However, in the running-wet mode, the local power density was much higher around the stagnation area in the mixed-phase conditions, compared to the purely liquid conditions. This is due to the power required to offset the thermodynamic heat-of-fusion necessary to melt the impacting ice particles that either fully or partially stick to the surface.

This may also explain why Pitot-style air intakes have not proved to be susceptible to mixed phase ice accretion within the air intake, and why Appendix C to CS-25 compliance methods adequately address those air intakes. Engines designed with reverse flow air intakes, or with air intakes involving considerable changes in airflow direction should be shown to comply with Appendix P to CS 25.

Compliance for Pitot-style air intakes, without considerable changes in airflow direction, may be shown through qualitative analysis of the design and supported by similarity to previous designs that have shown successful service histories.

1.6 Falling and Blowing Snow

1.6.1 CS 25.1093(b)(1) requires that each engine, with all icing protection systems operating, operate satisfactorily in falling and blowing snow throughout the flight power/thrust range, and ground idle. Falling and blowing snow is a weather condition which needs to be considered for the powerplants and essential Auxiliary Power Units (APUs) of transport category aeroplanes.

1.6.2 All engine air intakes, including those with plenum chambers, screens, particle-separators, variable geometry, or any other feature, such as an oil-cooler, struts or fairings, which may provide a potential accumulation site for snow, should be evaluated.

1.6.3 Although snow conditions can be encountered on the ground or in flight, there is little evidence that snow can cause adverse effects in flight on turbojet and turbofan engines with traditional Pitot style air intakes where protection against icing conditions is provided. However, service history has shown that inflight snow (and mixed phase) conditions have caused power interruptions on some turbine engines and APUs with air intakes that incorporate plenum chambers, reverse flow, or particle separating design features.

1.6.4 For turbojet and turbofan engines with traditional Pitot (straight duct) type air intakes, icing conditions are generally regarded as a more critical case than falling and blowing snow. For these types of air intake, compliance with the icing specifications (at least including the icing environment of Appendix C to CS-25) will be accepted in lieu of any specific snow testing or analysis.

1.6.5 For non-Pitot type air intakes, demonstration of compliance with the falling and blowing snow specification on ground should be conducted by tests and/or analysis. If acceptable powerplant operation can be shown in the following conditions, no take-off restriction on the operation of the aeroplane in snow will be necessary.

a. Visibility: 0.4 Km or less as limited by snow, provided this low visibility is only due to falling snow (i.e. no fog). This condition corresponds approximately to 1 g/m3.

b. Temperatures: − 3 °C to + 2 °C for wet (sticky) snow and – 9 °C to – 2 °C for dry snow, unless other temperatures are found to be critical (e.g. where dry snow at a lower temperature could cause runback ice where it contacts a heated surface).

c. Blowing snow: Where tests are conducted, the effects of blowing snow may be simulated by taxiing the aircraft at 15 to 25 kts, or by using another aircraft to blow snow over the test powerplant. This condition corresponds approximately to 3 g/m3.

d. Duration: It must be shown that there is no accumulation of snow or slush in the engine, air intake system or on airframe components, which would adversely affect engine operation during any intended ground operation. Compliance evidence should consider a duration which corresponds to the achievement of a steady state condition of accretion and (possible) shedding. Any snow shedding should be acceptable to the engine.

e. Operation: The methods for evaluating the effects of snow on the powerplant should be agreed by the Agency. All types of operation likely to be used on the ground should be considered for the test (or analysis). This should include prolonged idling and power transients consistent with taxiing and other ground manoeuvring conditions. Where any accumulation does occur, the engine should be run up to full power, to simulate take-off conditions and demonstrate that no hazardous shedding of snow or slush occurs. Adequate means should be used to determine the presence of any hazardous snow accumulation.

f. Snow concentration corresponding to the visibility prescribed is often extremely difficult to locate naturally and it is often difficult to maintain the desired concentrations for the duration of testing. Because of this, it is likely that exact target test conditions will not be achieved for all possible test conditions. Reasonable engineering judgment should be used in accepting critical test conditions and alternate approaches, with early coordination between the applicant and the Agency addressing these realities.

1.6.6 For in-flight snow (and mixed phase) conditions, some non-Pitot type air intakes with reverse flow particle separators have been found to accumulate snow/ice in the pocket lip (sometimes referred to as the “bird catcher” section) just below the splitter which divides the engine compressor from the air intake bypass duct. Eventually, the build-up of snow in the pocket (which can melt and refreeze into ice) either spans across to the compressor air intake side of the splitter lip or, the snow/ice build-up is released from the pocket and breaks up whereupon some of the ice pieces can be re-ingested into the compressor side of the inlet. The ingestion of this snow/ice has caused momentary or permanent flameouts and in some cases, foreign object damage to the compressor.

Some aeroplane manufacturers have tried to correct this condition by increasing the amount and/or frequency of applied thermal heat used around the pocket, splitter, and bypass sections of the air intake. However, short of modifying the engine ice protection systems to the point of operating fully evaporative, these fixes have mostly failed to achieve acceptable results.

1.6.7 Aeroplanes with turbine engine or essential APU air intakes which have plenum chambers, screens, particle separators, variable geometry, or any other feature (such as an oil cooler) which may provide a hazardous accumulation site for snow should be qualitatively evaluated for in-flight snow conditions. The qualitative assessment should include:

1) A visual review of the installed engine and air intake (or drawings) to identify potential snow accumulation sites,

2) A review of the engine and engine air intake ice protection systems to determine if the systems were designed to run wet, fully evaporative, or to de-ice during icing conditions, and

3) Unless the air intake ice protection means (e.g. thermal blanket, compressor bleed air, hot oil) operates in a fully evaporative state in and around potential air intake accumulation sites, inlet designs with reverse flow pockets exposed directly to in-flight snow ingestion should be avoided.

Flight testing may be necessary to validate the qualitative assessment.

2. Testing

The engine air intakes may be tested with the engine and propeller where appropriate in accordance with the specifications of CS-E 780 and AMC E 780.

Where the air intake is assessed separately (e.g. icing wind tunnel evaluation of IPS performance, lack of suitable test facilities for engine and air intake, change in the design of the air intake, air intake different from one tested with the engine), it should be shown that the effects of air intake icing would not invalidate the engine tests of CS-E.

Factors to be considered in such evaluations are:

— distortion of the airflow and partial blockage of the air intakes,

— the shedding into the engine of air intakes ice of a size greater than the engine has been shown to ingest per CS-E 780,

— the icing of any engine sensing devices, other subsidiary air intakes or equipment contained within the air intake, and

— the time required to bring the protective system into full operation.

In establishing compliance with the requirements of CS 25.1093(b)(1), reference should be made to AMC 25.1419, paragraph (b), for the assessment of the Appendix C icing environment. In conjunction with the CPA, a thorough validation of the IPS may include in particular the following aspects:

— flight tests in dry air with ice protection equipment operating,

— flight tests in icing conditions, natural or artificial, and

— ground tests in icing wind tunnel.

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.

2.1 Icing wind tunnel tests

Icing wind tunnels provide the ability to simulate natural icing conditions in a controlled environment and they have also been used in particular to evaluate performance of ice protection systems (IPS), such as pneumatic and thermal systems.

When the tests are conducted in non-altitude conditions, the system power supply and the external aerodynamic and atmospheric conditions should be so modified as to represent the required altitude condition as closely as possible.

Where an altitude facility is available, the altitudes to be represented should be consistent with the icing scenario considered. The appropriate inlet incidences or the most critical incidence should be simulated.

Icing tests may be performed in sea level facilities. In order to compensate for the altitude effects, consideration is given to the necessary amendments to the test parameters in order to achieve an adequate evaluation.

Flight conditions may need to be corrected to allow simulation in a wind tunnel. To achieve this, the location of the stagnation point on the inlet lip and the amount of water runback at the throat should be maintained between flight and wind tunnel conditions. Other test parameters, such as static or total air temperature, may require similitude adjustments to achieve the best match of icing condition parameters, such as those described in FAA AC 20-73A.

For each test, the ice protection supply should be representative of the minimum engine power/thrust for which satisfactory operation in icing conditions is claimed.

At the conclusion of each test, the applicants should assess the ice accumulations and compare them with the amount of ice the engine has satisfactorily demonstrated to ingest during engine certification (CS-E 780).

Test results may be used to validate the CPA in term of ice accretion prediction.

For the evaluation of the performance of the IPS, either the critical points determined by a CPA or the conditions defined in Table 1 below may be used to simulate CS-25 Appendix C conditions:

***Table 1 – Appendix C test conditions***

| Ambient Air Temperature ° C | Altitude | | Liquid Water Content g/m³ | | Mean Effective Droplet Diameter µm |
|---|---|---|---|---|---|
| | Ft | m | (a) Continuous Max | (b) Intermittent Max | |
| – 10 | 17 000 | 5 182 | 0.6 | 2.2 | 20 |
| – 20 | 20 000 | 6 096 | 0.3 | 1.7 | |
| – 30 | 25 000 | 7 620 | 0.2 | 1.0 | |

Note: The conditions of water concentration required by these tests are somewhat more severe than those implied by the Appendix C to CS-25 so as to provide margins.

A separate test should be conducted at each temperature condition of Table 1 above, the test being made up of repetitions of one of the following cycles:

1) 28 km (15.1 NM) in the conditions of Table 1, column (a), appropriate to the temperature, followed by 5 km (2.7 NM) in the conditions of Table 1, column (b), appropriate to the temperature, for a total duration of 30 minutes, or

2) 6 km (3.2 NM) in the conditions of Table 1, column (a), appropriate to the temperature, followed by 5 km (2.7 NM) in the conditions of Table 1, column (b), appropriate to the temperature, for a total duration of 10 minutes.

Each test should be run at, or should simulate, different engine power/thrust conditions, including the minimum power/thrust for which satisfactory operation in icing conditions is claimed.

Flight Idle power/thrust should be assessed against the conditions defined in Table 1 both for Column (a) and Column (b).

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, and this minimum power/thrust associated with descent in icing conditions should be assessed against the conditions in Table 1 above.

The test duration expressed above assume that steady state conditions (ice shedding cycles) are established. If this is not the case, the test should continue until a maximum duration of 45 minutes when using test 1) above or 15 minutes when using test 2) above, except for descent where the test duration may be limited to the time needed to cover an anticipated descent of 3 000 m.

Where an altitude facility is available, the altitudes to be represented should be as indicated in Table 1.

2.2 Delayed activation of the air intake IPS

When the ingestion tests under CS-E 780 do not adequately represent the particular airframe installation, then the delayed IPS activation test should be considered, even for aircraft equipped with PIDS to consider possible manual IPS activation in “degraded” mode.

Either by separate tests, or in combination with those of paragraph 2.1 above, it should be demonstrated that the ice accretion is acceptable after a representative delay in the selection of the IPS, 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 when exposed to Continuous Maximum exposure of Appendix C to CS-25. For thermal IPS, the time for the IPS to warm up should be added.

Similar to the accepted compliance with CS-E 780 ice ingestion tests, the use of engine auto-ignition and recovery systems are allowed to show compliance with the delayed activation tests of CS-25, as long as these automatic systems cannot be easily turned off by the flight crew.

In the case of De-iced air intakes (designed for a cyclic shedding of ice from the engine air intake into the engine) which incorporate, as part of their design, an air intake particle-separator that stops the ingestion of ice into the core of the engine, engine auto-recovery systems should not be a compensating design feature utilized to minimize the negative effects of an inadequate particle-separating air intake that is not in full compliance with CS 25.1093.

2.3 Natural Icing Flight Tests

Natural icing flight tests may also be used to show compliance with CS 25.1093(b)(1).

In this context, natural icing flight tests are intended to demonstrate that the engine is capable of operating throughout its flight power/thrust range (including idling), without an adverse effect. This includes the accumulation of ice on the engine, air intake system components, or airframe components that would have an adverse effect on the engine operation or cause a serious loss of power or thrust.

In addition to proving that the engine air intake icing analysis model is accurate, several other key issues exist, which the natural ice encounter may address. These include:

— the adequacy of flight crew procedures when operation in icing conditions,

— the acceptability of control indications to the flight crew as the aeroplane responds to engine fan blade ice shedding during various conditions,

— the performance of the engine vibration indication system, as well as other engine indication systems, and

— the confirmation that the powerplant installation performs satisfactorily while in icing conditions. This whole powerplant installation includes the engine, air intake, and the IPS system.

2.4 Testing in Non-Representative Conditions

When damage results from icing test conditions that fall significantly outside Appendices C, O and P to CS-25 icing envelopes, or when the aeroplane flight test is conducted in an abnormal manner and results in excessive ice shed damage, this may result in a test failure relative to the pre-test pass or fail criteria. Any abnormal conditions should be discussed with the Agency to determine if the test can be deemed “passed.” An example of an abnormal operation could be flying with one engine at idle while the aircraft is operated in level flight.

3. Comparative Analysis.

For showing compliance with the CS-25 certification specifications relative to SLD icing conditions represented by Appendix O, the applicant may use a comparative analysis. AMC 25.1420(f) provides guidance for comparative analysis.

(b) Compliance with CS 25.1093(b)(2)

Ground taxi exposure to Appendices C and O to CS-25

1. Critical Points Analysis (CPA).

The temperatures should result from a CPA, considering the full range of temperatures specified in CS 25.1093(b)(2), conducted to determine the critical ice accretion conditions for the air intake.

2. Ground taxi exposure to Appendix O conditions.

The service experience indicates that engine fan damage events exist from exposure to SLD during ground taxi operations. For this reason, an additional condition of a 30-minute, idle power/thrust exposure to SLD on the ground must be addressed. Applicants should include the terminal falling velocity of SLD (for example, freezing rain, freezing drizzle) in their trajectory assessment, relative to the protected sections of the air intake. The 100 micron minimum mean effective diameter (MED) is selected as a reasonably achievable condition, given current technology. To certify by analysis the applicant should evaluate the Appendix O drop sizes up to a maximum of 3 000 microns particle size to find a critical condition.

For showing compliance with the CS-25 certification specifications relative to SLD icing conditions represented by Appendix O, the applicant may use a comparative analysis. AMC 25.1420(f) provides guidance for comparative analysis.

3. Operating limitation.

The conditions defined in CS 25.1093(b)(2), in terms of time and temperature, should be considered as limitations necessary for the safe operation in freezing fog, and made available to the crew in the Aeroplane Flight Manual (refer to CS 25.1581).

Nevertheless, the applicant may use an analysis to substantiate safe operation of the engine at temperatures below the demonstrated minimum temperature. No limitation would then be required in the Aeroplane Flight Manual.

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

## CS 25.1103 Air intake system ducts and air duct systems

*ED Decision 2016/010/R*

(See AMC 25.1103)

(a) *Reserved.*

(b) Each air intake system must be –

(1) Strong enough to prevent structural failure resulting from engine surging; and

(2) Fire-resistant if it is in any fire zone for which a fire extinguishing system is required.

(c) Each duct connected to components between which relative motion could exist must have means for flexibility.

(d) For bleed air systems no hazard may result if a duct rupture or failure occurs at any point between the engine port and the aeroplane unit served by the bleed air. (See AMC 25.1103(d).)

[Amdt 25/18]

## AMC 25.1103(d) Air intake system ducts

*ED Decision 2003/2/RM*

For a single failure case leading to a fire and air duct rupture, consideration should be given to the possibility of fire aggravation due to air flowing into a designated fire zone of an engine from the remaining engine(s), or another source outside the affected fire zone.

# EXHAUST SYSTEM

## CS 25.1121 General

ED Decision 2016/010/R

(See AMC 25.1121)

For powerplant installations the following apply:

(a) Each exhaust system must ensure safe disposal of exhaust gases without fire hazard or carbon monoxide contamination in any personnel compartment. For test purposes, any acceptable carbon monoxide detection method may be used to show the absence of carbon monoxide. (See AMC 25.1121(a).)

(b) Each exhaust system part with a surface hot enough to ignite flammable fluids or vapours must be located or shielded so that leakage from any system carrying flammable fluids or vapours will not result in a fire caused by impingement of the fluids or vapours on any part of the exhaust system including shields for the exhaust system. (See AMC 25.1121(b).)

(c) Each component that hot exhaust gases could strike, or that could be subjected to high temperatures from exhaust system parts, must be fireproof. All exhaust system components must be separated by fireproof shields from adjacent parts of the aeroplane that are outside the engine compartment.

(d) No exhaust gases may discharge so as to cause a fire hazard with respect to any flammable fluid vent or drain.

(e) No exhaust gases may discharge where they will cause a glare seriously affecting pilot vision at night.

(f) Each exhaust system component must be ventilated to prevent points of excessively high temperature.

(g) Each exhaust shroud must be ventilated or insulated to avoid, during normal operation, a temperature high enough to ignite any flammable fluids or vapours external to the shroud.

[Amdt 25/18]

## AMC 25.1121(a) General

ED Decision 2003/2/RM

1 If necessary, each exhaust system should be provided with drains to prevent hazardous accumulation of fuel under all conditions of operation.

2 Tests should be made to demonstrate compliance with CS 25.1121(a) and these should include engine starting in downwind conditions and thrust reversal.

## AMC 25.1121(b) General

ED Decision 2003/2/RM

Leakage should be interpreted to include fuel discharged from the jet pipe under false start conditions both on the ground and in flight. It should be demonstrated that successive attempts to restart do not create a fire hazard. The maximum time for complete drainage of fuel following a false start should be established. This period will be used to determine the minimum interval between start attempts.

# CS 25.1123 Exhaust piping

*ED Decision 2003/2/RM*

For powerplant installations, the following apply:

(a) Exhaust piping must be heat and corrosion resistant, and must have provisions to prevent failure due to expansion by operating temperatures.

(b) Piping must be supported to withstand any vibration and inertia loads to which it would be subjected in operation; and

(c) Piping connected to components between which relative motion could exist must have means for flexibility.

# POWERPLANT CONTROLS AND ACCESSORIES

## CS 25.1141 Powerplant controls: general

*ED Decision 2016/010/R*

(See AMC 25.1141)

Each powerplant control must be located, arranged, and designed under CS 25.777 to 25.781 and marked under CS 25.1555. In addition, it must meet the following requirements:

(a) Each control must be located so that it cannot be inadvertently operated by persons entering, leaving, or moving normally in, the cockpit.

(b) Each flexible control must be approved or must be shown to be suitable for the particular application.

(c) Each control must have sufficient strength and rigidity to withstand operating loads without failure and without excessive deflection.

(d) Each control must be able to maintain any set position without constant attention by flight-crew members and without creep due to control loads or vibration.

(e) The portion of each powerplant control located in a designated fire zone that is required to be operated in the event of fire must be at least fire resistant. (See CS 25.903(c).)

(f) For Powerplant valve controls located in the flight deck there must be a means:

(1) for the flightcrew to select each intended position or function of the valve; and

(2) to indicate to the flightcrew:

(i) the selected position or function of the valve; and

(ii) when the valve has not responded as intended to the selected position or function. (See AMC 25.1141(f))

[Amdt 25/1]
[Amdt 25/18]

## AMC 25.1141(f) Powerplant controls, general

*ED Decision 2003/2/RM*

A continuous indicator need not be provided.

## CS 25.1143 Engine controls

*ED Decision 2003/2/RM*

(a) There must be a separate power or thrust control for each engine.

(b) Power and thrust controls must be arranged to allow –

(1) Separate control of each engine; and

(2) Simultaneous control of all engines.

(c) Each power and thrust control must provide a positive and immediately responsive means of controlling its engine.