

# CS-E 780 Ingestion of Rain and Hail

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September 2017

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# Ingestion of Rain and Hail

## (a) All Engines

(1) The ingestion of large hailstones (0.8 to 0.9 specific gravity) at the maximum true air speed, for altitudes up to 4 500 metres, associated with a representative aircraft operating in rough air, with the Engine at Maximum Continuous power/ thrust, must not cause unacceptable mechanical damage or unacceptable power or thrust loss after the ingestion, or require the Engine to be shut down. One-half the number of hailstones must be aimed randomly over the inlet face area and the other half aimed at the critical inlet face area. The hailstones must be ingested in a rapid sequence to simulate a hailstone encounter and the number and size of the hailstones must be determined as follows:

- (i) One 25-millimetres diameter hailstone for Engines with inlet throat areas of not more than 0.0645 m<sup>2</sup>.
- (ii) One 25-millimetres diameter and one 50-millimetres diameter hailstone for each 0.0968 m<sup>2</sup> of inlet throat area, or fraction thereof, for Engines with inlet throat areas of more than 0.0645 m<sup>2</sup>.

(2) In addition to complying with CS-E 790 (a)(1) and except as provided in CS-E 790 (b), it must be shown that each Engine is capable of acceptable operation throughout its specified operating envelope when subjected to sudden encounters with the certification standard concentrations of rain and hail as defined in Appendix A to CS-E. Acceptable Engine operation precludes, during any 3-minute continuous period in rain and during any 30-second continuous period in hail, the occurrence of flameout, rundown, continued or non recoverable surge or stall, or loss of acceleration and deceleration capability. It must also be shown after the ingestion that there is no unacceptable mechanical damage, unacceptable power or thrust loss, or other adverse Engine anomalies. (See AMC E 790 (a)(2))

# Ingestion of Rain and Hail: Delivery

3

## Water:

**External Full Spray Grid or internal e.g. at splitter.**

Water needs little special care, but needs additional evidence for “impact” aspects

## Hail:

**External multi-barrel “gun”**

No additional testing or assessment, but test equipment harder to manage, and cooling required for hailstone storage.

# Ingestion of Rain and Hail

**The engine should operate satisfactorily during the tests without unacceptable:**

- Immediate or ultimate reduction of engine performance
- Increase of engine operating temperatures
- Deterioration of engine handling characteristics
- Mechanical damage

**Any further Operational considerations for the Engine Operating Instructions are established from testing and incorporated as necessary.**

**Upon completion of the test, the engine should be in at least good condition and suitable for safe continued operation.**

# Ingestion of Rain and Hail: Rain

The ingestion of rain into the engine must not result in unacceptable mechanical damage, or cause an unacceptable loss of engine performance (run down, flame out, or loss of ability to accelerate from the minimum engine condition declared for operation in rain (idle))

The declared engine test, using a spray grid in front of the engine intake to feed water into the engine. CS-E defines the threat level in terms of a water concentration, and droplet size, and there are two tests required:

- a) Water equal to 4% of the intake mass-flow ingested for three minutes at flight idle, then accelerating to MTO, while still ingesting. The engine then spends two minutes at MTO without ingestion, to heat-soak the engine, and then ingestion is carried out for three minutes.
- b) Water concentration of 20 g/m<sup>3</sup>, at a water velocity equivalent to the most critical aircraft speed and flight condition (aircraft speed is a certification assumption.), ingested for 3 min, followed by acceleration to take-off power.

Scoop and flow concentration into core must be taken into account.



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# Ingestion of Rain and Hail: Hail

## Two issues are significant

- The effect of ingestion on the engine's performance & handling (Test)
- The mechanical damage done by hail impact. (Test, or by impact analysis.)

The hail test consists of a run for 30 seconds at an idle condition, with a hail concentration of  $10 \text{ g/m}^3$  at the engine speed and hail velocity for the most critical aircraft speed and flight condition. (*Certification assumption*)

An acceleration is therefore carried out after the thirty seconds.

Scoop and flow concentration into core must be taken into account.

The engine must not run down, or flame out during the ingestion test, and must have sufficient performance margin to allow it to accelerate from the minimum conditions declared by Rolls-Royce for operation in hail conditions.

For both rain and hail, any special handling procedures/logic become limits.



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# Water Equivalence & Impact

**Where “Water Equivalence” is used for hailstone testing, the question of appropriate impact resistance must still be addressed.**

Compliance with the CS-E requirements can be shown by analysis and comparison of impact energy of the largest hailstone with medium bird impact energy on the fan of the engine. The properties of hail and birds relevant to impact effects show that both are soft bodies relative to the strength and hardness of metal rotor blades such that impacts of equivalent kinetic energy will have similar effects. The analysis will be substantiated by medium bird rig test data and by comparison with test data and experience of other engine types which use similar hardware designs.

This approach can be used to show that the ingestion of 25 mm or 50 mm hailstones will not cause unacceptable mechanical damage or unacceptable thrust loss or require the engine to be shut down.