

Part 33 AIRWORTHINESS STANDARDS: AIRCRAFT ENGINES
Subpart E--Design and Construction; Turbine Aircraft Engines

Sec. 33.77

[Foreign object ingestion.]

[(a) Ingestion of a 4-pound bird, a piece of tire tread, or a broken rotor blade, under the conditions set forth in paragraph (f) of this section, may not cause the engine to--

- (1) Catch fire;
- (2) Burst (penetrate its case);
- (3) Generate loads greater than those specified in Sec. 33.23; or
- (4) Lose the capability of being shut down.

(b) Ingestion of 3-ounce birds, 1 1/2-pound birds, or mixed gravel and sand, under the conditions set forth in paragraph (f) of this section, may not cause more than a sustained 25 percent power or thrust loss or require the engine to be shut down.

(c) Ingestion of water, ice, or hail, under the conditions set forth in paragraph (f) of this section may not cause a sustained power or thrust loss or require the engine to be shut down.

(d) For an engine that incorporates a protective device, compliance with this section need not be demonstrated with respect to foreign objects sought to be ingested under the conditions set forth in paragraph (f) of this section, if it is shown that--

- (1) Such foreign objects are of a size that will not pass through the protective device;
- (2) The protective device will withstand the impact of the foreign objects; and
- (3) The foreign object or objects stopped by the protective device will not obstruct the flow of induction air into the engine.

(e) In showing compliance with paragraphs (a) and (b) of this section, the engine need be tested by ingesting only that foreign object specified in paragraph (a) which the applicant shows has the most severe effect on the engine and by ingesting the mixed gravel and sand specified in paragraph (b) and either the 3-ounce birds or the 1 1/2-pound birds, as specified in paragraph (f) of this section.

(f) The prescribed foreign object ingestion conditions are as follows:

<i>Foreign object</i>	<i>Test quantity</i>	<i>Speed of foreign object</i>
Birds: 3-oz size -----	One for each 50 sq. in. of inlet area or fraction thereof up to a maximum of 16 birds. 3-oz bird ingestion not required if a 1 1/2-lb. bird will pass the inlet guide vanes into the rotor blades.	Liftoff speed of typical aircraft.
1 1/2-lb. size -----	One for the first 300 sq. in. of inlet area, if it can enter the inlet, plus one for each additional 600 sq. in. of inlet area or fraction thereof up to maximum of 8 birds.	Initial climb speed of typical aircraft.
4-lb. size -----	One if it can enter the inlet.	Maximum climb --- speed.
Ice-----	Maximum accumulation on inlet cowl and engine face resulting from a 30-second delay in actuating anti-icing system.	Sucked in -----
Hail: (0.8 to 0.9 specific gravity).	For subsonic and supersonic engines: With inlet areas of not more than 100 sq. in.: one 1-in. hailstone. With inlet area of more than 100 sq. in.: one 1-in. and one 2-in. hailstones for each 150 sq. in. of inlet area or fraction thereof. For supersonic engines (in addition): 3 hailstones each having a diameter equal to that in a straight line variation from 1 in. at 35,000 ft. to 1/4 in. at 60,000 ft. using diameter corresponding to the lowest supersonic cruise altitude expected.	Rough air flight speed of typical aircraft. Supersonic cruise velocity. Alternate use subsonic velocities with large hailstones to give equivalent kinetic energy.
Water -----	4 percent of engine airflow by weight.	Sucked in -----
Mixed gravel and sand (one part stones with diameter not less than 3/16--nor more than 1/4 in. and 7 parts sand.)	1 oz. for each 100 sq. in. of inlet area or fraction thereof.	-----do-----
Broken rotor blade: (The heaviest compressor or turbine blade, broken at the outermost retention groove or member or at least 80% of an integral blade.)	One -----	-----
Tire tread:	-----do-----	-----do-----
(Having width----- and length equal to full width of tread.)		

¹Blade containment must be demonstrated with a complete engine to evaluate secondary effects of blade loss and to determine blade fragment trajectories, except that in fan engines, the fan assembly may be tested separately for blade containment if it is demonstrated that fan blade or vane debris would not enter the compressor after a fan blade failure.]

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