload and increase the probability of procedural compliance.

2.2 Either total or static temperatures are acceptable as cues. If static is used, a display of static air temperature should be provided to allow the flight crew to easily determine when to activate the systems. As an alternative, a placard showing corrections for the available temperature, to the nearest degree Celsius, can be used, so the flight crew can determine the static air temperature in the region of interest (that is, around 0 ºC).

2.3 Aeroplane Flight Manual (AFM).

The Limitations section of the AFM should identify the specific static or total air temperature and visible moisture conditions that must be considered as conditions conducive to airframe icing and should specify that the IPS must be operated when these conditions are encountered.

(e) CS 25.1419(f)

This subparagraph of CS 25.1419 states that requirements of CS 25.1419(e)(1), CS 25.1419(e)(2) or CS 25.1419(e)(3) are applicable to all phases of flight unless it can be shown that the IPS need not be operated. To substantiate that the IPS need not be operated during certain phases of flight, the applicant should consider ice accretions that form during these phases, without the IPS operating, and establish that the aeroplane can safely operate in the relevant icing environment

(f) CS 25.1419(g)

This subparagraph of CS 25.1419 requires that after the initial activation of the IPS:

— The IPS must operate continuously, or

— The aeroplane must be equipped with a system that automatically cycles the IPS, or

— An ice detection system must be provided to alert the flight crew each time the IPS must be cycled.

Some examples of systems that automatically cycle the IPS are:

— A system that senses ice accretion on a detector and correlates it to ice accretion on a protected surface. This system then cycles the IPS at a predetermined rate.

— A system that uses a timer to cycle the IPS. The applicant should substantiate that the aeroplane can safely operate with the ice accretions that form between the time one de-icing cycle is completed and the time the next cycle is initiated. If more than one cycling time is provided to the flight crew (for example choosing between a 1- or 3-minute intervals), it should be substantiated that the flight crew can determine which cycle time is appropriate.

— A system that directly senses the ice thickness on a protected surface and cycles the IPS.

A common attribute of the above systems is that the pilot is not required to manually cycle the IPS after initial activation.

Some types of ice detection systems that alert the flight crew each time the IPS must be cycled could operate in a manner similar to the automatic systems discussed above, except that the crew would need to manually cycle the system. Flight crew workload associated with such a system should be evaluated. Because of flight crew workload and human factors considerations, a timed system without an ice sensing capability should not be used to meet this requirement. The ice shedding effectiveness of the selected means for cycling the ice protection system should be evaluated during testing in natural icing conditions. All inter-cycle and runback ice should be considered when showing compliance with CS 25.21(g).

(g) CS 25.1419(h)

CS 25.1419(h) requires that AFM procedures for operation of the IPS, including activation and deactivation, must be established. Procedures for IPS deactivation must be consistent with the CS 25.1419(e) requirements for activation of the IPS. The exact timing of deactivation should consider the type of ice protection system (e.g., de-icing, anti-icing, or running wet) and all delays in deactivation necessary to ensure that residual ice is minimized. Pneumatic boots should be operated for three complete cycles following the absence of the cues used for activation. However, if the aeroplane's stall protection system reverts from an icing schedule to a non-icing schedule when the airframe IPS is deactivated, AFM procedures should state that the airframe IPS should not be deactivated until the flight crew are certain that the critical wing surfaces are free of ice.

[Amdt 25/16]

CS 25.1420 Supercooled large drop icing conditions

ED Decision 2016/010/R

(see AMC 25.1420)

(a) If certification for flight in icing conditions is sought, in addition to the requirements of CS 25.1419, the aeroplane must be capable of operating in accordance with sub-paragraphs (a)(1), (a)(2), or (a)(3) of this paragraph.

(1) Operating safely after encountering the icing conditions defined in Appendix O:

(i) The aeroplane must have a means to detect that it is operating in Appendix O icing conditions; and

(ii) Following detection of Appendix O icing conditions, the aeroplane must be capable of operating safely while exiting all icing conditions.

(2) Operating safely in a portion of the icing conditions defined in Appendix O as selected by the applicant.

(i) The aeroplane must have a means to detect that it is operating in conditions that exceed the selected portion of Appendix O icing conditions; and

(ii) Following detection, the aeroplane must be capable of operating safely while exiting all icing conditions.

(3) Operating safely in the icing conditions defined in Appendix O.

(b) To establish that the aeroplane can operate safely as required in sub-paragraph (a) of this paragraph, an applicant must show through analysis that the ice protection for the various components of the aeroplane is adequate, taking into account the various aeroplane operational configurations. To verify the analysis, one, or more as found necessary, of the following methods must be used:

(1) Laboratory dry air or simulated icing tests, or a combination of both, of the components or models of the components.

(2) Laboratory dry air or simulated icing tests, or a combination of both, of models of the aeroplane.

(3) Flight tests of the aeroplane or its components in simulated icing conditions, measured as necessary to support the analysis.

(4) Flight tests of the aeroplane with simulated ice shapes.

(5) Flight tests of the aeroplane in natural icing conditions, measured as necessary to support the analysis.

(c) For an aeroplane certified in accordance with sub-paragraph (a)(2) or (a)(3) of this paragraph, the requirements of CS 25.1419(e), (f), (g), and (h) must be met for the icing conditions defined in Appendix O in which the aeroplane is certified to operate.

(d) A comparative analysis may be used as an alternative to CS 25.1420(b) to establish that the aeroplane can operate safely as required in CS 25.1420(a), and as an alternative to CS 25.1420(c) regarding methods of icing detection and activation of the airframe ice protection system. In this case, tests may not be required (see AMC 25.1420(f)).

[Amdt 25/16]
[Amdt 25/18]

AMC 25.1420 Supercooled large drop icing conditions

ED Decision 2016/010/R

If certification for flight in icing conditions is sought, in addition to the requirements of CS 25.1419, the aeroplane must be capable of operating in accordance with subparagraphs (a)(1), (a)(2), or (a)(3) of CS 25.1420.

Besides being able to operate safely in Appendix C icing conditions, the aeroplane must also be able to safely operate in or exit the icing conditions defined by CS-25, Appendix O. The applicant, however, has several certification options available for Appendix O icing conditions. The aeroplane can be certified for:

— The ability to detect Appendix O conditions and safely exit all icing conditions , or

— The ability to operate safely throughout a portion of Appendix O icing conditions and safely exit all icing conditions when that portion of Appendix O is exceeded, or

— The ability to operate safely throughout all Appendix O icing conditions.

In the context of this AMC:

— 'Relevant icing environment' means the Appendix O or a portion of the Appendix O as applicable.

— 'All icing conditions' means Appendix C and Appendix O icing environment.

— 'Simulated Icing Test' means testing conducted in simulated icing conditions, such as in an icing tunnel or behind an icing tanker.

— 'Simulated Ice Shape' means an ice shape fabricated from wood, epoxy, or other materials by any construction technique.

CS 25.1420 provides specific airframe requirements for certification for flight in the icing conditions defined in Appendix O. Additionally, for other parts of the aeroplane (i.e. engine, engine inlet, propeller, flight instrument external probes, windshield) there are more specific icing related CS-25 specifications and associated acceptable means of compliance.

Appendix O Spectra

Appendix O defines freezing drizzle and freezing rain environments by using four spectra of drop sizes with associated liquid water content (LWC) limits. An FAA detailed report on the development of Appendix O is available from the FAA William J. Hughes Technical Center (reference report DOT/FAA/AR-09/10, dated March 2009). Following are the four drop size spectra:

a) Freezing drizzle environment with a median volume diameter (MVD) less than 40 microns (µm). In addition to drizzle drops, which are defined as measuring 100 to 500 µm in diameter, this environment contains drops less than 100 µm, with a sufficient number of drops less than 40 µm so the MVD is less than 40 µm.

b) Freezing drizzle environment with an MVD greater than 40 µm. In addition to freezing drizzle drops, this environment contains smaller drops, with diameters less than 100 µm.

c) Freezing rain environment with an MVD less than 40 µm. In addition to freezing rain drops, which are defined as measuring more than 500 µm in diameter, this environment also contains smaller drops of less than 500 µm with a sufficient number of drops less than 40 µm so the MVD is less than 40 µm.

d) Freezing rain environment with an MVD greater than 40 µm. In addition to freezing rain drops, this environment also contains smaller drops of less than 100 µm.

Caution information:

CS 25.1420 describes requirements that are in addition to the requirements in CS 25.1419 for certain aeroplanes and does not contain a requirement complementary to CS 25.1419(c). Instead, it relies on compliance with CS 25.1309(c) to ensure that adequate warning is provided to the flight crew of unsafe system operating conditions. Warning information required by CS 25.1309(c), to alert the flight crew of unsafe system operating conditions, is applicable to design features installed to meet the additional requirements in CS 25.1420 and must be provided in accordance with CS 25.1322.

(a) CS 25.1420(a)(1) Detect Appendix O icing conditions and safely exit all icing conditions

When complying with CS 25.1420(a)(1), the applicant must provide a method for detecting that the aeroplane is operating in Appendix O icing conditions. Following detection, the aeroplane must be capable of operating safely while exiting all icing conditions until landing.

Substantiated methods of alerting flight crews when Appendix O icing conditions are encountered are required. It is acceptable to use an ice detection system that detects accretions behind the aeroplane’s protected areas. Considerations in paragraph (b) below, related to CS 25.1420(a)(2) acceptable means of alerting flight crews when Appendix O icing conditions are encountered, are also relevant for this paragraph.

(b) CS 25.1420(a)(2) Operate safely throughout a portion of Appendix O icing conditions

If the applicant seeks certification for safe operation in portions of Appendix O icing conditions, such as freezing drizzle only, or during specific phases of flight, CS 25.1420(a)(2) applies. If this option is chosen, following detection of conditions that exceed the selected portion of Appendix O, the aeroplane must be capable of operating safely while exiting all icing conditions until landing.

Substantiated methods of alerting flight crews when those portions of Appendix O are exceeded are required.

Certification for flight in a portion of Appendix O icing conditions depends upon the applicant substantiating an acceptable way for the flight crew to distinguish the portion of Appendix O conditions for which the aeroplane is certified from the portion of Appendix O conditions for which the aeroplane is not approved. Certification for a portion of Appendix O allows latitude for certification with a range of techniques. Ice shapes will need to be developed to test for the portion of the envelope for which approval is sought, as well as for detecting and exiting icing conditions beyond the selected portion. The icing conditions the aeroplane may be certified to fly through may be defined in terms of any parameters that define Appendix O conditions and could include phase of flight limits, such as take-off or holding, in Appendix O or a portion of Appendix O. For example, an aeroplane may be certificated to take off in portions of Appendix O conditions, but not be certificated for holding in those same conditions. Substantiated means must be provided to inform flight crews when the selected icing conditions boundary is exceeded. The applicant must show compliance with CS 25.21(g) for exiting the restricted Appendix O icing conditions. Ice shapes to be tested are those representing the critical Appendix O icing conditions during recognition and subsequent exit from those icing conditions.

Ice shapes developed using the approved portion of the icing envelope should account for the range of drop distribution and water content and consider the proposed method for identifying icing conditions that must be exited. The definition of the certificated portion of Appendix O for a particular aeroplane should be based on measured characteristics of the selected icing environment and be consistent with methods used for developing Appendix O. Initial certification for flight in a portion of Appendix O conditions will likely include all of freezing drizzle or all of freezing rain. Such certification could be restricted to operation in Appendix O conditions by phase of flight.

Methods of defining the selected Appendix O icing conditions boundary should be considered early in the certification process, with concurrence from the Agency.

Determining whether the selected Appendix O icing conditions boundary has been exceeded can potentially be accomplished using:

— substantiated visual cues,

— an ice detection system, or

— an aerodynamic performance monitor.

The relevant AFM section(s) (possibly the limitation and the emergency procedure) should detail the method to warn the flight crew that the certified icing envelope has been exceeded.

1. Substantiated visual cues

Substantiated visual cues can range from direct observation of ice accretions aft of the aeroplane's protected surfaces to observation of ice accretions on reference surfaces. Methods used to substantiate visual cues should be agreed upon with the Agency. Responding to a visual cue should not require the flight crew to judge the ice to be a specific thickness or size.

Examples of potential visual cues are accretions forming on the side windshields, the sides of nacelles, the propeller spinners aft of a reference point, the radomes aft of a reference point, and/or aft of protected surfaces.

Visual cues should be developed with the following considerations:

(i) Visual cues should be within the flight crew's primary field of view if possible. If outside the primary field of view, the visual cues should be visible from the design eye point and easily incorporated into the flight crew's visual scan with a minimum of head movement while seated and performing their normal duties.

(ii) Visual cues should be visible during all modes of operation (day, night) without use of a handheld flashlight.

During the certification process, the applicant should verify the ability of the crew to observe visual cues or reference surfaces. Visibility of the visual cues should be evaluated from the most adverse flight crew seat locations in combination with the range of flight crew heights, within the approved range of eye reference point locations, if available. A visual cue is required for both the left and right seats. If a single visual cue is used, it should be visible from each seat. Consideration should be given to the difficulty of observing clear ice. The adequacy of the detection method should be evaluated in all expected flight conditions. The applicant may carry out night evaluations with simulated ice shapes to assess visibility in and out of cloud.

Visual cues should be substantiated by tests and analysis, including tests in measured natural icing, or icing tanker tests, or potentially through icing wind tunnel tests. The applicant should consider the drop distributions of Appendix O when developing the visual cue, and the applicant should substantiate that these cues would be present in all the restricted Appendix O icing conditions. If a reference surface is used, the applicant should substantiate that it accumulates ice at the same time as or prior to ice accumulation on the critical surfaces.

AMC 25.21(g) should be reviewed for guidance on the time flight crews need to visually detect Appendix O icing conditions.

2. Ice detection systems

An ice detection system installed for compliance with CS 25.1420(a) is meant to determine when conditions have reached the boundary of the Appendix O icing conditions in which the aeroplane has been demonstrated to operate safely. The applicant should accomplish a drop impingement analysis and/or tests to ensure that the ice detector is properly located to function during the aeroplane operational conditions and in Appendix O icing conditions. The applicant may use analysis to determine that the ice detector is located properly for functioning throughout the drop range of Appendix O icing conditions when validated with methods described in document SAE ARP5903 “Drop Impingement and Ice Accretion Computer Codes”, dated October 2003. The applicant should ensure that the system minimizes nuisance warnings when operating in icing conditions.

The low probability of finding conditions conducive to Appendix O ice accumulation may make natural icing flight tests a difficult way to demonstrate that the system functions in conditions exceeding Appendix C. The applicant may use flight tests of the aeroplane under simulated icing conditions (icing tanker). The applicant may also use icing wind tunnel tests of a representative aerofoil section and an ice detector to demonstrate proper functioning of the system and to correlate signals provided by the detectors with the actual ice accretion on the surface.

3. Aerodynamic performance monitor (APM)

A crew alerting system using pressure probes and signal processors could be developed for quantifying pressure fluctuations in the flow field from contamination over the wing surface. This technology does exist, but full development is necessary before incorporating it into the crew alerting system.

(c) CS 25.1420(a)(3) Operate safely throughout all Appendix O icing conditions

CS 25.1420(a)(3) applies when the applicant seeks certification for all of the icing conditions described in Appendix O. An aeroplane certified to CS 25.1420(a)(3) must be capable of safely operating throughout the conditions described in Appendix O and does not need a means to distinguish Appendix O conditions from Appendix C conditions. The provisions in CS 25.1419 which require a method to detect icing conditions and activate the ice protection system are still applicable. If the aeroplane is certified for unrestricted flight in Appendix O conditions, the ice detection method must be substantiated to function throughout Appendix O. In effect, when CS 25.1420(a)(3) is chosen, the aeroplane is certificated for flight in icing without any specific aeroplane flight manual procedures or limitations to exit icing conditions.

If the AFM performance data reflects the most critical ice accretion (Appendix C and Appendix O) and no special normal or abnormal procedures are required in Appendix O conditions, then a means to indicate when the aeroplane has encountered Appendix O icing conditions is not required. However, a means to alert the flight crew that the airplane has encountered icing conditions is still required in accordance with CS 25.1419.

(d) CS 25.1420 (b)

1. Analysis

AMC 25.1419(a) applies and in addition, the following should be considered specifically for compliance with CS 25.1420(b):

1.1 Analysis of areas and components to be protected.

In assessing the areas and components to be protected, unless comparative analysis is used as the means of compliance, considerations should be given on the fact that areas that do not accrete ice in Appendix C conditions may accrete ice in the Appendix O conditions.

1.2 Failure analysis

Applying the system safety principles of CS 25.1309 is helpful in determining the need for system requirements to address potential hazards from an Appendix O icing environment. The following addresses application of the CS 25.1309 principles to Appendix O conditions and may be used for showing compliance with CS 25.1309. Alternatively, a comparative analysis, if applicable, may be used as defined in paragraph (e) of this AMC.

1.2.1 Hazard classification

Assessing a hazard classification for compliance with CS 25.1309 is typically a process combining quantitative and qualitative factors based on the assessment of the failure conditions and the associated severity of the effects. If the design is new and novel and has little similarity to previous designs, a hazard classification based on past experience may not be appropriate. If the design is derivative in nature, the assessment can consider the icing event history of similarly designed aeroplanes and, if applicable, the icing event history of all conventional design aeroplanes. The applicant should consider specific effects of supercooled large drop icing when assessing similarity to previous designs.

1.2.2 Qualitative Analysis

The following qualitative analysis may be used to determine the hazard classification for an unannunciated encounter with Appendix O icing conditions. The analysis can be applied to aeroplanes shown to be similar to previous designs with respect to Appendix O icing effects, and to which the icing event history of all conventional design aeroplanes is applicable.

1.2.2.1 Assumptions

The aeroplane is certificated to either:

a. Detect Appendix O icing conditions and safely exit all icing conditions after detection of Appendix O icing conditions, or

b. Safely operate in a selected portion of Appendix O icing conditions and safely exit all icing conditions after detection of Appendix O icing conditions beyond those for which it is certificated.

The 'unannunciated encounter with Appendix O' refers to Appendix O icing conditions in which the aeroplane has not been shown to operate safely.

The airframe and propulsion ice protection systems have been activated prior to the unannunciated encounter.

1.2.2.2 Service history

The applicant may use service history, design, and installation appraisals to support hazard classifications for CS 25.1309. Service history may be appropriate to support a hazard classification if a new or derivative aeroplane has similar design features to a previously certificated aeroplane. Service history data are limited to the fleet of aeroplane type(s) for which the applicant is the holder of the Type Certificate(s), the owner of the data, or, if accepted by the Agency, has an agreement in place with the owner of the data that permits its use by the applicant for this purpose (see also paragraph (f)3.2 of this AMC).

1.2.2.3 Historical perspective

While definitive statistics are not available, a historical perspective can provide some guidance. Many aeroplanes flying through icing have been exposed to supercooled large drop conditions without the pilot being aware of it. The interval of exposure to the supercooled large drop conditions may have varied from a brief amount of time (such as could occur during a vertical transition through a cloud) to a more sustained exposure (such as during a hold). Severity of the exposure conditions in terms of water content may have varied significantly. Therefore, the hazard from encountering supercooled large drop conditions may be highly variable and dependent on various factors.

1.2.2.4 Icing event history of aeroplanes of conventional design certified before the introduction of CS 25.1420.

Given the volume of aeroplane operations and the number of reported incidents that did not result in a catastrophe, a factor of around 1 in 100 is a reasonable assumption of probability for a catastrophic event if an aeroplane encounters the icing conditions represented by Appendix O Appendix O in which it has not been shown capable of safely operating, while the aeroplane's ice protection systems are operating normally (in accordance with approved procedures for the icing conditions represented by Appendix C). An applicant may assume that the hazard classification for an unannunciated encounter with the icing conditions represented by Appendix O while these ice protection systems are operating normally is hazardous in accordance with AMC 25.1309, provided that the following are true:

— The aeroplane is similar to previous designs with respect to icing effects in the icing conditions represented by Appendix O, and

— The applicant can show that the icing event history of all aeroplanes of conventional design is relevant to the aeroplane being considered for certification.