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and other similar equipment or procedures. If items of a safety system are outside the control of the engine manufacturer, the assumptions of the safety analysis with respect to the reliability of these parts must be clearly stated in the analysis and identified in the installation instructions under §33.5 of this part.

(e) If the safety analysis depends on one or more of the following items, those items must be identified in the analysis and appropriately substantiated.

(1) Maintenance actions being carried out at stated intervals. This includes the verification of the serviceability of items that could fail in a latent manner. When necessary to prevent hazardous engine effects, these maintenance actions and intervals must be published in the instructions for continued airworthiness required under §33.4 of this part. Additionally, if errors in maintenance of the engine, including the control system, could lead to hazardous engine effects, the appropriate procedures must be included in the relevant engine manuals.

(2) Verification of the satisfactory functioning of safety or other devices at pre-flight or other stated periods. The details of this satisfactory functioning must be published in the appropriate manual.

(3) The provisions of specific instrumentation not otherwise required.

(4) Flight crew actions to be specified in the operating instructions established under §33.5.

(f) If applicable, the safety analysis must also include, but not be limited to, investigation of the following:

- (1) Indicating equipment;
- (2) Manual and automatic controls;
- (3) Compressor bleed systems;
- (4) Refrigerant injection systems;
- (5) Gas temperature control systems;
- (6) Engine speed, power, or thrust governors and fuel control systems;
- (7) Engine overspeed, overtemperature, or topping limiters;
- (8) Propeller control systems; and
- (9) Engine or propeller thrust reversal systems.

(g) Unless otherwise approved by the FAA and stated in the safety analysis, for compliance with part 33, the fol-

lowing failure definitions apply to the engine:

(1) An engine failure in which the only consequence is partial or complete loss of thrust or power (and associated engine services) from the engine will be regarded as a minor engine effect.

(2) The following effects will be regarded as hazardous engine effects:

- (i) Non-containment of high-energy debris;
- (ii) Concentration of toxic products in the engine bleed air intended for the cabin sufficient to incapacitate crew or passengers;
- (iii) Significant thrust in the opposite direction to that commanded by the pilot;
- (iv) Uncontrolled fire;
- (v) Failure of the engine mount system leading to inadvertent engine separation;
- (vi) Release of the propeller by the engine, if applicable; and
- (vii) Complete inability to shut the engine down.

(3) An effect whose severity falls between those effects covered in paragraphs (g)(1) and (g)(2) of this section will be regarded as a major engine effect.

[Amdt. 33-24, 72 FR 50867, Sept. 4, 2007]

§ 33.76 Bird ingestion.

(a) *General.* Compliance with paragraphs (b), (c), and (d) of this section shall be in accordance with the following:

(1) Except as specified in paragraph (d) of this section, all ingestion tests must be conducted with the engine stabilized at no less than 100-percent take-off power or thrust, for test day ambient conditions prior to the ingestion. In addition, the demonstration of compliance must account for engine operation at sea level takeoff conditions on the hottest day that a minimum engine can achieve maximum rated takeoff thrust or power.

(2) The engine inlet throat area as used in this section to determine the bird quantity and weights will be established by the applicant and identified as a limitation in the installation instructions required under §33.5.

(3) The impact to the front of the engine from the large single bird, the single largest medium bird which can enter the inlet, and the large flocking bird must be evaluated. Applicants must show that the associated components when struck under the conditions prescribed in paragraphs (b), (c) or (d) of this section, as applicable, will not affect the engine to the extent that the engine cannot comply with the requirements of paragraphs (b)(3), (c)(6) and (d)(4) of this section.

(4) For an engine that incorporates an inlet protection device, compliance with this section shall be established with the device functioning. The engine approval will be endorsed to show that compliance with the requirements has been established with the device functioning.

(5) Objects that are accepted by the Administrator may be substituted for birds when conducting the bird ingestion tests required by paragraphs (b), (c) and (d) of this section.

(6) If compliance with the requirements of this section is not established, the engine type certification documentation will show that the engine shall be limited to aircraft installations in which it is shown that a bird cannot strike the engine, or be ingested into the engine, or adversely restrict airflow into the engine.

(b) *Large single bird.* Compliance with the large bird ingestion requirements shall be in accordance with the following:

(1) The large bird ingestion test shall be conducted using one bird of a weight determined from Table 1 aimed at the most critical exposed location on the first stage rotor blades and ingested at a bird speed of 200-knots for engines to be installed on airplanes, or the maximum airspeed for normal rotorcraft flight operations for engines to be installed on rotorcraft.

(2) Power lever movement is not permitted within 15 seconds following ingestion of the large bird.

(3) Ingestion of a single large bird tested under the conditions prescribed in this section may not result in any condition described in §33.75(g)(2) of this part.

(4) Compliance with the large bird ingestion requirements of this paragraph

may be shown by demonstrating that the requirements of §33.94(a) constitute a more severe demonstration of blade containment and rotor unbalance than the requirements of this paragraph.

TABLE 1 TO § 33.76—LARGE BIRD WEIGHT REQUIREMENTS

Engine Inlet Throat Area (A)—Square-meters (square-inches)	Bird weight kg. (lb.)
1.35 (2,092) > A .....	1.85 (4.07) minimum, unless a smaller bird is determined to be a more severe demonstration.
1.35 (2,092) ≤ A < 3.90 (6,045)	2.75 (6.05)
3.90 (6,045) ≤ A .....	3.65 (8.03)

(c) *Small and medium flocking bird.* Compliance with the small and medium bird ingestion requirements shall be in accordance with the following:

(1) Analysis or component test, or both, acceptable to the Administrator, shall be conducted to determine the critical ingestion parameters affecting power loss and damage. Critical ingestion parameters shall include, but are not limited to, the effects of bird speed, critical target location, and first stage rotor speed. The critical bird ingestion speed should reflect the most critical condition within the range of airspeeds used for normal flight operations up to 1,500 feet above ground level, but not less than V<sub>1</sub> minimum for airplanes.

(2) Medium bird engine tests shall be conducted so as to simulate a flock encounter, and will use the bird weights and quantities specified in Table 2. When only one bird is specified, that bird will be aimed at the engine core primary flow path; the other critical locations on the engine face area must be addressed, as necessary, by appropriate tests or analysis, or both. When two or more birds are specified in Table 2, the largest of those birds must be aimed at the engine core primary flow path, and a second bird must be aimed at the most critical exposed location on the first stage rotor blades. Any remaining birds must be evenly distributed over the engine face area.

(3) In addition, except for rotorcraft engines, it must also be substantiated by appropriate tests or analysis or both, that when the full fan assembly is subjected to the ingestion of the quantity and weights of bird from

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Table 3, aimed at the fan assembly’s most critical location outboard of the primary core flowpath, and in accordance with the applicable test conditions of this paragraph, that the engine can comply with the acceptance criteria of this paragraph.

(4) A small bird ingestion test is not required if the prescribed number of medium birds pass into the engine rotor blades during the medium bird test.

(5) Small bird ingestion tests shall be conducted so as to simulate a flock encounter using one 85 gram (0.187 lb.) bird for each 0.032 square-meter (49.6 square-inches) of inlet area, or fraction thereof, up to a maximum of 16 birds. The birds will be aimed so as to account for any critical exposed locations on the first stage rotor blades, with any remaining birds evenly distributed over the engine face area.

(6) Ingestion of small and medium birds tested under the conditions prescribed in this paragraph may not cause any of the following:

- (i) More than a sustained 25-percent power or thrust loss;
- (ii) The engine to be shut down during the required run-on demonstration prescribed in paragraphs (c)(7) or (c)(8) of this section;
- (iii) The conditions defined in paragraph (b)(3) of this section.
- (iv) Unacceptable deterioration of engine handling characteristics.

(7) Except for rotorcraft engines, the following test schedule shall be used:

- (i) Ingestion so as to simulate a flock encounter, with approximately 1 second elapsed time from the moment of the first bird ingestion to the last.
- (ii) Followed by 2 minutes without power lever movement after the ingestion.
- (iii) Followed by 3 minutes at 75-percent of the test condition.
- (iv) Followed by 6 minutes at 60-percent of the test condition.
- (v) Followed by 6 minutes at 40-percent of the test condition.
- (vi) Followed by 1 minute at approach idle.
- (vii) Followed by 2 minutes at 75-percent of the test condition.
- (viii) Followed by stabilizing at idle and engine shut down.

(ix) The durations specified are times at the defined conditions with the power being changed between each condition in less than 10 seconds.

(8) For rotorcraft engines, the following test schedule shall be used:

- (i) Ingestion so as to simulate a flock encounter within approximately 1 second elapsed time between the first ingestion and the last.
- (ii) Followed by 3 minutes at 75-percent of the test condition.
- (iii) Followed by 90 seconds at descent flight idle.
- (iv) Followed by 30 seconds at 75-percent of the test condition.
- (v) Followed by stabilizing at idle and engine shut down.
- (vi) The durations specified are times at the defined conditions with the power being changed between each condition in less than 10 seconds.

(9) Engines intended for use in multi-engine rotorcraft are not required to comply with the medium bird ingestion portion of this section, providing that the appropriate type certificate documentation is so endorsed.

(10) If any engine operating limit(s) is exceeded during the initial 2 minutes without power lever movement, as provided by paragraph (c)(7)(ii) of this section, then it shall be established that the limit exceedence will not result in an unsafe condition.

TABLE 2 TO § 33.76—MEDIUM FLOCKING BIRD WEIGHT AND QUANTITY REQUIREMENTS

Engine Inlet Throat Area (A)— Square-meters (square-inches)	Bird quantity	Bird weight kg. (lb.)
0.05 (77.5) > A	none	
0.05 (77.5) ≤ A < 0.10 (155)	1	0.35 (0.77)
0.10 (155) ≤ A < 0.20 (310)	1	0.45 (0.99)
0.20 (310) ≤ A < 0.40 (620)	2	0.45 (0.99)
0.40 (620) ≤ A < 0.60 (930)	2	0.70 (1.54)
0.60 (930) ≤ A < 1.00 (1,550)	3	0.70 (1.54)
1.00 (1,550) ≤ A < 1.35 (2,092)	4	0.70 (1.54)
1.35 (2,092) ≤ A < 1.70 (2,635)	1 plus 3	1.15 (2.53) 0.70 (1.54)
1.70 (2,635) ≤ A < 2.10 (3,255)	1 plus 4	1.15 (2.53) 0.70 (1.54)
2.10 (3,255) ≤ A < 2.50 (3,875)	1 plus 5	1.15 (2.53) 0.70 (1.54)
2.50 (3,875) ≤ A < 3.90 (6,045)	1 plus 6	1.15 (2.53) 0.70 (1.54)
3.90 (6,045) ≤ A < 4.50 (6,975)	3	1.15 (2.53)
4.50 (6,975) ≤ A	4	1.15 (2.53)

TABLE 3 TO § 33.76—ADDITIONAL INTEGRITY ASSESSMENT

Engine Inlet Throat Area (A)—square-meters (square-inches)	Bird quantity	Bird weight kg. (lb.)
1.35 (2,092) > A	none	
1.35 (2,092) ≤ A < 2.90 (4,495)	1	1.15 (2.53)
2.90 (4,495) ≤ A < 3.90 (6,045)	2	1.15 (2.53)
3.90 (6,045) ≤ A	1 plus 6	1.15 (2.53) 0.70 (1.54)

(d) *Large flocking bird.* An engine test will be performed as follows:

(1) Large flocking bird engine tests will be performed using the bird mass and weights in Table 4, and ingested at a bird speed of 200 knots.

(2) Prior to the ingestion, the engine must be stabilized at no less than the mechanical rotor speed of the first exposed stage or stages that, on a standard day, would produce 90 percent of the sea level static maximum rated takeoff power or thrust.

(3) The bird must be targeted on the first exposed rotating stage or stages at a blade airfoil height of not less than 50 percent measured at the leading edge.

(4) Ingestion of a large flocking bird under the conditions prescribed in this paragraph must not cause any of the following:

(i) A sustained reduction of power or thrust to less than 50 percent of maximum rated takeoff power or thrust during the run-on segment specified under paragraph (d)(5)(i) of this section.

(ii) Engine shutdown during the required run-on demonstration specified in paragraph (d)(5) of this section.

(iii) The conditions specified in paragraph (b)(3) of this section.

(5) The following test schedule must be used:

(i) Ingestion followed by 1 minute without power lever movement.

(ii) Followed by 13 minutes at not less than 50 percent of maximum rated takeoff power or thrust.

(iii) Followed by 2 minutes between 30 and 35 percent of maximum rated takeoff power or thrust.

(iv) Followed by 1 minute with power or thrust increased from that set in paragraph (d)(5)(iii) of this section, by between 5 and 10 percent of maximum rated takeoff power or thrust.

(v) Followed by 2 minutes with power or thrust reduced from that set in

paragraph (d)(5)(iv) of this section, by between 5 and 10 percent of maximum rated takeoff power or thrust.

(vi) Followed by a minimum of 1 minute at ground idle then engine shutdown. The durations specified are times at the defined conditions. Power lever movement between each condition will be 10 seconds or less, except that power lever movements allowed within paragraph (d)(5)(ii) of this section are not limited, and for setting power under paragraph (d)(5)(iii) of this section will be 30 seconds or less.

(6) Compliance with the large flocking bird ingestion requirements of this paragraph (d) may also be demonstrated by:

(i) Incorporating the requirements of paragraph (d)(4) and (d)(5) of this section, into the large single bird test demonstration specified in paragraph (b)(1) of this section; or

(ii) Use of an engine subassembly test at the ingestion conditions specified in paragraph (b)(1) of this section if:

(A) All components critical to complying with the requirements of paragraph (d) of this section are included in the subassembly test;

(B) The components of paragraph (d)(6)(ii)(A) of this section are installed in a representative engine for a run-on demonstration in accordance with paragraphs (d)(4) and (d)(5) of this section; except that section (d)(5)(i) is deleted and section (d)(5)(ii) must be 14 minutes in duration after the engine is started and stabilized; and

(C) The dynamic effects that would have been experienced during a full engine ingestion test can be shown to be negligible with respect to meeting the requirements of paragraphs (d)(4) and (d)(5) of this section.

(7) Applicants must show that an unsafe condition will not result if any engine operating limit is exceeded during the run-on period.

TABLE 4 TO § 33.76—LARGE FLOCKING BIRD MASS AND WEIGHT

Engine inlet throat area (square meters/square inches)	Bird quantity	Bird mass and weight (kg (lbs))
A < 2.50 (3875)	none	
2.50 (3875) ≤ A < 3.50 (5425)	1	1.85 (4.08)
3.50 (5425) ≤ A < 3.90 (6045)	1	2.10 (4.63)
3.90 (6045) ≤ A	1	2.50 (5.51)

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[Doc. No. FAA-1998-4815, 65 FR 55854, Sept. 14, 2000, as amended by Amdt. 33-20, 68 FR 75391, Dec. 31, 2003; Amdt. 33-24, 72 FR 50868, Sept. 4, 2007; Amdt. 33-23, 72 FR 58974, Oct. 17, 2007]

#### § 33.77 Foreign object ingestion—ice.

(a)–(b) [Reserved]

(c) Ingestion of ice under the conditions of paragraph (e) of this section may not—

(1) Cause a sustained power or thrust loss; or

(2) Require the engine to be shut-down.

(d) For an engine that incorporates a protection device, compliance with this section need not be demonstrated with respect to foreign objects to be ingested under the conditions prescribed in paragraph (e) 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 with a resultant sustained reduction in power or thrust greater than those values required by paragraph (c) of this section.

(e) Compliance with paragraph (c) of this section must be shown by engine test under the following ingestion conditions:

(1) Ice quantity will be the maximum accumulation on a typical inlet cowl and engine face resulting from a 2-minute delay in actuating the anti-icing system; or a slab of ice which is comparable in weight or thickness for that size engine.

(2) The ingestion velocity will simulate ice being sucked into the engine inlet.

(3) Engine operation will be maximum cruise power or thrust.

(4) The ingestion will simulate a continuous maximum icing encounter at 25 degrees Fahrenheit.

[Doc. No. 16919, 49 FR 6852, Feb. 23, 1984, as amended by Amdt. 33-19, 63 FR 14798, Mar. 26, 1998; 63 FR 53278, Oct. 5, 1998; Amdt. 33-20, 65 FR 55856, Sept. 14, 2000]

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#### § 33.78 Rain and hail ingestion.

(a) *All engines.* (1) The ingestion of large hailstones (0.8 to 0.9 specific gravity) at the maximum true air speed, up to 15,000 feet (4,500 meters), associated with a representative aircraft operating in rough air, with the engine at maximum continuous power, may 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 shall be aimed randomly over the inlet face area and the other half aimed at the critical inlet face area. The hailstones shall be ingested in a rapid sequence to simulate a hailstone encounter and the number and size of the hailstones shall be determined as follows:

(i) One 1-inch (25 millimeters) diameter hailstone for engines with inlet areas of not more than 100 square inches (0.0645 square meters).

(ii) One 1-inch (25 millimeters) diameter and one 2-inch (50 millimeters) diameter hailstone for each 150 square inches (0.0968 square meters) of inlet area, or fraction thereof, for engines with inlet areas of more than 100 square inches (0.0645 square meters).

(2) In addition to complying with paragraph (a)(1) of this section and except as provided in paragraph (b) of this section, 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 B to this part. Acceptable engine operation precludes flameout, run down, continued or non-recoverable surge or stall, or loss of acceleration and deceleration capability, during any three minute continuous period in rain and during any 30 second continuous period in hail. 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.

(b) *Engines for rotorcraft.* As an alternative to the requirements specified in paragraph (a)(2) of this section, for rotorcraft turbine engines only, it must be shown that each engine is capable of acceptable operation during