AMC 25.1027(b) Propeller Feathering

ED Decision 2003/002/RM

The amount of trapped oil should be sufficient to cover one feathering operation; taking into account the maximum oil leakage in the feathering system due to wear and deterioration in service.

COOLING

CS 25.1041 General

ED Decision 2003/2/RM

The powerplant cooling provisions must be able to maintain the temperatures of powerplant components, and engine fluids, within the temperature limits established for these components and fluids, under ground and flight operating conditions, and after normal engine shutdown.

CS 25.1043 Cooling tests

ED Decision 2016/010/R

(See AMC 25.1043)

(a) *General*. Compliance with CS 25.1041 must be shown by tests, under critical ground and flight operating conditions. For these tests, the following apply:

(1) If the tests are conducted under conditions deviating from the maximum ambient atmospheric temperature, the recorded power-plant temperatures must be corrected under sub-paragraph (c) of this paragraph.

(2) No corrected temperatures determined under sub-paragraph (1) of this paragraph may exceed established limits.

(3) *Reserved.*

(b) *Maximum ambient atmospheric temperature.* A maximum ambient atmospheric temperature corresponding to sea level conditions of at least 37.8°C (100°F) must be established. The assumed temperature lapse rate is 6.6°C per thousand meter (3·6°F per thousand feet) of altitude above sea level until a temperature of -56.5°C (–69·7°F) is reached, above which altitude the temperature is considered at -56.5°C (–69·7°F). However, for winterization installations, the applicant may select a maximum ambient atmospheric temperature corresponding to sea-level conditions of less than 37.8°C (100°F).

(c) *Correction factor*. Unless a more rational correction applies, temperatures of engine fluids and powerplant components for which temperature limits are established, must be corrected by adding to them the difference between the maximum ambient atmospheric temperature and the temperature of the ambient air at the time of the first occurrence of the maximum component or fluid temperature recorded during the cooling test.

[Amdt 25/18]

AMC 25.1043 Cooling tests

ED Decision 2014/026/R

In accordance with CS 25.1041, applicants must show that the cooling provisions can maintain the temperatures of powerplant components and engine fluids within the temperature limits for which they have been certified, under ground and flight operating conditions, and after normal engine shutdown.

CS 25.1043(b) establishes 37.8° C (100°F) at sea level as the lowest maximum ambient temperature, except for winterisation installations. Applicants may establish a higher temperature limit if desired.

The assumed temperature lapse rate is 6.6°C per thousand meter (3.6°F per thousand feet) of altitude above sea level until a temperature of -56.5°C (–69.7°F) is reached, above which altitude the temperature is considered at -56.5°C (–69.7°F). The compliance demonstration flight test should be conducted with an ambient temperature as close to the desired maximum ambient atmospheric temperature as practical; the maximum temperature deviation should not normally exceed 13.9°C (25°F). If testing is accomplished at lower ambient temperatures, then the test data must be corrected to that which would have resulted from testing on a day with the maximum ambient atmospheric temperature.

The maximum ambient temperature selected and demonstrated satisfactorily, taking account of correction factors, shall not be less than the minimum hot day conditions prescribed by CS 25.1043(b) and shall be an aeroplane operating limitation per the requirements of CS 25.1521(d). The applicant should correct the engine temperatures to as high a value as possible in order to minimise the impact of this limitation.

[Amdt 25/15]

CS 25.1045 Cooling test procedures

ED Decision 2003/2/RM

(a) Compliance with CS 25.1041 must be shown for the take-off, climb, en-route, and landing stages of flight that correspond to the applicable performance requirements. The cooling tests must be conducted with the aeroplane in the configuration, and operating under the conditions, that are critical relative to cooling during each stage of flight. For the cooling tests, a temperature is 'stabilised' when its rate of change is less than 1°C (2°F) per minute.

(b) Temperatures must be stabilised under the conditions from which entry is made into each stage of flight being investigated, unless the entry condition normally is not one during which component and engine fluid temperatures would stabilise (in which case, operation through the full entry condition must be conducted before entry into the stage of flight being investigated in order to allow temperatures to reach their natural levels at the time of entry). The take-off cooling test must be preceded by a period during which the powerplant component and engine fluid temperatures are stabilised with the engines at ground idle.

(c) Cooling tests for each stage of flight must be continued until –

(1) The component and engine fluid temperatures stabilise;

(2) The stage of flight is completed; or

(3) An operating limitation is reached.

AIR INTAKE SYSTEM

CS 25.1091 Air intake

ED Decision 2016/010/R

(See AMC 25.1091)

(a) The air intake system for each engine must supply –

(1) The air required by that engine under each operating condition for which certification is requested; and

(2) The air for proper fuel metering and mixture distribution with the air intake system valves in any position.

(b) *Reserved.*

(c) Air intakes may not open within the cowling, unless that part of the cowling is isolated from the engine accessory section by means of a fireproof diaphragm.

(d) (1) There must be means to prevent hazardous quantities of fuel leakage or overflow from drains, vents, or other components of flammable fluid systems from entering the engine air intake system; and

(2) The aeroplane must be designed to prevent water or slush on the runway, taxiway, or other airport operating surfaces from being directed into the engine air intake ducts in hazardous quantities, and the air intake ducts must be located or protected so as to minimise the ingestion of foreign matter during take-off, landing and taxying. (See AMC 25.1091(d)(2).)

(e) If the engine air intake system contains parts or components that could be damaged by foreign objects entering the air intake, it must be shown by tests or, if appropriate, by analysis that the air intake system design can withstand the foreign object ingestion test conditions of CS-E 790 and CS-E 800 without failure of parts or components that could create a hazard. (See AMC 25.1091(e).)

[Amdt 25/18]

AMC 25.1091(d)(2) Precipitation Covered Runways

ED Decision 2003/2/RM

1 Except where it is obvious by inspection or other means, that precipitation on the runway would not enter the engine air intake under the declared operating conditions, including the use of the thrust reverser, compliance with the requirements should be demonstrated by tests using tyres representative of those to be approved for operational use. These tests should clear the aeroplane for operation from runways which are normally clear and also for operation in precipitation up to 13 mm (0·5 in) depth of water or dense slush. The tests should be conducted with the minimum depth of 13 mm (0·5 in) and an average depth of 19 mm (0·75 in), or if approval is sought for a greater depth than 13 mm (0·5 in), the average depth should be 1·5 times the depth for which the take-offs are to be permitted, and the minimum depth should be not less than the depth for which take-offs are to be permitted.

2 It should be shown that the engines operate satisfactorily without unacceptable loss of power at all speeds from zero up to lift-off speed and in the attitudes likely to be used. Any special aeroplane handling techniques necessary to ensure compliance with the requirement should comply with the handling techniques assumed in establishing the scheduled performance of the aircraft.

3 The tests may be made in water or slush either by complete take-offs and landings as necessary in the specified precipitation conditions, or by a series of demonstrations in areas of precipitation sufficiently large to permit the spray pattern to become stabilised and to determine engine behaviour and response. Experience has shown that where a trough is used, a length of 70 to 90 m (230 to 295 ft) is usually satisfactory. If marginal results are obtained the effect of the difference between water and slush should be examined.

4 The effects of cross-winds should be examined and where necessary a cross-wind limitation established for inclusion in the Flight Manual for operation from precipitation covered runways.

5 It may be difficult to deduce the effect of low density precipitation (dry snow) from high density testing, but nevertheless clearance of the aeroplane for operation in dense precipitation up to 13 mm (0·5 in) will usually clear the aeroplane for operation in low density precipitation of depths greater than 10 cm (4 in) depth. If clearance is requested for operation in low density precipitation of depths greater than 10 cm (4 in) additional tests (in low density precipitation having a depth close to that for which approval is sought) will be necessary.

6 When auxiliary devices are fitted to prevent spray from being ingested by the engines it will be necessary to do additional tests in low density precipitation to permit operations in depths greater than 25 mm (1 in).

AMC 25.1091(e) Air Intake System

ED Decision 2003/2/RM

The parts or components to be considered are, for example, intake splitters, acoustic lining if in a vulnerable location and inlet duct-mounted instrumentation.

CS 25.1093 Air intake system de-icing and anti-icing provisions

ED Decision 2016/010/R

(See AMC 25.1093)

(a) *Reserved.*

(b) Turbine engines

Each engine, with all icing protection systems operating, must:

(1) Operate throughout its flight power range, including the minimum descent idling speeds, in the icing conditions defined in Appendices C, O and P, and in falling and blowing snow within the limitations established for the aeroplane for such operation, without the accumulation of ice on the engine, air intake system components or airframe components that would do any of the following:

(i) Adversely affect installed engine operation or cause a sustained loss of power or thrust; or an unacceptable increase in gas path operating temperature; or an airframe/engine incompatibility; or

(ii) Result in unacceptable temporary power or thrust loss or engine damage; or

(iii) Cause a stall, surge, or flameout or loss of engine controllability (for example, rollback).

(2) Idle for a minimum of 30 minutes on the ground in the following icing conditions shown in Table 1 below, unless replaced by similar test conditions that are more critical. These conditions must be demonstrated with the available air bleed for icing protection at its critical condition, without adverse effect, followed by an acceleration to take-off power or thrust, in accordance with the procedures defined in the aeroplane flight manual. During the idle operation the engine may be run up periodically to a moderate power or thrust setting in a manner acceptable to the Agency. The applicant must document the engine run-up procedure (including the maximum time interval between run-ups from idle, run-up power setting, and duration at power), the associated minimum ambient temperature, if any, and the maximum time interval. These conditions must be used in the analysis that establishes the aeroplane operating limitations in accordance with CS 25.1521. (See AMC 25.1093(b))

Table 1- Icing conditions for ground tests

Condition	Total air temperature	Water concentration (minimum)	Mean effective particle diameter	Demonstration
(i) Rime ice condition	-18 to -9°C (0 to 15°F)	Liquid—0.3 g/m3	15–25 µm	By test, analysis or combination of the two.
(ii) Glaze ice condition	-9 to -1°C (15 to 30°F)	Liquid—0.3 g/m3	15–25 µm	By test, analysis or combination of the two.
(iii) Large drop condition	-9 to -1°C (15 to 30°F)	Liquid—0.3 g/m3	100-3000 µm	By test, analysis or combination of the two.

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

AMC 25.1093(b) Power plant icing

ED Decision 2016/010/R

Compliance with CS 25.1093(b) is required even if certification for flight in icing conditions is not sought. Applicants must, therefore, propose acceptable means of compliance which may include flight tests in natural icing conditions.

The results of tests and analysis used for compliance with CS-E 780 may be used to support compliance with CS 25.1093(b). This requires close coordination between the engine manufacturer and the aeroplane manufacturer to make sure that CS-E 780 tests cover all potential ice sources.

If an applicant can show that the ice protection and the ice ingestion capability of a powerplant is equivalent to a previously certified powerplant installation which has demonstrated a safe in-service experience, then certification may be shown by similarity to previous designs. Other airframe ice shedding sources should also be reviewed if necessary.

(a) Compliance with CS 25.1093(b)(1)

Compliance with CS 25.1093(b)(1) can be shown by analysis, laboratory testing, ground testing, dry air flight testing, similarity, and/or natural icing flight testing as necessary.

As a general rule, engine air intake systems, including auxiliary components (e.g. scoops, oil coolers, struts, fairings…), should be shown to operate continuously in icing conditions without regard to time, as in a hold condition. An exception would be for low engine power/thrust conditions where a sustained level flight is not possible. Even then, a conservative approach must be used when a series of multiple horizontal and vertical cloud extent factors are assumed. Applicants are reminded that the cloud horizontal extent factor is not intended to be used to limit the severity of exposure to icing conditions where it is reasonable to assume that the aircraft will be required to operate in that condition. The applicant will show by analysis, and verify by test, that the engine air intake Ice Protection System (IPS) provides adequate protection under all flight operations.

If there is a minimum power/thrust required for descent to ensure satisfactory operation in icing conditions, the increase to that minimum power/thrust in icing conditions should be automatic when the IPS is switched on. The engine may revert back to normal flight idle for short term operation, such as on final approach to landing; in such a case, this reversion to normal flight idle should be assessed in term of engine ice ingestion, and any required operational time limitation or pilot action should be included in the AFM.

1. Analysis & Test Point Selection.

Applicants will adequately analyse the engine air intake IPS performance and address potential ingestion hazards to the engine from any predicted ice build-up on the engine air intake, including any runback or lip ice.

In establishing compliance with the requirements of CS 25.1093(b)(1), reference should be made to AMC 25.1419 paragraph (a) for the assessment of the CS-25 Appendix C icing environment. In particular for the following aspects:

— Analytical Simulation Methods;

— Analysis of areas and components to be protected;

— Impingement Limit Analysis;

— Ice Shedding Analysis;

— Thermal Analysis and Runback Ice; and

— Similarity Analysis.

In establishing compliance with the requirements of CS 25.1093(b)(1), reference should be made to AMC 25.1420 paragraph (d) for the assessment of the Appendix O icing environment in particular for the following aspects:

— Analysis of areas and components to be protected;

— Failure analysis, and

— Similarity analysis.

In addition, the following specific analysis should be conducted:

1.1 Critical Points Analysis (CPA)

A Critical Points Analysis (CPA) is one analytical approach to identify the most critical operational icing conditions to show that an engine air intake system, including auxiliary components (e.g. scoops, oil-coolers, struts, fairings…), complies with CS 25.1093(b)(1).

For Appendix C icing conditions, in lieu of a detailed CPA, the conditions specified in paragraph 2.1, “Icing wind tunnel tests”, are acceptable and can be used for testing without further justification.

The CPA provides a means to predict critical conditions to be assessed and allows for a selection of conditions which will ensure that the ice protection system will be adequate throughout the combined aircraft operation/icing envelope.

The CPA should include ice accretion calculations that account for freezing fraction and aerodynamic effects of the ice as it moves into the air intake, forward aircraft airspeed effects, engine configuration effects and altitude effects such as bypass ratio effects. It should also include prolonged flight operation in icing (for example, in-flight hold pattern), or repeated icing encounters.

The CPA should consider:

1. the aircraft/engine operating envelope. This should consider climb, cruise, hold and flight idle descent conditions in the icing envelopes.
2. the environmental icing envelopes defined in CS-25 Appendices C, O and P. The Intermittent Maximum Icing Conditions of Appendix C envelope extension down to −40°C should also be considered.
3. thermal behavior of the ice protection system in icing conditions. For each icing condition a heat balance can be made to assess the material temperature and runback water/ice accretion in icing conditions. This balance considers the heat available from the de-icing/anti-icing system and the heat lost to the impinging liquid water and external convection. The result determines the need to undertake an icing test at that point.

Applicants should determine the critical ice accretion conditions and compare each of them individually with the amount of ice the engine has satisfactorily demonstrated to ingest during engine certification (CS-E 780). Applicants may assume that 1/3 of the ice on the air intake perimeter is ingested as one piece. This assumption is consistent with the historical approach taken by the engine manufacturers.

The critical ice accretion including runback ice (if any) may be different for each flight phases. If this is the case, the engine manufacturer should provide the relevant information. A particular attention should be made to:

— ice accretion occurring during the holding phase, which may be ingested during descent at Idle power/thrust (potentially critical for engine performance and handling characteristics) or
— ice accretion occurring during the descent at Idle power/thrust (with potentially reduced ice protection availability), which may be ingested during a Go Around at Take-Off power/thrust (potentially critical for mechanical damage).

Airspeed and scoop factor should be part of this assessment.

Applicants should demonstrate that the full flight envelope and the full range of atmospheric icing conditions specified in Appendices C, O and P to CS-25 have been considered, including the mean effective drop / particle diameter, liquid / total water content, and temperature appropriate to the flight conditions (for example, configuration, speed, angle-of-attack, and altitude).

To demonstrate unlimited operation of an air intake system in icing conditions, the system should:

— either operate fully evaporative, or

— any ice accretion, including runback ice, which forms should result in less ice than the engine has been demonstrated to ingest per CS-E 780.

The test duration may be reduced if a repeatable build and shed cycle is demonstrated.

It has been historically shown that an air intake thermal IPS designed to be evaporative for the critical points in Appendix C continuous maximum icing conditions, and running wet in Appendix C intermittent maximum icing conditions, provides satisfactory performance. If the air intake is running wet in continuous maximum icing conditions, then the applicant should calculate the amount of runback ice that would accumulate during any relevant flight phase and compare that to the maximum certified ingestion capability of the engine per CS-E 780.

Scenario to be considered:

The applicant should justify the icing scenarios to be considered when determining the critical ice accretion conditions. The flight phases as defined in Part II of Appendix C and Part II of Appendix O could be used to support the justification.

For holding ice accretion, the applicant should determine the effect of a 45-minute holding in continuous maximum icing conditions of Appendix C. The analysis should assume that the aeroplane remains in a rectangular "race track" pattern, with all turns being made within the icing cloud. Therefore, no horizontal extent correction should be used for this analysis.

If ETOPS certification is desired, the applicant should consider the maximum ETOPS diversion scenarios.

1.2 Two Minutes Delayed Selection of Air intake IPS Accretion Analysis

It should be demonstrated that the ice accretion is acceptable after a representative delay in the selection of the ice protection systems, such as might occur during inadvertent entry into the conditions. In lack of other evidence, a delay of two minutes to switch on the IPS should be assumed. For thermal IPS, the time for the IPS to warm up should be added.

Applicants should calculate the amount of air intake lip ice that forms using a continuous maximum condition from Appendix C to CS-25, with a liquid water content factor of one. Of the total lip ice, only the ice on the inner barrel side of the stagnation point would be ingested into the engine. Applicants may assume that 1/3 of the ice on the air intake perimeter is ingested as one piece.

1.3 Ice accretion sources

Examples of airframe sources of ice accretion include the radome, the spinner, the antenna and the inboard section of the wing for aft fuselage mounted engines.

Clear ice may also occur on the wing upper surfaces when cold-soaked fuel (due to aircraft prolonged operation at high altitude) is in contact with the fuel tanks' upper surfaces, or cold soaked structural part is in contact with upper surfaces, and the aeroplane is exposed to conditions of atmospheric moisture (for example, fog, precipitation, and condensation of humid air) at ambient temperatures above freezing. This atmospheric moisture, when in contact with cold wing surfaces, may freeze. Simultaneous ice shedding from both wings of an aeroplane may damage surrounding components or structure parts and result in ice ingestion damage and power/thrust loss in all engines during take-off of flight for aeroplanes with aft fuselage mounted engines.

Identification of Engine Air intake ice accretion sources includes, for Appendix O to CS-25 icing environment, an assessment of air intake differing impingement limits, catch efficiency, distribution effects, and water contents. The applicant should evaluate the potential ice accumulation aft of the engine air intake protected surfaces for the possibility of ice ingestion by the engine.

The applicant should assess the ice accumulations and compare them on the basis of the size or the kinetic energy of the ice slab. It is possible to show that ice accumulations are smaller in size and therefore have equal or less kinetic energy than the CS-E 780 ice ingestion demonstration. Alternatively, kinetic energy may be used as an acceptable method for comparing the airframe ice source to the results of the CS-E 780 ice ingestion demonstration. Any kinetic energy method must be agreed to by the Agency.

1.4 Ice Detection

1.4.1 Upper wing mounted ice detection systems

For aircraft with aft fuselage mounted engines equipped with upper wing mounted ice detection systems to warn the flight crew of clear ice build-up on the upper surface of the wings, applicants should demonstrate that any undetected ice, including ice formed from cold-soaked fuel, is not greater than the ice ingestion demonstrated for CS-E 780 compliance.

1.4.2 Primary Ice Detection System (PIDS).

The relevant provisions of the AMC 25.1419 paragraph (d) apply.

In addition, if a detection threshold exists in the PIDS (in terms of Liquid Water Content (LWC), amount of ice accretion, etc…) it must be demonstrated that the ice accretion that will occur before the actual detection threshold is reached is consistent with CS-E 780 ice ingestion demonstration. Prolonged exposure (up to a 45-minute holding configuration in continuous maximum condition from Appendix C to CS-25) shall be considered at the limit of the detection threshold to evaluate a conservative amount of ice accretion.

For aft fuselage mounted engines, both the engine air intake and the part of the wing in front of the engines should be considered. A conservative assumption is that the ice accretion may detach from both sites simultaneously and be ingested by the engines when the IPS is switched on.

1.5 Appendix P Icing Environment and Pitot-style air intakes design

The results of FAA aerofoil testing in a mixed phase icing environment indicate that these icing conditions do not appreciably accrete on unheated aircraft wings. Furthermore the testing showed that exposure to mixed phase environment results in the same or less ice accretion than exposure to supercooled liquid water environment with the same Total Water Content (TWC). The overall power required by the running-wet ice protection system was essentially unchanged between all-liquid and mixed-phase conditions.