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by the applicant or by the manufacturers of balloon parts will be distributed.

A31.2 FORMAT

(a) The Instructions for Continued Airworthiness must be in the form of a manual or manuals as appropriate for the quantity of data to be provided.

(b) The format of the manual or manuals must provide for a practical arrangement.

A31.3 CONTENT

The contents of the manual or manuals must be prepared in the English language. The Instructions for Continued Airworthiness must contain the following information:

(a) Introduction information that includes an explanation of the balloon's features and data to the extent necessary for maintenance or preventive maintenance.

(b) A description of the balloon and its systems and installations.

(c) Basic control and operation information for the balloon and its components and systems.

(d) Servicing information that covers details regarding servicing of balloon components, including burner nozzles, fuel tanks, and valves during operations.

(e) Maintenance information for each part of the balloon and its envelope, controls, rigging, basket structure, fuel systems, instruments, and heater assembly that provides the recommended periods at which they should be cleaned, adjusted, tested, and lubricated, the applicable wear tolerances, and the degree of work recommended at these periods. However, the applicant may refer to an accessory, instrument, or equipment manufacturer as the source of this information if the applicant shows that the item has an exceptionally high degree of complexity requiring specialized maintenance techniques, test equipment, or expertise. The recommended overhaul periods and necessary cross references to the Airworthiness Limitations section of the manual must also be included. In addition, the applicant must include an inspection program that includes the frequency and extent of the inspections necessary to provide for the continued airworthiness of the balloon.

(f) Troubleshooting information describing probable malfunctions, how to recognize those malfunctions, and the remedial action for those malfunctions.

(g) Details of what, and how, to inspect after a hard landing.

(h) Instructions for storage preparation including any storage limits.

(i) Instructions for repair on the balloon envelope and its basket or trapeze.

A31.4 AIRWORTHINESS LIMITATIONS SECTION

The Instructions for Continued Airworthiness must contain a section titled Airworthiness Limitations that is segregated and clearly distinguishable from the rest of the document. This section must set forth each mandatory replacement time, structural inspection interval, and related structural inspection procedure, including envelope structural integrity, required for type certification. If the Instructions for Continued Airworthiness consist of multiple documents, the section required by this paragraph must be included in the principal manual. This section must contain a legible statement in a prominent location that reads: ''The Airworthiness Limitations section is FAA approved and specifies maintenance required under §§43.16 and 91.403 of the Federal Aviation Regulations.''

[Amdt. 31–4, 45 FR 60180, Sept. 11, 1980, as amended by Amdt. 31–5, 54 FR 34330, Aug. 18, 1989]

PART 33—AIRWORTHINESS STANDARDS: AIRCRAFT ENGINES

Subpart A—General

Sec.
33.1 Applicability.
33.3 General.
33.4 Instructions for Continued Airworthiness.
33.5 Instruction manual for installing and operating the engine.
33.7 Engine ratings and operating limitations.
33.8 Selection of engine power and thrust ratings.

Subpart B—Design and Construction; General

33.11 Applicability.
33.13 [Reserved]
33.15 Materials.
33.17 Fire protection.
33.19 Durability.
33.21 Engine cooling.
33.23 Engine mounting attachments and structure.
33.25 Accessory attachments.
33.27 Turbine, compressor, fan, and turbosupercharger rotor overspeed.
33.28 Engine control systems.
33.29 Instrument connection.

Subpart C—Design and Construction; Reciprocating Aircraft Engines

33.31 Applicability.
33.33 Vibration.
33.34 Turbocharger rotors.
33.35 Fuel and induction system.
33.37 Ignition system.
33.39 Lubrication system.

Subpart D—Block Tests; Reciprocating Aircraft Engines

33.41 Applicability.
33.42 General.
33.43 Vibration test.
33.45 Calibration tests.
33.47 Detonation test.
33.49 Endurance test.
33.51 Operation test.
33.53 Engine system and component tests.
33.55 Teardown inspection.
33.57 General conduct of block tests.

Subpart E—Design and Construction; Turbine Aircraft Engines

33.61 Applicability.
33.62 Stress analysis.
33.63 Vibration.
33.64 Pressurized engine static parts.
33.65 Surge and stall characteristics.
33.66 Bleed air system.
33.67 Fuel system.
33.68 Induction system icing.
33.69 Ignitions system.
33.70 Engine life-limited parts.
33.71 Lubrication system.
33.72 Hydraulic actuating systems.
33.73 Power or thrust response.
33.74 Continued rotation.
33.75 Safety analysis.
33.76 Bird ingestion.
33.77 Foreign object ingestion—ice.
33.78 Rain and hail ingestion.
33.79 Fuel burning thrust augmentor.

Subpart F—Block Tests; Turbine Aircraft Engines

33.81 Applicability.
33.82 General.
33.83 Vibration test.
33.84 Engine overtorque test.
33.85 Calibration tests.
33.87 Endurance test.
33.88 Engine overtemperature test.
33.89 Operation test.
33.90 Initial maintenance inspection test.
33.91 Engine system and component tests.
33.92 Rotor locking tests.
33.93 Teardown inspection.
33.94 Blade containment and rotor unbalance tests.
33.95 Engine-propeller systems tests.
33.96 Engine tests in auxiliary power unit (APU) mode.
33.97 Thrust reversers.
33.99 General conduct of block tests.

Subpart G—Special Requirements: Turbine Aircraft Engines

33.201 Design and test requirements for Early ETOPS eligibility.
APPENDIX A TO PART 33—INSTRUCTIONS FOR CONTINUED AIRWORTHINESS
APPENDIX B TO PART 33—CERTIFICATION STANDARD ATMOSPHERIC CONCENTRATIONS OF RAIN AND HAIL
APPENDIX C TO PART 33 [RESERVED]
APPENDIX D TO PART 33—MIXED PHASE AND ICE CRYSTAL ICING ENVELOPE (DEEP CONVECTIVE CLOUDS)

AUTHORITY: 49 U.S.C. 106(g), 40113, 44701, 44702, 44704.

SOURCE: Docket No. 3025, 29 FR 7453, June 10, 1964, unless otherwise noted.

NOTE: For miscellaneous amendments to cross references in this Part 33, see Amdt. 33–2, 31 FR 9211, July 6, 1966.

Subpart A—General

§ 33.1 Applicability.

(a) This part prescribes airworthiness standards for the issue of type certificates and changes to those certificates, for aircraft engines.

(b) Each person who applies under part 21 for such a certificate or change must show compliance with the applicable requirements of this part and the applicable requirements of part 34 of this chapter.

[Amdt. 33–7, 41 FR 55474, Dec. 20, 1976, as amended by Amdt. 33–14, 55 FR 32861, Aug. 10, 1990]

§ 33.3 General.

Each applicant must show that the aircraft engine concerned meets the applicable requirements of this part.

§ 33.4 Instructions for Continued Airworthiness.

The applicant must prepare Instructions for Continued Airworthiness in accordance with appendix A to this part that are acceptable to the Administrator. The instructions may be incomplete at type certification if a program exists to ensure their completion prior to delivery of the first aircraft with the engine installed, or upon issuance of a standard certificate of airworthiness for the aircraft with the engine installed, whichever occurs later.

[Amdt. 33–9, 45 FR 60181, Sept. 11, 1980]

§ 33.5 Instruction manual for installing and operating the engine.

Each applicant must prepare and make available to the Administrator

prior to the issuance of the type certificate, and to the owner at the time of delivery of the engine, approved instructions for installing and operating the engine. The instructions must include at least the following:

(a) *Installation instructions.* (1) The location of engine mounting attachments, the method of attaching the engine to the aircraft, and the maximum allowable load for the mounting attachments and related structure.

(2) The location and description of engine connections to be attached to accessories, pipes, wires, cables, ducts, and cowling.

(3) An outline drawing of the engine including overall dimensions.

(4) A definition of the physical and functional interfaces with the aircraft and aircraft equipment, including the propeller when applicable.

(5) Where an engine system relies on components that are not part of the engine type design, the interface conditions and reliability requirements for those components upon which engine type certification is based must be specified in the engine installation instructions directly or by reference to appropriate documentation.

(6) A list of the instruments necessary for control of the engine, including the overall limits of accuracy and transient response required of such instruments for control of the operation of the engine, must also be stated so that the suitability of the instruments as installed may be assessed.

(b) *Operation instructions.* (1) The operating limitations established by the Administrator.

(2) The power or thrust ratings and procedures for correcting for nonstandard atmosphere.

(3) The recommended procedures, under normal and extreme ambient conditions for—

(i) Starting;

(ii) Operating on the ground; and

(iii) Operating during flight.

(4) For rotorcraft engines having one or more OEI ratings, applicants must provide data on engine performance characteristics and variability to enable the aircraft manufacturer to establish aircraft power assurance procedures.

(5) A description of the primary and all alternate modes, and any back-up system, together with any associated limitations, of the engine control system and its interface with the aircraft systems, including the propeller when applicable.

(c) *Safety analysis assumptions.* The assumptions of the safety analysis as described in § 33.75(d) with respect to the reliability of safety devices, instrumentation, early warning devices, maintenance checks, and similar equipment or procedures that are outside the control of the engine manufacturer.

[Amdt. 33–6, 39 FR 35463, Oct. 1, 1974, as amended by Amdt. 33–9, 45 FR 60181, Sept. 11, 1980; Amdt. 33–24, 47 FR 50867, Sept. 4, 2007; Amdt. 33–25, 73 FR 48123, Aug. 18, 2008; Amdt. 33–26, 73 FR 48284, Aug. 19, 2008]

§ 33.7 Engine ratings and operating limitations.

(a) Engine ratings and operating limitations are established by the Administrator and included in the engine certificate data sheet specified in § 21.41 of this chapter, including ratings and limitations based on the operating conditions and information specified in this section, as applicable, and any other information found necessary for safe operation of the engine.

(b) For reciprocating engines, ratings and operating limitations are established relating to the following:

(1) Horsepower or torque, r.p.m., manifold pressure, and time at critical pressure altitude and sea level pressure altitude for—

(i) Rated maximum continuous power (relating to unsupercharged operation or to operation in each supercharger mode as applicable); and

(ii) Rated takeoff power (relating to unsupercharged operation or to operation in each supercharger mode as applicable).

(2) Fuel grade or specification.

(3) Oil grade or specification.

(4) Temperature of the—

(i) Cylinder;

(ii) Oil at the oil inlet; and

(iii) Turbosupercharger turbine wheel inlet gas.

(5) Pressure of—

(i) Fuel at the fuel inlet; and

(ii) Oil at the main oil gallery.

(6) Accessory drive torque and overhang moment.

(7) Component life.

(8) Turbosupercharger turbine wheel r.p.m.

(c) For turbine engines, ratings and operating limitations are established relating to the following:

(1) Horsepower, torque, or thrust, r.p.m., gas temperature, and time for—

(i) Rated maximum continuous power or thrust (augmented);

(ii) Rated maximum continuous power or thrust (unaugmented);

(iii) Rated takeoff power or thrust (augmented);

(iv) Rated takeoff power or thrust (unaugmented);

(v) Rated 30-minute OEI power;

(vi) Rated 2½-minute OEI power;

(vii) Rated continuous OEI power; and

(viii) Rated 2-minute OEI Power;

(ix) Rated 30-second OEI power; and

(x) Auxiliary power unit (APU) mode of operation.

(2) Fuel designation or specification.

(3) Oil grade or specification.

(4) Hydraulic fluid specification.

(5) Temperature of—

(i) Oil at a location specified by the applicant;

(ii) Induction air at the inlet face of a supersonic engine, including steady state operation and transient overtemperature and time allowed;

(iii) Hydraulic fluid of a supersonic engine;

(iv) Fuel at a location specified by the applicant; and

(v) External surfaces of the engine, if specified by the applicant.

(6) Pressure of—

(i) Fuel at the fuel inlet;

(ii) Oil at a location specified by the applicant;

(iii) Induction air at the inlet face of a supersonic engine, including steady state operation and transient overpressure and time allowed; and

(iv) Hydraulic fluid.

(7) Accessory drive torque and overhang moment.

(8) Component life.

(9) Fuel filtration.

(10) Oil filtration.

(11) Bleed air.

(12) The number of start-stop stress cycles approved for each rotor disc and spacer.

(13) Inlet air distortion at the engine inlet.

(14) Transient rotor shaft overspeed r.p.m., and number of overspeed occurrences.

(15) Transient gas overtemperature, and number of overtemperature occurrences.

(16) Transient engine overtorque, and number of overtorque occurrences.

(17) Maximum engine overtorque for turbopropeller and turboshaft engines incorporating free power turbines.

(18) For engines to be used in supersonic aircraft, engine rotor windmilling rotational r.p.m.

(d) In determining the engine performance and operating limitations, the overall limits of accuracy of the engine control system and of the necessary instrumentation as defined in § 33.5(a)(6) must be taken into account.

[Amdt. 33–6, 39 FR 35463, Oct. 1, 1974, as amended by Amdt. 33–10, 49 FR 6850, Feb. 23, 1984; Amdt. 33–11, 51 FR 10346, Mar. 25, 1986; Amdt. 33–12, 53 FR 34220, Sept. 2, 1988; Amdt. 33–18, 61 FR 31328, June 19, 1996; Amdt. 33–26, 73 FR 48284, Aug. 19, 2008; Amdt. 33–30, 74 FR 45310, Sept. 2, 2009]

§ 33.8 Selection of engine power and thrust ratings.

(a) Requested engine power and thrust ratings must be selected by the applicant.

(b) Each selected rating must be for the lowest power or thrust that all engines of the same type may be expected to produce under the conditions used to determine that rating.

[Amdt. 33–3, 32 FR 3736, Mar. 4, 1967]

Subpart B—Design and Construction; General

§ 33.11 Applicability.

This subpart prescribes the general design and construction requirements for reciprocating and turbine aircraft engines.

§ 33.13 [Reserved]

§ 33.15 Materials.

The suitability and durability of materials used in the engine must—

(a) Be established on the basis of experience or tests; and

(b) Conform to approved specifications (such as industry or military specifications) that ensure their having the strength and other properties assumed in the design data.

(Secs. 313(a), 601, and 603, 72 Stat. 759, 775, 49 U.S.C. 1354(a), 1421, and 1423; sec. 6(c), 49 U.S.C. 1655(c))

[Amdt. 33–8, 42 FR 15047, Mar. 17, 1977, as amended by Amdt. 33–10, 49 FR 6850, Feb. 23, 1984]

§ 33.17 Fire protection.

(a) The design and construction of the engine and the materials used must minimize the probability of the occurrence and spread of fire during normal operation and failure conditions, and must minimize the effect of such a fire. In addition, the design and construction of turbine engines must minimize the probability of the occurrence of an internal fire that could result in structural failure or other hazardous effects.

(b) Except as provided in paragraph (c) of this section, each external line, fitting, and other component, which contains or conveys flammable fluid during normal engine operation, must be fire resistant or fireproof, as determined by the Administrator. Components must be shielded or located to safeguard against the ignition of leaking flammable fluid.

(c) A tank, which contains flammable fluids and any associated shut-off means and supports, which are part of and attached to the engine, must be fireproof either by construction or by protection unless damage by fire will not cause leakage or spillage of a hazardous quantity of flammable fluid. For a reciprocating engine having an integral oil sump of less than 23.7 liters capacity, the oil sump need not be fireproof or enclosed by a fireproof shield.

(d) An engine component designed, constructed, and installed to act as a firewall must be:

(1) Fireproof;

(2) Constructed so that no hazardous quantity of air, fluid or flame can pass around or through the firewall; and,

(3) Protected against corrosion;

(e) In addition to the requirements of paragraphs (a) and (b) of this section, engine control system components that are located in a designated fire zone must be fire resistant or fireproof, as determined by the Administrator.

(f) Unintentional accumulation of hazardous quantities of flammable fluid within the engine must be prevented by draining and venting.

(g) Any components, modules, or equipment, which are susceptible to or are potential sources of static discharges or electrical fault currents must be designed and constructed to be properly grounded to the engine reference, to minimize the risk of ignition in external areas where flammable fluids or vapors could be present.

[Doc. No. FAA–2007–28503, 74 FR 37930, July 30, 2009]

§ 33.19 Durability.

(a) Engine design and construction must minimize the development of an unsafe condition of the engine between overhaul periods. The design of the compressor and turbine rotor cases must provide for the containment of damage from rotor blade failure. Energy levels and trajectories of fragments resulting from rotor blade failure that lie outside the compressor and turbine rotor cases must be defined.

(b) Each component of the propeller blade pitch control system which is a part of the engine type design must meet the requirements of §§ 35.21, 35.23, 35.42 and 35.43 of this chapter.

[Doc. No. 3025, 29 FR 7453, June 10, 1964, as amended by Amdt. 33–9, 45 FR 60181, Sept. 11, 1980; Amdt. 33–10, 49 FR 6851, Feb. 23, 1984; Amdt. 33–28, 73 FR 63346, Oct. 24, 2008]

§ 33.21 Engine cooling.

Engine design and construction must provide the necessary cooling under conditions in which the airplane is expected to operate.

§ 33.23 Engine mounting attachments and structure.

(a) The maximum allowable limit and ultimate loads for engine mounting attachments and related engine structure must be specified.

(b) The engine mounting attachments and related engine structure must be able to withstand—

(1) The specified limit loads without permanent deformation; and

(2) The specified ultimate loads without failure, but may exhibit permanent deformation.

[Amdt. 33–10, 49 FR 6851, Feb. 23, 1984]

§ 33.25 Accessory attachments.

The engine must operate properly with the accessory drive and mounting attachments loaded. Each engine accessory drive and mounting attachment must include provisions for sealing to prevent contamination of, or unacceptable leakage from, the engine interior. A drive and mounting attachment requiring lubrication for external drive splines, or coupling by engine oil, must include provisions for sealing to prevent unacceptable loss of oil and to prevent contamination from sources outside the chamber enclosing the drive connection. The design of the engine must allow for the examination, adjustment, or removal of each accessory required for engine operation.

[Amdt. 33–10, 49 FR 6851, Feb. 23, 1984]

§ 33.27 Turbine, compressor, fan, and turbosupercharger rotor overspeed.

(a) For each fan, compressor, turbine, and turbosupercharger rotor, the applicant must establish by test, analysis, or a combination of both, that each rotor will not burst when operated in the engine for 5 minutes at whichever of the conditions defined in paragraph (b) of this section is the most critical with respect to the integrity of such a rotor.

(1) Test rotors used to demonstrate compliance with this section that do not have the most adverse combination of material properties and dimensional tolerances must be tested at conditions which have been adjusted to ensure the minimum specification rotor possesses the required overspeed capability. This can be accomplished by increasing test speed, temperature, and/or loads.

(2) When an engine test is being used to demonstrate compliance with the overspeed conditions listed in paragraph (b)(3) or (b)(4) of this section and the failure of a component or system is sudden and transient, it may not be possible to operate the engine for 5 minutes after the failure. Under these circumstances, the actual overspeed duration is acceptable if the required maximum overspeed is achieved.

(b) When determining the maximum overspeed condition applicable to each rotor in order to comply with paragraphs (a) and (c) of this section, the applicant must evaluate the following rotor speeds taking into consideration the part's operating temperatures and temperature gradients throughout the engine's operating envelope:

(1) 120 percent of the maximum permissible rotor speed associated with any of the engine ratings except one-engine-inoperative (OEI) ratings of less than 2½ minutes.

(2) 115 percent of the maximum permissible rotor speed associated with any OEI ratings of less than 2½ minutes.

(3) 105 percent of the highest rotor speed that would result from either:

(i) The failure of the component or system which, in a representative installation of the engine, is the most critical with respect to overspeed when operating at any rating condition except OEI ratings of less than 2½ minutes, or

(ii) The failure of any component or system in a representative installation of the engine, in combination with any other failure of a component or system that would not normally be detected during a routine pre-flight check or during normal flight operation, that is the most critical with respect to overspeed, except as provided by paragraph (c) of this section, when operating at any rating condition except OEI ratings of less than 2½ minutes.

(4) 100 percent of the highest rotor speed that would result from the failure of the component or system which, in a representative installation of the engine, is the most critical with respect to overspeed when operating at any OEI rating of less than 2½ minutes.

(c) The highest overspeed that results from a complete loss of load on a turbine rotor, except as provided by paragraph (f) of this section, must be included in the overspeed conditions considered by paragraphs (b)(3)(i), (b)(3)(ii), and (b)(4) of this section, regardless of whether that overspeed results from a failure within the engine

or external to the engine. The overspeed resulting from any other single failure must be considered when selecting the most limiting overspeed conditions applicable to each rotor. Overspeeds resulting from combinations of failures must also be considered unless the applicant can show that the probability of occurrence is not greater than extremely remote (probability range of 10^{-7} to 10^{-9} per engine flight hour).

(d) In addition, the applicant must demonstrate that each fan, compressor, turbine, and turbosupercharger rotor complies with paragraphs (d)(1) and (d)(2) of this section for the maximum overspeed achieved when subjected to the conditions specified in paragraphs (b)(3) and (b)(4) of this section. The applicant must use the approach in paragraph (a) of this section which specifies the required test conditions.

(1) Rotor Growth must not cause the engine to:

(i) Catch fire,

(ii) Release high-energy debris through the engine casing or result in a hazardous failure of the engine casing,

(iii) Generate loads greater than those ultimate loads specified in § 33.23(a), or

(iv) Lose the capability of being shut down.

(2) Following an overspeed event and after continued operation, the rotor may not exhibit conditions such as cracking or distortion which preclude continued safe operation.

(e) The design and functioning of engine control systems, instruments, and other methods not covered under § 33.28 must ensure that the engine operating limitations that affect turbine, compressor, fan, and turbosupercharger rotor structural integrity will not be exceeded in service.

(f) Failure of a shaft section may be excluded from consideration in determining the highest overspeed that would result from a complete loss of load on a turbine rotor if the applicant:

(1) Identifies the shaft as an engine life-limited-part and complies with § 33.70.

(2) Uses material and design features that are well understood and that can be analyzed by well-established and validated stress analysis techniques.

(3) Determines, based on an assessment of the environment surrounding the shaft section, that environmental influences are unlikely to cause a shaft failure. This assessment must include complexity of design, corrosion, wear, vibration, fire, contact with adjacent components or structure, overheating, and secondary effects from other failures or combination of failures.

(4) Identifies and declares, in accordance with § 33.5, any assumptions regarding the engine installation in making the assessment described above in paragraph (f)(3) of this section.

(5) Assesses, and considers as appropriate, experience with shaft sections of similar design.

(6) Does not exclude the entire shaft.

(g) If analysis is used to meet the overspeed requirements, then the analytical tool must be validated to prior overspeed test results of a similar rotor. The tool must be validated for each material. The rotor being certified must not exceed the boundaries of the rotors being used to validate the analytical tool in terms of geometric shape, operating stress, and temperature. Validation includes the ability to accurately predict rotor dimensional growth and the burst speed. The predictions must also show that the rotor being certified does not have lower burst and growth margins than rotors used to validate the tool.

[Doc. No. FAA–2010–0398, Amdt. 33–31, 76 FR 42023, July 18, 2011]

§ 33.28 Engine control systems.

(a) *Applicability*. These requirements are applicable to any system or device that is part of engine type design, that controls, limits, or monitors engine operation, and is necessary for the continued airworthiness of the engine.

(b) *Validation*—(1) *Functional aspects*. The applicant must substantiate by tests, analysis, or a combination thereof, that the engine control system performs the intended functions in a manner which:

(i) Enables selected values of relevant control parameters to be maintained and the engine kept within the

approved operating limits over changing atmospheric conditions in the declared flight envelope;

(ii) Complies with the operability requirements of §§ 33.51, 33.65 and 33.73, as appropriate, under all likely system inputs and allowable engine power or thrust demands, unless it can be demonstrated that failure of the control function results in a non-dispatchable condition in the intended application;

(iii) Allows modulation of engine power or thrust with adequate sensitivity over the declared range of engine operating conditions; and

(iv) Does not create unacceptable power or thrust oscillations.

(2) *Environmental limits.* The applicant must demonstrate, when complying with §§ 33.53 or 33.91, that the engine control system functionality will not be adversely affected by declared environmental conditions, including electromagnetic interference (EMI), High Intensity Radiated Fields (HIRF), and lightning. The limits to which the system has been qualified must be documented in the engine installation instructions.

(c) *Control transitions.* (1) The applicant must demonstrate that, when fault or failure results in a change from one control mode to another, from one channel to another, or from the primary system to the back-up system, the change occurs so that:

(i) The engine does not exceed any of its operating limitations;

(ii) The engine does not surge, stall, or experience unacceptable thrust or power changes or oscillations or other unacceptable characteristics; and

(iii) There is a means to alert the flight crew if the crew is required to initiate, respond to, or be aware of the control mode change. The means to alert the crew must be described in the engine installation instructions, and the crew action must be described in the engine operating instructions;

(2) The magnitude of any change in thrust or power and the associated transition time must be identified and described in the engine installation instructions and the engine operating instructions.

(d) *Engine control system failures.* The applicant must design and construct the engine control system so that:

(1) The rate for Loss of Thrust (or Power) Control (LOTC/LOPC) events, consistent with the safety objective associated with the intended application can be achieved;

(2) In the full-up configuration, the system is single fault tolerant, as determined by the Administrator, for electrical or electronic failures with respect to LOTC/LOPC events;

(3) Single failures of engine control system components do not result in a hazardous engine effect; and

(4) Foreseeable failures or malfunctions leading to local events in the intended aircraft installation, such as fire, overheat, or failures leading to damage to engine control system components, do not result in a hazardous engine effect due to engine control system failures or malfunctions.

(e) S*ystem safety assessment.* When complying with this section and § 33.75, the applicant must complete a System Safety Assessment for the engine control system. This assessment must identify faults or failures that result in a change in thrust or power, transmission of erroneous data, or an effect on engine operability producing a surge or stall together with the predicted frequency of occurrence of these faults or failures.

(f) *Protection systems.* (1) The design and functioning of engine control devices and systems, together with engine instruments and operating and maintenance instructions, must provide reasonable assurance that those engine operating limitations that affect turbine, compressor, fan, and turbosupercharger rotor structural integrity will not be exceeded in service.

(2) When electronic overspeed protection systems are provided, the design must include a means for testing, at least once per engine start/stop cycle, to establish the availability of the protection function. The means must be such that a complete test of the system can be achieved in the minimum number of cycles. If the test is not fully automatic, the requirement for a manual test must be contained in the engine instructions for operation.

(3) When overspeed protection is provided through hydromechanical or mechanical means, the applicant must

demonstrate by test or other acceptable means that the overspeed function remains available between inspection and maintenance periods.

(g) *Software*. The applicant must design, implement, and verify all associated software to minimize the existence of errors by using a method, approved by the FAA, consistent with the criticality of the performed functions.

(h) *Aircraft-supplied data*. Single failures leading to loss, interruption or corruption of aircraft-supplied data (other than thrust or power command signals from the aircraft), or data shared between engines must:

(1) Not result in a hazardous engine effect for any engine; and

(2) Be detected and accommodated. The accommodation strategy must not result in an unacceptable change in thrust or power or an unacceptable change in engine operating and starting characteristics. The applicant must evaluate and document in the engine installation instructions the effects of these failures on engine power or thrust, engine operability, and starting characteristics throughout the flight envelope.

(i) *Aircraft-supplied electrical power*. (1) The applicant must design the engine control system so that the loss, malfunction, or interruption of electrical power supplied from the aircraft to the engine control system will not result in any of the following:

(i) A hazardous engine effect, or

(ii) The unacceptable transmission of erroneous data.

(2) When an engine dedicated power source is required for compliance with paragraph (i)(1) of this section, its capacity should provide sufficient margin to account for engine operation below idle where the engine control system is designed and expected to recover engine operation automatically.

(3) The applicant must identify and declare the need for, and the characteristics of, any electrical power supplied from the aircraft to the engine control system for starting and operating the engine, including transient and steady state voltage limits, in the engine instructions for installation.

(4) Low voltage transients outside the power supply voltage limitations declared in paragraph (i)(3) of this section must meet the requirements of paragraph (i)(1) of this section. The engine control system must be capable of resuming normal operation when aircraft-supplied power returns to within the declared limits.

(j) *Air pressure signal*. The applicant must consider the effects of blockage or leakage of the signal lines on the engine control system as part of the System Safety Assessment of paragraph (e) of this section and must adopt the appropriate design precautions.

(k) *Automatic availability and control of engine power for 30-second OEI rating*. Rotorcraft engines having a 30-second OEI rating must incorporate a means, or a provision for a means, for automatic availability and automatic control of the 30-second OEI power within its operating limitations.

(l) *Engine shut down means*. Means must be provided for shutting down the engine rapidly.

(m) *Programmable logic devices*. The development of programmable logic devices using digital logic or other complex design technologies must provide a level of assurance for the encoded logic commensurate with the hazard associated with the failure or malfunction of the systems in which the devices are located. The applicant must provide evidence that the development of these devices has been done by using a method, approved by the FAA, that is consistent with the criticality of the performed function.

[Amdt. 33–26, 73 FR 48284, Aug. 19, 2008]

§ 33.29 Instrument connection.

(a) Unless it is constructed to prevent its connection to an incorrect instrument, each connection provided for powerplant instruments required by aircraft airworthiness regulations or necessary to insure operation of the engine in compliance with any engine limitation must be marked to identify it with its corresponding instrument.

(b) A connection must be provided on each turbojet engine for an indicator system to indicate rotor system unbalance.

(c) Each rotorcraft turbine engine having a 30-second OEI rating and a 2-minute OEI rating must have a means or a provision for a means to:

(1) Alert the pilot when the engine is at the 30-second OEI and the 2-minute OEI power levels, when the event begins, and when the time interval expires;

(2) Automatically record each usage and duration of power at the 30-second OEI and 2-minute OEI levels;

(3) Alert maintenance personnel in a positive manner that the engine has been operated at either or both of the 30-second and 2-minute OEI power levels, and permit retrieval of the recorded data; and

(4) Enable routine verification of the proper operation of the above means.

(d) The means, or the provision for a means, of paragraphs (c)(2) and (c)(3) of this section must not be capable of being reset in flight.

(e) The applicant must make provision for the installation of instrumentation necessary to ensure operation in compliance with engine operating limitations. Where, in presenting the safety analysis, or complying with any other requirement, dependence is placed on instrumentation that is not otherwise mandatory in the assumed aircraft installation, then the applicant must specify this instrumentation in the engine installation instructions and declare it mandatory in the engine approval documentation.

(f) As part of the System Safety Assessment of § 33.28(e), the applicant must assess the possibility and subsequent effect of incorrect fit of instruments, sensors, or connectors. Where necessary, the applicant must take design precautions to prevent incorrect configuration of the system.

(g) The sensors, together with associated wiring and signal conditioning, must be segregated, electrically and physically, to the extent necessary to ensure that the probability of a fault propagating from instrumentation and monitoring functions to control functions, or vice versa, is consistent with the failure effect of the fault.

(h) The applicant must provide instrumentation enabling the flight crew to monitor the functioning of the turbine cooling system unless appropriate inspections are published in the relevant manuals and evidence shows that:

(1) Other existing instrumentation provides adequate warning of failure or impending failure;

(2) Failure of the cooling system would not lead to hazardous engine effects before detection; or

(3) The probability of failure of the cooling system is extremely remote.

[Amdt. 33–5, 39 FR 1831, Jan. 15, 1974, as amended by Amdt. 33–6, 39 FR 35465, Oct. 1, 1974; Amdt. 33–18, 61 FR 31328, June 19, 1996; Amdt. 33–25, 73 FR 48123, Aug. 18, 2008; Amdt. 33–26, 73 FR 48285, Aug. 19, 2008]

Subpart C—Design and Construction; Reciprocating Aircraft Engines

§ 33.31 Applicability.

This subpart prescribes additional design and construction requirements for reciprocating aircraft engines.

§ 33.33 Vibration.

The engine must be designed and constructed to function throughout its normal operating range of crankshaft rotational speeds and engine powers without inducing excessive stress in any of the engine parts because of vibration and without imparting excessive vibration forces to the aircraft structure.

§ 33.34 Turbocharger rotors.

Each turbocharger case must be designed and constructed to be able to contain fragments of a compressor or turbine that fails at the highest speed that is obtainable with normal speed control devices inoperative.

[Amdt. 33–22, 72 FR 50860, Sept. 4, 2007]

§ 33.35 Fuel and induction system.

(a) The fuel system of the engine must be designed and constructed to supply an appropriate mixture of fuel to the cylinders throughout the complete operating range of the engine under all flight and atmospheric conditions.

(b) The intake passages of the engine through which air or fuel in combination with air passes for combustion purposes must be designed and constructed to minimize the danger of ice accretion in those passages. The engine must be designed and constructed to

permit the use of a means for ice prevention.

(c) The type and degree of fuel filtering necessary for protection of the engine fuel system against foreign particles in the fuel must be specified. The applicant must show that foreign particles passing through the prescribed filtering means will not critically impair engine fuel system functioning.

(d) Each passage in the induction system that conducts a mixture of fuel and air must be self-draining, to prevent a liquid lock in the cylinders, in all attitudes that the applicant establishes as those the engine can have when the aircraft in which it is installed is in the static ground attitude.

(e) If provided as part of the engine, the applicant must show for each fluid injection (other than fuel) system and its controls that the flow of the injected fluid is adequately controlled.

[Doc. No. 3025, 29 FR 7453, June 10, 1964, as amended by Amdt. 33–10, 49 FR 6851, Feb. 23, 1984]

§ 33.37 Ignition system.

Each spark ignition engine must have a dual ignition system with at least two spark plugs for each cylinder and two separate electric circuits with separate sources of electrical energy, or have an ignition system of equivalent in-flight reliability.

§ 33.39 Lubrication system.

(a) The lubrication system of the engine must be designed and constructed so that it will function properly in all flight attitudes and atmospheric conditions in which the airplane is expected to operate. In wet sump engines, this requirement must be met when only one-half of the maximum lubricant supply is in the engine.

(b) The lubrication system of the engine must be designed and constructed to allow installing a means of cooling the lubricant.

(c) The crankcase must be vented to the atmosphere to preclude leakage of oil from excessive pressure in the crankcase.

Subpart D—Block Tests; Reciprocating Aircraft Engines

§ 33.41 Applicability.

This subpart prescribes the block tests and inspections for reciprocating aircraft engines.

§ 33.42 General.

Before each endurance test required by this subpart, the adjustment setting and functioning characteristic of each component having an adjustment setting and a functioning characteristic that can be established independent of installation on the engine must be established and recorded.

[Amdt. 33–6, 39 FR 35465, Oct. 1, 1974]

§ 33.43 Vibration test.

(a) Each engine must undergo a vibration survey to establish the torsional and bending vibration characteristics of the crankshaft and the propeller shaft or other output shaft, over the range of crankshaft speed and engine power, under steady state and transient conditions, from idling speed to either 110 percent of the desired maximum continuous speed rating or 103 percent of the maximum desired takeoff speed rating, whichever is higher. The survey must be conducted using, for airplane engines, the same configuration of the propeller type which is used for the endurance test, and using, for other engines, the same configuration of the loading device type which is used for the endurance test.

(b) The torsional and bending vibration stresses of the crankshaft and the propeller shaft or other output shaft may not exceed the endurance limit stress of the material from which the shaft is made. If the maximum stress in the shaft cannot be shown to be below the endurance limit by measurement, the vibration frequency and amplitude must be measured. The peak amplitude must be shown to produce a stress below the endurance limit; if not, the engine must be run at the condition producing the peak amplitude until, for steel shafts, 10 million stress reversals have been sustained without fatigue failure and, for other shafts, until it is shown that fatigue will not

occur within the endurance limit stress of the material.

(c) Each accessory drive and mounting attachment must be loaded, with the loads imposed by each accessory used only for an aircraft service being the limit load specified by the applicant for the drive or attachment point.

(d) The vibration survey described in paragraph (a) of this section must be repeated with that cylinder not firing which has the most adverse vibration effect, in order to establish the conditions under which the engine can be operated safely in that abnormal state. However, for this vibration survey, the engine speed range need only extend from idle to the maximum desired takeoff speed, and compliance with paragraph (b) of this section need not be shown.

[Amdt. 33–6, 39 FR 35465, Oct. 1, 1974, as amended by Amdt. 33–10, 49 FR 6851, Feb. 23, 1984]

§ 33.45 Calibration tests.

(a) Each engine must be subjected to the calibration tests necessary to establish its power characteristics and the conditions for the endurance test specified in § 33.49. The results of the power characteristics calibration tests form the basis for establishing the characteristics of the engine over its entire operating range of crankshaft rotational speeds, manifold pressures, fuel/air mixture settings, and altitudes. Power ratings are based upon standard atmospheric conditions with only those accessories installed which are essential for engine functioning.

(b) A power check at sea level conditions must be accomplished on the endurance test engine after the endurance test. Any change in power characteristics which occurs during the endurance test must be determined. Measurements taken during the final portion of the endurance test may be used in showing compliance with the requirements of this paragraph.

[Doc. No. 3025, 29 FR 7453, June 10, 1964, as amended by Amdt. 33–6, 39 FR 35465, Oct. 1, 1974]

§ 33.47 Detonation test.

Each engine must be tested to establish that the engine can function without detonation throughout its range of intended conditions of operation.

§ 33.49 Endurance test.

(a) *General*. Each engine must be subjected to an endurance test that includes a total of 150 hours of operation (except as provided in paragraph (e)(1)(iii) of this section) and, depending upon the type and contemplated use of the engine, consists of one of the series of runs specified in paragraphs (b) through (e) of this section, as applicable. The runs must be made in the order found appropriate by the Administrator for the particular engine being tested. During the endurance test the engine power and the crankshaft rotational speed must be kept within ±3 percent of the rated values. During the runs at rated takeoff power and for at least 35 hours at rated maximum continuous power, one cylinder must be operated at not less than the limiting temperature, the other cylinders must be operated at a temperature not lower than 50 degrees F. below the limiting temperature, and the oil inlet temperature must be maintained within ±10 degrees F. of the limiting temperature. An engine that is equipped with a propeller shaft must be fitted for the endurance test with a propeller that thrust-loads the engine to the maximum thrust which the engine is designed to resist at each applicable operating condition specified in this section. Each accessory drive and mounting attachment must be loaded. During operation at rated takeoff power and rated maximum continuous power, the load imposed by each accessory used only for an aircraft service must be the limit load specified by the applicant for the engine drive or attachment point.

(b) *Unsupercharged engines and engines incorporating a gear-driven single-speed supercharger*. For engines not incorporating a supercharger and for engines incorporating a gear-driven single-speed supercharger the applicant must conduct the following runs:

(1) A 30-hour run consisting of alternate periods of 5 minutes at rated takeoff power with takeoff speed, and 5 minutes at maximum best economy cruising power or maximum recommended cruising power.

(2) A 20-hour run consisting of alternate periods of 1½ hours at rated maximum continuous power with maximum continuous speed, and ½ hour at 75 percent rated maximum continuous power and 91 percent maximum continuous speed.

(3) A 20-hour run consisting of alternate periods of 1½ hours at rated maximum continuous power with maximum continuous speed, and ½ hour at 70 percent rated maximum continuous power and 89 percent maximum continuous speed.

(4) A 20-hour run consisting of alternate periods of 1½ hours at rated maximum continuous power with maximum continuous speed, and ½ hour at 65 percent rated maximum continuous power and 87 percent maximum continuous speed.

(5) A 20-hour run consisting of alternate periods of 1½ hours at rated maximum continuous power with maximum continuous speed, and ½ hour at 60 percent rated maximum continuous power and 84.5 percent maximum continuous speed.

(6) A 20-hour run consisting of alternate periods of 1½ hours at rated maximum continuous power with maximum continuous speed, and ½ hour at 50 percent rated maximum continuous power and 79.5 percent maximum continuous speed.

(7) A 20-hour run consisting of alternate periods of 2½ hours at rated maximum continuous power with maximum continuous speed, and 2½ hours at maximum best economy cruising power or at maximum recommended cruising power.

(c) *Engines incorporating a gear-driven two-speed supercharger*. For engines incorporating a gear-driven two-speed supercharger the applicant must conduct the following runs:

(1) A 30-hour run consisting of alternate periods in the lower gear ratio of 5 minutes at rated takeoff power with takeoff speed, and 5 minutes at maximum best economy cruising power or at maximum recommended cruising power. If a takeoff power rating is desired in the higher gear ratio, 15 hours of the 30-hour run must be made in the higher gear ratio in alternate periods of 5 minutes at the observed horsepower obtainable with the takeoff critical altitude manifold pressure and takeoff speed, and 5 minutes at 70 percent high ratio rated maximum continuous power and 89 percent high ratio maximum continuous speed.

(2) A 15-hour run consisting of alternate periods in the lower gear ratio of 1 hour at rated maximum continuous power with maximum continuous speed, and ½ hour at 75 percent rated maximum continuous power and 91 percent maximum continuous speed.

(3) A 15-hour run consisting of alternate periods in the lower gear ratio of 1 hour at rated maximum continuous power with maximum continuous speed, and ½ hour at 70 percent rated maximum continuous power and 89 percent maximum continuous speed.

(4) A 30-hour run in the higher gear ratio at rated maximum continuous power with maximum continuous speed.

(5) A 5-hour run consisting of alternate periods of 5 minutes in each of the supercharger gear ratios. The first 5 minutes of the test must be made at maximum continuous speed in the higher gear ratio and the observed horsepower obtainable with 90 percent of maximum continuous manifold pressure in the higher gear ratio under sea level conditions. The condition for operation for the alternate 5 minutes in the lower gear ratio must be that obtained by shifting to the lower gear ratio at constant speed.

(6) A 10-hour run consisting of alternate periods in the lower gear ratio of 1 hour at rated maximum continuous power with maximum continuous speed, and 1 hour at 65 percent rated maximum continuous power and 87 percent maximum continuous speed.

(7) A 10-hour run consisting of alternate periods in the lower gear ratio of 1 hour at rated maximum continuous power with maximum continuous speed, and 1 hour at 60 percent rated maximum continuous power and 84.5 percent maximum continuous speed.

(8) A 10-hour run consisting of alternate periods in the lower gear ratio of 1 hour at rated maximum continuous power with maximum continuous speed, and 1 hour at 50 percent rated maximum continuous power and 79.5 percent maximum continuous speed.

(9) A 20-hour run consisting of alternate periods in the lower gear ratio of 2 hours at rated maximum continuous power with maximum continuous speed, and 2 hours at maximum best economy cruising power and speed or at maximum recommended cruising power.

(10) A 5-hour run in the lower gear ratio at maximum best economy cruising power and speed or at maximum recommended cruising power and speed.

Where simulated altitude test equipment is not available when operating in the higher gear ratio, the runs may be made at the observed horsepower obtained with the critical altitude manifold pressure or specified percentages thereof, and the fuel-air mixtures may be adjusted to be rich enough to suppress detonation.

(d) *Helicopter engines.* To be eligible for use on a helicopter each engine must either comply with paragraphs (a) through (j) of § 29.923 of this chapter, or must undergo the following series of runs:

(1) A 35-hour run consisting of alternate periods of 30 minutes each at rated takeoff power with takeoff speed, and at rated maximum continuous power with maximum continuous speed.

(2) A 25-hour run consisting of alternate periods of 2½ hours each at rated maximum continuous power with maximum continuous speed, and at 70 percent rated maximum continuous power with maximum continuous speed.

(3) A 25-hour run consisting of alternate periods of 2½ hours each at rated maximum continuous power with maximum continuous speed, and at 70 percent rated maximum continuous power with 80 to 90 percent maximum continuous speed.

(4) A 25-hour run consisting of alternate periods of 2½ hours each at 30 percent rated maximum continuous power with takeoff speed, and at 30 percent rated maximum continuous power with 80 to 90 percent maximum continuous speed.

(5) A 25-hour run consisting of alternate periods of 2½ hours each at 80 percent rated maximum continuous power with takeoff speed, and at either rated maximum continuous power with 110 percent maximum continuous speed or at rated takeoff power with 103 percent takeoff speed, whichever results in the greater speed.

(6) A 15-hour run at 105 percent rated maximum continuous power with 105 percent maximum continuous speed or at full throttle and corresponding speed at standard sea level carburetor entrance pressure, if 105 percent of the rated maximum continuous power is not exceeded.

(e) *Turbosupercharged engines.* For engines incorporating a turbosupercharger the following apply except that altitude testing may be simulated provided the applicant shows that the engine and supercharger are being subjected to mechanical loads and operating temperatures no less severe than if run at actual altitude conditions:

(1) For engines used in airplanes the applicant must conduct the runs specified in paragraph (b) of this section, except—

(i) The entire run specified in paragraph (b)(1) of this section must be made at sea level altitude pressure;

(ii) The portions of the runs specified in paragraphs (b)(2) through (7) of this section at rated maximum continuous power must be made at critical altitude pressure, and the portions of the runs at other power must be made at 8,000 feet altitude pressure; and

(iii) The turbosupercharger used during the 150-hour endurance test must be run on the bench for an additional 50 hours at the limiting turbine wheel inlet gas temperature and rotational speed for rated maximum continuous power operation unless the limiting temperature and speed are maintained during 50 hours of the rated maximum continuous power operation.

(2) For engines used in helicopters the applicant must conduct the runs specified in paragraph (d) of this section, except—

(i) The entire run specified in paragraph (d)(1) of this section must be made at critical altitude pressure;

(ii) The portions of the runs specified in paragraphs (d)(2) and (3) of this section at rated maximum continuous power must be made at critical altitude pressure and the portions of the

runs at other power must be made at 8,000 feet altitude pressure;

(iii) The entire run specified in paragraph (d)(4) of this section must be made at 8,000 feet altitude pressure;

(iv) The portion of the runs specified in paragraph (d)(5) of this section at 80 percent of rated maximum continuous power must be made at 8,000 feet altitude pressure and the portions of the runs at other power must be made at critical altitude pressure;

(v) The entire run specified in paragraph (d)(6) of this section must be made at critical altitude pressure; and

(vi) The turbosupercharger used during the endurance test must be run on the bench for 50 hours at the limiting turbine wheel inlet gas temperature and rotational speed for rated maximum continuous power operation unless the limiting temperature and speed are maintained during 50 hours of the rated maximum continuous power operation.

[Amdt. 33–3, 32 FR 3736, Mar. 4, 1967, as amended by Amdt. 33–6, 39 FR 35465, Oct. 1, 1974; Amdt. 33–10, 49 FR 6851, Feb. 23, 1984]

§ 33.51 Operation test.

The operation test must include the testing found necessary by the Administrator to demonstrate backfire characteristics, starting, idling, acceleration, overspeeding, functioning of propeller and ignition, and any other operational characteristic of the engine. If the engine incorporates a multispeed supercharger drive, the design and construction must allow the supercharger to be shifted from operation at the lower speed ratio to the higher and the power appropriate to the manifold pressure and speed settings for rated maximum continuous power at the higher supercharger speed ratio must be obtainable within five seconds.

[Doc. No. 3025, 29 FR 7453, June 10, 1964, as amended by Amdt. 33–3, 32 FR 3737, Mar. 4, 1967]

§ 33.53 Engine system and component tests.

(a) For those systems and components that cannot be adequately substantiated in accordance with endurance testing of § 33.49, the applicant must conduct additional tests to demonstrate that systems or components are able to perform the intended functions in all declared environmental and operating conditions.

(b) Temperature limits must be established for each component that requires temperature controlling provisions in the aircraft installation to assure satisfactory functioning, reliability, and durability.

[Doc. No. 3025, 29 FR 7453, June 10, 1964, as amended by Amdt. 33–26, 73 FR 48285, Aug. 19, 2008]

§ 33.55 Teardown inspection.

After completing the endurance test—

(a) Each engine must be completely disassembled;

(b) Each component having an adjustment setting and a functioning characteristic that can be established independent of installation on the engine must retain each setting and functioning characteristic within the limits that were established and recorded at the beginning of the test; and

(c) Each engine component must conform to the type design and be eligible for incorporation into an engine for continued operation, in accordance with information submitted in compliance with § 33.4.

[Amdt. 33–6, 39 FR 35466, Oct. 1, 1974, as amended by Amdt. 33–9, 45 FR 60181, Sept. 11, 1980]

§ 33.57 General conduct of block tests.

(a) The applicant may, in conducting the block tests, use separate engines of identical design and construction in the vibration, calibration, detonation, endurance, and operation tests, except that, if a separate engine is used for the endurance test it must be subjected to a calibration check before starting the endurance test.

(b) The applicant may service and make minor repairs to the engine during the block tests in accordance with the service and maintenance instructions submitted in compliance with § 33.4. If the frequency of the service is excessive, or the number of stops due to engine malfunction is excessive, or a major repair, or replacement of a part is found necessary during the block tests or as the result of findings from the teardown inspection, the engine or

its parts may be subjected to any additional test the Administrator finds necessary.

(c) Each applicant must furnish all testing facilities, including equipment and competent personnel, to conduct the block tests.

[Doc. No. 3025, 29 FR 7453, June 10, 1964, as amended by Amdt. 33–6, 39 FR 35466, Oct. 1, 1974; Amdt. 33–9, 45 FR 60181, Sept. 11, 1980]

Subpart E—Design and Construction; Turbine Aircraft Engines

§ 33.61 Applicability.

This subpart prescribes additional design and construction requirements for turbine aircraft engines.

§ 33.62 Stress analysis.

A stress analysis must be performed on each turbine engine showing the design safety margin of each turbine engine rotor, spacer, and rotor shaft.

[Amdt. 33–6, 39 FR 35466, Oct. 1, 1974]

§ 33.63 Vibration.

Each engine must be designed and constructed to function throughout its declared flight envelope and operating range of rotational speeds and power/thrust, without inducing excessive stress in any engine part because of vibration and without imparting excessive vibration forces to the aircraft structure.

[Doc. No. 28107, 61 FR 28433, June 4, 1996]

§ 33.64 Pressurized engine static parts.

(a) Strength. The applicant must establish by test, validated analysis, or a combination of both, that all static parts subject to significant gas or liquid pressure loads for a stabilized period of one minute will not:

(1) Exhibit permanent distortion beyond serviceable limits or exhibit leakage that could create a hazardous condition when subjected to the greater of the following pressures:

(i) 1.1 times the maximum working pressure;

(ii) 1.33 times the normal working pressure; or

(iii) 35 kPa (5 p.s.i.) above the normal working pressure.

(2) Exhibit fracture or burst when subjected to the greater of the following pressures:

(i) 1.15 times the maximum possible pressure;

(ii) 1.5 times the maximum working pressure; or

(iii) 35 kPa (5 p.s.i.) above the maximum possible pressure.

(b) Compliance with this section must take into account:

(1) The operating temperature of the part;

(2) Any other significant static loads in addition to pressure loads;

(3) Minimum properties representative of both the material and the processes used in the construction of the part; and

(4) Any adverse geometry conditions allowed by the type design.

[Amdt. 33–27; 73 FR 55437, Sept. 25, 2008; Amdt. 33–27, 73 FR 57235, Oct. 2, 2008]

§ 33.65 Surge and stall characteristics.

When the engine is operated in accordance with operating instructions required by § 33.5(b), starting, a change of power or thrust, power or thrust augmentation, limiting inlet air distortion, or inlet air temperature may not cause surge or stall to the extent that flameout, structural failure, overtemperature, or failure of the engine to recover power or thrust will occur at any point in the operating envelope.

[Amdt. 33–6, 39 FR 35466, Oct. 1, 1974]

§ 33.66 Bleed air system.

The engine must supply bleed air without adverse effect on the engine, excluding reduced thrust or power output, at all conditions up to the discharge flow conditions established as a limitation under § 33.7(c)(11). If bleed air used for engine anti-icing can be controlled, provision must be made for a means to indicate the functioning of the engine ice protection system.

[Amdt. 33–10, 49 FR 6851, Feb. 23, 1984]

§ 33.67 Fuel system.

(a) With fuel supplied to the engine at the flow and pressure specified by the applicant, the engine must function properly under each operating condition required by this part. Each fuel control adjusting means that may

not be manipulated while the fuel control device is mounted on the engine must be secured by a locking device and sealed, or otherwise be inaccessible. All other fuel control adjusting means must be accessible and marked to indicate the function of the adjustment unless the function is obvious.

(b) There must be a fuel strainer or filter between the engine fuel inlet opening and the inlet of either the fuel metering device or the engine-driven positive displacement pump whichever is nearer the engine fuel inlet. In addition, the following provisions apply to each strainer or filter required by this paragraph (b):

(1) It must be accessible for draining and cleaning and must incorporate a screen or element that is easily removable.

(2) It must have a sediment trap and drain except that it need not have a drain if the strainer or filter is easily removable for drain purposes.

(3) It must be mounted so that its weight is not supported by the connecting lines or by the inlet or outlet connections of the strainer or filter, unless adequate strength margins under all loading conditions are provided in the lines and connections.

(4) It must have the type and degree of fuel filtering specified as necessary for protection of the engine fuel system against foreign particles in the fuel. The applicant must show:

(i) That foreign particles passing through the specified filtering means do not impair the engine fuel system functioning; and

(ii) That the fuel system is capable of sustained operation throughout its flow and pressure range with the fuel initially saturated with water at 80 °F (27 °C) and having 0.025 fluid ounces per gallon (0.20 milliliters per liter) of free water added and cooled to the most critical condition for icing likely to be encountered in operation. However, this requirement may be met by demonstrating the effectiveness of specified approved fuel anti-icing additives, or that the fuel system incorporates a fuel heater which maintains the fuel temperature at the fuel strainer or fuel inlet above 32 °F (0 °C) under the most critical conditions.

(5) The applicant must demonstrate that the filtering means has the capacity (with respect to engine operating limitations) to ensure that the engine will continue to operate within approved limits, with fuel contaminated to the maximum degree of particle size and density likely to be encountered in service. Operation under these conditions must be demonstrated for a period acceptable to the Administrator, beginning when indication of impending filter blockage is first given by either:

(i) Existing engine instrumentation; or

(ii) Additional means incorporated into the engine fuel system.

(6) Any strainer or filter bypass must be designed and constructed so that the release of collected contaminants is minimized by appropriate location of the bypass to ensure that collected contaminants are not in the bypass flow path.

(c) If provided as part of the engine, the applicant must show for each fluid injection (other than fuel) system and its controls that the flow of the injected fluid is adequately controlled.

[Amdt. 33–6, 39 FR 35466, Oct. 1, 1974, as amended by Amdt. 33–10, 49 FR 6851, Feb. 23, 1984; Amdt. 33–18, 61 FR 31328, June 19, 1996; Amdt. 33–25, 73 FR 48123, Aug. 18, 2008; Amdt. 33–26, 73 FR 48285, Aug. 19, 2008]

§ 33.68 Induction system icing.

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

(a) Operate throughout its flight power range, including the minimum descent idle rotor speeds achievable in flight, in the icing conditions defined for turbojet, turbofan, and turboprop engines in Appendices C and O of part 25 of this chapter, and Appendix D of this part, and for turboshaft engines in Appendix C of part 29 of this chapter, without the accumulation of ice on the engine components that:

(1) Adversely affects engine operation or that causes an unacceptable permanent loss of power or thrust or unacceptable increase in engine operating temperature; or

(2) Results in unacceptable temporary power loss or engine damage; or

(3) Causes a stall, surge, or flameout or loss of engine controllability. The

applicant must account for in-flight ram effects in any critical point analysis or test demonstration of these flight conditions.

(b) Operate throughout its flight power range, including minimum descent idle rotor speeds achievable in flight, in the icing conditions defined for turbojet, turbofan, and turboprop engines in Appendices C and O of part 25 of this chapter, and for turboshaft engines in Appendix C of part 29 of this chapter. In addition:

(1) It must be shown through Critical Point Analysis (CPA) that the complete ice envelope has been analyzed, and that the most critical points must be demonstrated by engine test, analysis, or a combination of the two to operate acceptably. Extended flight in critical flight conditions such as hold, descent, approach, climb, and cruise, must be addressed, for the ice conditions defined in these appendices.

(2) It must be shown by engine test, analysis, or a combination of the two that the engine can operate acceptably for the following durations:

(i) At engine powers that can sustain level flight: A duration that achieves repetitive, stabilized operation for turbojet, turbofan, and turboprop engines in the icing conditions defined in Appendices C and O of part 25 of this chapter, and for turboshaft engines in the icing conditions defined in Appendix C of part 29 of this chapter.

(ii) At engine power below that which can sustain level flight:

(A) Demonstration in altitude flight simulation test facility: A duration of 10 minutes consistent with a simulated flight descent of 10,000 ft (3 km) in altitude while operating in Continuous Maximum icing conditions defined in Appendix C of part 25 of this chapter for turbojet, turbofan, and turboprop engines, and for turboshaft engines in the icing conditions defined in Appendix C of part 29 of this chapter, plus 40 percent liquid water content margin, at the critical level of airspeed and air temperature; or

(B) Demonstration in ground test facility: A duration of 3 cycles of alternating icing exposure corresponding to the liquid water content levels and standard cloud lengths starting in Intermittent Maximum and then in Continuous Maximum icing conditions defined in Appendix C of part 25 of this chapter for turbojet, turbofan, and turboprop engines, and for turboshaft engines in the icing conditions defined in Appendix C of part 29 of this chapter, at the critical level of air temperature.

(c) In addition to complying with paragraph (b) of this section, the following conditions shown in Table 1 of this section unless replaced by similar CPA test conditions that are more critical or produce an equivalent level of severity, must be demonstrated by an engine test:

TABLE 1—CONDITIONS THAT MUST BE DEMONSTRATED BY AN ENGINE TEST

Condition	Total air temperature	Supercooled water concentrations (minimum)	Median volume drop diameter	Duration
1. Glaze ice conditions.	21 to 25 °F (−6 to −4 °C).	2 g/m³	25 to 35 microns	(a) 10-minutes for power below sustainable level flight (idle descent). (b) Must show repetitive, stabilized operation for higher powers (50%, 75%, 100%MC).
2. Rime ice conditions	−10 to 0 °F (−23 to −18 °C).	1 g/m³	15 to 25 microns	(a) 10-minutes for power below sustainable level flight (idle descent). (b) Must show repetitive, stabilized operation for higher powers (50%, 75%, 100%MC).

TABLE 1—CONDITIONS THAT MUST BE DEMONSTRATED BY AN ENGINE TEST—Continued

Condition	Total air temperature	Supercooled water concentrations (minimum)	Median volume drop diameter	Duration
3. Glaze ice holding conditions. (Turbojet, turbofan, and turboprop only).	Turbojet and Turbofan, only: 10 to 18 °F (−12 to −8 °C). Turboprop, only: 2 to 10 °F (−17 to −12 °C).	Alternating cycle: First 1.7 g/m³ (1 minute), Then 0.3 g/m³ (6 minute). .	20 to 30 microns	Must show repetitive, stabilized operation (or 45 minutes max).
4. Rime ice holding conditions. (Turbojet, turbofan, and turboprop only).	Turbojet and Turbofan, only: −10 to 0 °F (−23 to −18 °C). Turboprop, only: 2 to 10 °F (−17 to −12 °C).	0.25 g/m³	20 to 30 microns	Must show repetitive, stabilized operation (or 45 minutes max).

(d) Operate at ground idle speed for a minimum of 30 minutes at each of the following icing conditions shown in Table 2 of this section with the available air bleed for icing protection at its critical condition, without adverse effect, followed by acceleration to takeoff power or thrust. During the idle operation, the engine may be run up periodically to a moderate power or thrust setting in a manner acceptable to the Administrator. Analysis may be used to show ambient temperatures below the tested temperature are less critical. The applicant must document any demonstrated run ups and minimum ambient temperature capability in the engine operating manual as mandatory in icing conditions. The applicant must demonstrate, with consideration of expected airport elevations, the following:

TABLE 2—DEMONSTRATION METHODS FOR SPECIFIC ICING CONDITIONS

Condition	Total air temperature	Supercooled water concentrations (minimum)	Mean effective particle diameter	Demonstration
1. Rime ice condition	0 to 15 °F (−18 to −9 °C).	Liquid—0.3 g/m³	15–25 microns	By engine test.
2. Glaze ice condition	20 to 30 °F (−7 to −1 °C).	Liquid—0.3 g/m³	15–25 microns	By engine test.
3. Snow ice condition	26 to 32 °F (−3 to 0 °C).	Ice—0.9 g/m³	100 microns (minimum)	By test, analysis or combination of the two.
4. Large drop glaze ice condition (Turbojet, turbofan, and turboprop only).	15 to 30 °F (-9 to -1 °C).	Liquid—0.3 g/m³	100 microns (minimum)	By test, analysis or combination of the two.

(e) Demonstrate by test, analysis, or combination of the two, acceptable operation for turbojet, turbofan, and turboprop engines in mixed phase and ice crystal icing conditions throughout Appendix D of this part, icing envelope throughout its flight power range, including minimum descent idling speeds.

[Amdt. 33–34, 79 FR 66536, Nov. 4, 2014]

§ 33.69 Ignitions system.

Each engine must be equipped with an ignition system for starting the engine on the ground and in flight. An electric ignition system must have at least two igniters and two separate secondary electric circuits, except that only one igniter is required for fuel burning augmentation systems.

[Amdt. 33–6, 39 FR 35466, Oct. 1, 1974]

§ 33.70 Engine life-limited parts.

By a procedure approved by the FAA, operating limitations must be established which specify the maximum allowable number of flight cycles for each engine life-limited part. Engine life-limited parts are rotor and major static structural parts whose primary failure is likely to result in a hazardous engine effect. Typically, engine life-limited parts include, but are not limited to disks, spacers, hubs, shafts, high-pressure casings, and non-redundant mount components. For the purposes of this section, a hazardous engine effect is any of the conditions listed in § 33.75 of this part. The applicant will establish the integrity of each engine life-limited part by:

(a) An engineering plan that contains the steps required to ensure each engine life-limited part is withdrawn from service at an approved life before hazardous engine effects can occur. These steps include validated analysis, test, or service experience which ensures that the combination of loads, material properties, environmental influences and operating conditions, including the effects of other engine parts influencing these parameters, are sufficiently well known and predictable so that the operating limitations can be established and maintained for each engine life-limited part. Applicants must perform appropriate damage tolerance assessments to address the potential for failure from material, manufacturing, and service induced anomalies within the approved life of the part. Applicants must publish a list of the life-limited engine parts and the approved life for each part in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness as required by § 33.4 of this part.

(b) A manufacturing plan that identifies the specific manufacturing constraints necessary to consistently produce each engine life-limited part with the attributes required by the engineering plan.

(c) A service management plan that defines in-service processes for maintenance and the limitations to repair for each engine life-limited part that will maintain attributes consistent with those required by the engineering plan. These processes and limitations will become part of the Instructions for Continued Airworthiness.

[Amdt. 33–22, 72 FR 50860, Sept. 4, 2007]

§ 33.71 Lubrication system.

(a) *General*. Each lubrication system must function properly in the flight attitudes and atmospheric conditions in which an aircraft is expected to operate.

(b) *Oil strainer or filter*. There must be an oil strainer or filter through which all of the engine oil flows. In addition:

(1) Each strainer or filter required by this paragraph that has a bypass must be constructed and installed so that oil will flow at the normal rate through the rest of the system with the strainer or filter element completely blocked.

(2) The type and degree of filtering necessary for protection of the engine oil system against foreign particles in the oil must be specified. The applicant must demonstrate that foreign particles passing through the specified filtering means do not impair engine oil system functioning.

(3) Each strainer or filter required by this paragraph must have the capacity (with respect to operating limitations established for the engine) to ensure that engine oil system functioning is not impaired with the oil contaminated to a degree (with respect to particle size and density) that is greater than that established for the engine in paragraph (b)(2) of this section.

(4) For each strainer or filter required by this paragraph, except the strainer or filter at the oil tank outlet, there must be means to indicate contamination before it reaches the capacity established in accordance with paragraph (b)(3) of this section.

(5) Any filter bypass must be designed and constructed so that the release of collected contaminants is minimized by appropriate location of the bypass to ensure that the collected contaminants are not in the bypass flow path.

(6) Each strainer or filter required by this paragraph that has no bypass, except the strainer or filter at an oil tank outlet or for a scavenge pump, must have provisions for connection with a warning means to warn the pilot of the occurance of contamination of

the screen before it reaches the capacity established in accordance with paragraph (b)(3) of this section.

(7) Each strainer or filter required by this paragraph must be accessible for draining and cleaning.

(c) *Oil tanks.* (1) Each oil tank must have an expansion space of not less than 10 percent of the tank capacity.

(2) It must be impossible to inadvertently fill the oil tank expansion space.

(3) Each recessed oil tank filler connection that can retain any appreciable quantity of oil must have provision for fitting a drain.

(4) Each oil tank cap must provide an oil-tight seal. For an applicant seeking eligibility for an engine to be installed on an airplane approved for ETOPS, the oil tank must be designed to prevent a hazardous loss of oil due to an incorrectly installed oil tank cap.

(5) Each oil tank filler must be marked with the word ''oil.''

(6) Each oil tank must be vented from the top part of the expansion space, with the vent so arranged that condensed water vapor that might freeze and obstruct the line cannot accumulate at any point.

(7) There must be means to prevent entrance into the oil tank or into any oil tank outlet, of any object that might obstruct the flow of oil through the system.

(8) There must be a shutoff valve at the outlet of each oil tank, unless the external portion of the oil system (including oil tank supports) is fireproof.

(9) Each unpressurized oil tank may not leak when subjected to a maximum operating temperature and an internal pressure of 5 p.s.i., and each pressurized oil tank must meet the requirements of § 33.64.

(10) Leaked or spilled oil may not accumulate between the tank and the remainder of the engine.

(11) Each oil tank must have an oil quantity indicator or provisions for one.

(12) If the propeller feathering system depends on engine oil—

(i) There must be means to trap an amount of oil in the tank if the supply becomes depleted due to failure of any part of the lubricating system other than the tank itself;

(ii) The amount of trapped oil must be enough to accomplish the feathering opeation and must be available only to the feathering pump; and

(iii) Provision must be made to prevent sludge or other foreign matter from affecting the safe operation of the propeller feathering system.

(d) *Oil drains.* A drain (or drains) must be provided to allow safe drainage of the oil system. Each drain must—

(1) Be accessible; and

(2) Have manual or automatic means for positive locking in the closed position.

(e) *Oil radiators.* Each oil radiator must withstand, without failure, any vibration, inertia, and oil pressure load to which it is subjected during the block tests.

[Amdt. 33–6, 39 FR 35466, Oct. 1, 1974, as amended by Amdt. 33–10, 49 FR 6852, Feb. 23, 1984; Amdt. 33–21, 72 FR 1877, Jan. 16, 2007; Amdt. 33–27, 73 FR 55437, Sept. 25, 2008; Amdt. 33–27, 73 FR 57235, Oct. 2, 2008]

§ 33.72 Hydraulic actuating systems.

Each hydraulic actuating system must function properly under all conditions in which the engine is expected to operate. Each filter or screen must be accessible for servicing and each tank must meet the design criteria of § 33.71.

[Amdt. 33–6, 39 FR 35467, Oct. 1, 1974]

§ 33.73 Power or thrust response.

The design and construction of the engine must enable an increase—

(a) From minimum to rated takeoff power or thrust with the maximum bleed air and power extraction to be permitted in an aircraft, without overtemperature, surge, stall, or other detrimental factors occurring to the engine whenever the power control lever is moved from the minimum to the maximum position in not more than 1 second, except that the Administrator may allow additional time increments for different regimes of control operation requiring control scheduling; and

(b) From the fixed minimum flight idle power lever position when provided, or if not provided, from not more than 15 percent of the rated takeoff power or thrust available to 95 percent rated takeoff power or thrust in not over 5 seconds. The 5-second power or

thrust response must occur from a stabilized static condition using only the bleed air and accessories loads necessary to run the engine. This takeoff rating is specified by the applicant and need not include thrust augmentation.

[Amdt. 33–1, 36 FR 5493, Mar. 24, 1971]

§ 33.74 Continued rotation.

If any of the engine main rotating systems continue to rotate after the engine is shutdown for any reason while in flight, and if means to prevent that continued rotation are not provided, then any continued rotation during the maximum period of flight, and in the flight conditions expected to occur with that engine inoperative, may not result in any condition described in § 33.75(g)(2)(i) through (vi) of this part.

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

§ 33.75 Safety analysis.

(a) (1) The applicant must analyze the engine, including the control system, to assess the likely consequences of all failures that can reasonably be expected to occur. This analysis will take into account, if applicable:

(i) Aircraft-level devices and procedures assumed to be associated with a typical installation. Such assumptions must be stated in the analysis.

(ii) Consequential secondary failures and latent failures.

(iii) Multiple failures referred to in paragraph (d) of this section or that result in the hazardous engine effects defined in paragraph (g)(2) of this section.

(2) The applicant must summarize those failures that could result in major engine effects or hazardous engine effects, as defined in paragraph (g) of this section, and estimate the probability of occurrence of those effects. Any engine part the failure of which could reasonably result in a hazardous engine effect must be clearly identified in this summary.

(3) The applicant must show that hazardous engine effects are predicted to occur at a rate not in excess of that defined as extremely remote (probability range of 10^{-7} to 10^{-9} per engine flight hour). Since the estimated probability for individual failures may be insufficiently precise to enable the applicant to assess the total rate for hazardous engine effects, compliance may be shown by demonstrating that the probability of a hazardous engine effect arising from an individual failure can be predicted to be not greater than 10^{-8} per engine flight hour. In dealing with probabilities of this low order of magnitude, absolute proof is not possible, and compliance may be shown by reliance on engineering judgment and previous experience combined with sound design and test philosophies.

(4) The applicant must show that major engine effects are predicted to occur at a rate not in excess of that defined as remote (probability range of 10^{-5} to 10^{-7} per engine flight hour).

(b) The FAA may require that any assumption as to the effects of failures and likely combination of failures be verified by test.

(c) The primary failure of certain single elements cannot be sensibly estimated in numerical terms. If the failure of such elements is likely to result in hazardous engine effects, then compliance may be shown by reliance on the prescribed integrity requirements of §§ 33.15, 33.27, and 33.70 as applicable. These instances must be stated in the safety analysis.

(d) If reliance is placed on a safety system to prevent a failure from progressing to hazardous engine effects, the possibility of a safety system failure in combination with a basic engine failure must be included in the analysis. Such a safety system may include safety devices, instrumentation, early warning devices, maintenance checks, 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 following 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 takeoff 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_1 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 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	1.15 (2.53)
	plus 3	0.70 (1.54)
1.70 (2,635)≤A <2.10 (3,255)	1	1.15 (2.53)
	plus 4	0.70 (1.54)
2.10 (3,255)≤A <2.50 (3,875)	1	1.15 (2.53)
	plus 5	0.70 (1.54)
2.50 (3,875)≤A <3.90 (6045)	1	1.15 (2.53)
	plus 6	0.70 (1.54)
3.90 (6045)≤A <4.50 (6975)	3	1.15 (2.53)
4.50 (6975)≤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	1.15 (2.53)
	plus 6	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)

[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) Compliance with the requirements of this section must be demonstrated by engine ice ingestion test or by validated analysis showing equivalence of other means for demonstrating soft body damage tolerance.

(b) [Reserved]

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

(1) Cause an immediate or ultimate unacceptable sustained power or thrust loss; or

(2) Require the engine to be shutdown.

(d) For an engine that incorporates a protection device, compliance with this section need not be demonstrated with respect to ice formed forward of the protection device if it is shown that—

(1) Such ice is of a size that will not pass through the protective device;

(2) The protective device will withstand the impact of the ice; and

(3) The ice 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 defined by paragraph (c) of this section.

(e) Compliance with the requirements of this section must be demonstrated by engine ice ingestion test under the following ingestion conditions or by validated analysis showing equivalence of other means for demonstrating soft body damage tolerance.

(1) The minimum ice quantity and dimensions will be established by the engine size as defined in Table 1 of this section.

(2) The ingested ice dimensions are determined by linear interpolation between table values, and are based on the actual engine's inlet hilite area.

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

(4) Engine operation will be at the maximum cruise power or thrust unless lower power is more critical.

TABLE 1—MINIMUM ICE SLAB DIMENSIONS BASED ON ENGINE INLET SIZE

Engine Inlet Hilite area (sq. inch)	Thickness (inch)	Width (inch)	Length (inch)
0	0.25	0	3.6
80	0.25	6	3.6
300	0.25	12	3.6
700	0.25	12	4.8
2800	0.35	12	8.5
5000	0.43	12	11.0
7000	0.50	12	12.7
7900	0.50	12	13.4
9500	0.50	12	14.6
11300	0.50	12	15.9
13300	0.50	12	17.1
16500	0.5	12	18.9
20000	0.5	12	20.0

[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; Amdt. 33–34, 79 FR 65537, Nov. 4, 2014]

§ 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 and after the ingestion of rain with an overall ratio of water droplet flow to airflow, by weight, with a uniform distribution at the inlet plane, of at least four percent. Acceptable engine operation precludes flameout, run down, 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 loss, or other adverse engine anomalies. The rain ingestion must occur under the following static ground level conditions:

(1) A normal stabilization period at take-off power without rain ingestion, followed immediately by the suddenly commencing ingestion of rain for three minutes at takeoff power, then

(2) Continuation of the rain ingestion during subsequent rapid deceleration to minimum idle, then

(3) Continuation of the rain ingestion during three minutes at minimum idle power to be certified for flight operation, then

(4) Continuation of the rain ingestion during subsequent rapid acceleration to takeoff power.

(c) *Engines for supersonic airplanes.* In addition to complying with paragraphs (a)(1) and (a)(2) of this section, a separate test for supersonic airplane engines only, shall be conducted with three hailstones ingested at supersonic cruise velocity. These hailstones shall be aimed at the engine's critical face area, and their ingestion must not cause unacceptable mechanical damage or unacceptable power or thrust loss after the ingestion or require the engine to be shut down. The size of these hailstones shall be determined from the linear variation in diameter from 1-inch (25 millimeters) at 35,000 feet (10,500 meters) to ¼-inch (6 millimeters) at 60,000 feet (18,000 meters) using the diameter corresponding to the lowest expected supersonic cruise altitude. Alternatively, three larger hailstones may be ingested at subsonic velocities such that the kinetic energy of these larger hailstones is equivalent to the applicable supersonic ingestion conditions.

(d) For an engine that incorporates or requires the use of a protection device, demonstration of the rain and hail ingestion capabilities of the engine, as required in paragraphs (a), (b), and (c) of this section, may be waived wholly or in part by the Administrator if the applicant shows that:

(1) The subject rain and hail constituents are of a size that will not pass through the protection device;

(2) The protection device will withstand the impact of the subject rain and hail constituents; and

(3) The subject of rain and hail constituents, stopped by the protection device, will not obstruct the flow of induction air into the engine, resulting in damage, power or thrust loss, or other adverse engine anomalies in excess of what would be accepted in paragraphs (a), (b), and (c) of this section.

[Doc. No. 28652, 63 FR 14799, Mar. 26, 1998]

§ 33.79 Fuel burning thrust augmentor.

Each fuel burning thrust augmentor, including the nozzle, must—

(a) Provide cutoff of the fuel burning thrust augmentor;

(b) Permit on-off cycling;

(c) Be controllable within the intended range of operation;

(d) Upon a failure or malfunction of augmentor combustion, not cause the engine to lose thrust other than that provided by the augmentor; and

(e) Have controls that function compatibly with the other engine controls and automatically shut off augmentor fuel flow if the engine rotor speed drops below the minimum rotational speed at

which the augmentor is intended to function.

[Amdt. 33–6, 39 FR 35468, Oct. 1, 1974]

Subpart F—Block Tests; Turbine Aircraft Engines

§ 33.81 Applicability.

This subpart prescribes the block tests and inspections for turbine engines.

[Doc. No. 3025, 29 FR 7453, June 10, 1964, as amended by Amdt. 33–6, 39 FR 35468, Oct. 1, 1974]

§ 33.82 General.

Before each endurance test required by this subpart, the adjustment setting and functioning characteristic of each component having an adjustment setting and a functioning characteristic that can be established independent of installation on the engine must be established and recorded.

[Amdt. 36–6, 39 FR 35468, Oct. 1, 1974]

§ 33.83 Vibration test.

(a) Each engine must undergo vibration surveys to establish that the vibration characteristics of those components that may be subject to mechanically or aerodynamically induced vibratory excitations are acceptable throughout the declared flight envelope. The engine surveys shall be based upon an appropriate combination of experience, analysis, and component test and shall address, as a minimum, blades, vanes, rotor discs, spacers, and rotor shafts.

(b) The surveys shall cover the ranges of power or thrust, and both the physical and corrected rotational speeds for each rotor system, corresponding to operations throughout the range of ambient conditions in the declared flight envelope, from the minimum rotational speed up to 103 percent of the maximum physical and corrected rotational speed permitted for rating periods of two minutes or longer, and up to 100 percent of all other permitted physical and corrected rotational speeds, including those that are overspeeds. If there is any indication of a stress peak arising at the highest of those required physical or corrected rotational speeds, the surveys shall be extended sufficiently to reveal the maximum stress values present, except that the extension need not cover more than a further 2 percentage points increase beyond those speeds.

(c) Evaluations shall be made of the following:

(1) The effects on vibration characteristics of operating with scheduled changes (including tolerances) to variable vane angles, compressor bleeds, accessory loading, the most adverse inlet air flow distortion pattern declared by the manufacturer, and the most adverse conditions in the exhaust duct(s); and

(2) The aerodynamic and aeromechanical factors which might induce or influence flutter in those systems susceptible to that form of vibration.

(d) Except as provided by paragraph (e) of this section, the vibration stresses associated with the vibration characteristics determined under this section, when combined with the appropriate steady stresses, must be less than the endurance limits of the materials concerned, after making due allowances for operating conditions for the permitted variations in properties of the materials. The suitability of these stress margins must be justified for each part evaluated. If it is determined that certain operating conditions, or ranges, need to be limited, operating and installation limitations shall be established.

(e) The effects on vibration characteristics of excitation forces caused by fault conditions (such as, but not limited to, out-of balance, local blockage or enlargement of stator vane passages, fuel nozzle blockage, incorrectly schedule compressor variables, etc.) shall be evaluated by test or analysis, or by reference to previous experience and shall be shown not to create a hazardous condition.

(f) Compliance with this section shall be substantiated for each specific installation configuration that can affect the vibration characteristics of the engine. If these vibration effects cannot be fully investigated during engine certification, the methods by which they can be evaluated and methods by which

compliance can be shown shall be substantiated and defined in the installation instructions required by § 33.5.

[Doc. No. 28107, 61 FR 28433, June 4, 1996, as amended by Amdt. 33–33, 77 FR 39624, July 5, 2012; 77 FR 58301, Sept. 20, 2012]

§ 33.84 Engine overtorque test.

(a) If approval of a maximum engine overtorque is sought for an engine incorporating a free power turbine, compliance with this section must be demonstrated by testing.

(1) The test may be run as part of the endurance test requirement of § 33.87. Alternatively, tests may be performed on a complete engine or equivalent testing on individual groups of components.

(2) Upon conclusion of tests conducted to show compliance with this section, each engine part or individual groups of components must meet the requirements of § 33.93(a)(1) and (a)(2).

(b) The test conditions must be as follows:

(1) A total of 15 minutes run at the maximum engine overtorque to be approved. This may be done in separate runs, each being of at least 2½ minutes duration.

(2) A power turbine rotational speed equal to the highest speed at which the maximum overtorque can occur in service. The test speed may not be more than the limit speed of take-off or OEI ratings longer than 2 minutes.

(3) For engines incorporating a reduction gearbox, a gearbox oil temperature equal to the maximum temperature when the maximum engine overtorque could occur in service; and for all other engines, an oil temperature within the normal operating range.

(4) A turbine entry gas temperature equal to the maximum steady state temperature approved for use during periods longer than 20 seconds when operating at conditions not associated with 30-second or 2 minutes OEI ratings. The requirement to run the test at the maximum approved steady state temperature may be waived by the FAA if the applicant can demonstrate that other testing provides substantiation of the temperature effects when considered in combination with the other parameters identified in paragraphs (b)(1), (b)(2) and (b)(3) of this section.

[Doc. No. 2007–28502, 74 FR 45310, Sept. 2, 2009]

§ 33.85 Calibration tests.

(a) Each engine must be subjected to those calibration tests necessary to establish its power characteristics and the conditions for the endurance test specified § 33.87. The results of the power characteristics calibration tests form the basis for establishing the characteristics of the engine over its entire operating range of speeds, pressures, temperatures, and altitudes. Power ratings are based upon standard atmospheric conditions with no airbleed for aircraft services and with only those accessories installed which are essential for engine functioning.

(b) A power check at sea level conditions must be accomplished on the endurance test engine after the endurance test and any change in power characteristics which occurs during the endurance test must be determined. Measurements taken during the final portion of the endurance test may be used in showing compliance with the requirements of this paragraph.

(c) In showing compliance with this section, each condition must stabilize before measurements are taken, except as permitted by paragraph (d) of this section.

(d) In the case of engines having 30-second OEI, and 2-minute OEI ratings, measurements taken during the applicable endurance test prescribed in § 33.87(f) (1) through (8) may be used in showing compliance with the requirements of this section for these OEI ratings.

[Doc. No. 3025, 29 FR 7453, June 10, 1964, as amended by Amdt. 33–6, 39 FR 35468, Oct. 1, 1974; Amdt. 33–18, 61 FR 31328, June 19, 1996]

§ 33.87 Endurance test.

(a) *General.* Each engine must be subjected to an endurance test that includes a total of at least 150 hours of operation and, depending upon the type and contemplated use of the engine, consists of one of the series of runs specified in paragraphs (b) through (g) of this section, as applicable. For engines tested under paragraphs (b), (c),

(d), (e) or (g) of this section, the prescribed 6-hour test sequence must be conducted 25 times to complete the required 150 hours of operation. Engines for which the 30-second OEI and 2-minute OEI ratings are desired must be further tested under paragraph (f) of this section. The following test requirements apply:

(1) The runs must be made in the order found appropriate by the FAA for the particular engine being tested.

(2) Any automatic engine control that is part of the engine must control the engine during the endurance test except for operations where automatic control is normally overridden by manual control or where manual control is otherwise specified for a particular test run.

(3) Except as provided in paragraph (a)(5) of this section, power or thrust, gas temperature, rotor shaft rotational speed, and, if limited, temperature of external surfaces of the engine must be at least 100 percent of the value associated with the particular engine operation being tested. More than one test may be run if all parameters cannot be held at the 100 percent level simultaneously.

(4) The runs must be made using fuel, lubricants and hydraulic fluid which conform to the specifications specified in complying with § 33.7(c).

(5) Maximum air bleed for engine and aircraft services must be used during at least one-fifth of the runs, except for the test required under paragraph (f) of this section, provided the validity of the test is not compromised. However, for these runs, the power or thrust or the rotor shaft rotational speed may be less than 100 percent of the value associated with the particular operation being tested if the FAA finds that the validity of the endurance test is not compromised.

(6) Each accessory drive and mounting attachment must be loaded in accordance with paragraphs (a)(6)(i) and (ii) of this section, except as permitted by paragraph (a)(6)(iii) of this section for the test required under paragraph (f) of this section.

(i) The load imposed by each accessory used only for aircraft service must be the limit load specified by the applicant for the engine drive and attachment point during rated maximum continuous power or thrust and higher output.

(ii) The endurance test of any accessory drive and mounting attachment under load may be accomplished on a separate rig if the validity of the test is confirmed by an approved analysis.

(iii) The applicant is not required to load the accessory drives and mounting attachments when running the tests under paragraphs (f)(1) through (f)(8) of this section if the applicant can substantiate that there is no significant effect on the durability of any accessory drive or engine component. However, the applicant must add the equivalent engine output power extraction from the power turbine rotor assembly to the engine shaft output.

(7) During the runs at any rated power or thrust the gas temperature and the oil inlet temperature must be maintained at the limiting temperature except where the test periods are not longer than 5 minutes and do not allow stabilization. At least one run must be made with fuel, oil, and hydraulic fluid at the minimum pressure limit and at least one run must be made with fuel, oil, and hydraulic fluid at the maximum pressure limit with fluid temperature reduced as necessary to allow maximum pressure to be attained.

(8) If the number of occurrences of either transient rotor shaft overspeed, transient gas overtemperature or transient engine overtorque is limited, that number of the accelerations required by paragraphs (b) through (g) of this section must be made at the limiting overspeed, overtemperature or overtorque. If the number of occurrences is not limited, half the required accelerations must be made at the limiting overspeed, overtemperature or overtorque.

(9) For each engine type certificated for use on supersonic aircraft the following additional test requirements apply:

(i) To change the thrust setting, the power control lever must be moved from the initial position to the final position in not more than one second except for movements into the fuel

burning thrust augmentor augmentation position if additional time to confirm ignition is necessary.

(ii) During the runs at any rated augmented thrust the hydraulic fluid temperature must be maintained at the limiting temperature except where the test periods are not long enough to allow stabilization.

(iii) During the simulated supersonic runs the fuel temperature and induction air temperature may not be less than the limiting temperature.

(iv) The endurance test must be conducted with the fuel burning thrust augmentor installed, with the primary and secondary exhaust nozzles installed, and with the variable area exhaust nozzles operated during each run according to the methods specified in complying with § 33.5(b).

(v) During the runs at thrust settings for maximum continuous thrust and percentages thereof, the engine must be operated with the inlet air distortion at the limit for those thrust settings.

(b) *Engines other than certain rotorcraft engines.* For each engine except a rotorcraft engine for which a rating is desired under paragraph (c), (d), or (e) of this section, the applicant must conduct the following runs:

(1) *Takeoff and idling.* One hour of alternate five-minute periods at rated takeoff power or thrust and at idling power or thrust. The developed powers or thrusts at takeoff and idling conditions and their corresponding rotor speed and gas temperature conditions must be as established by the power control in accordance with the schedule established by the applicant. The applicant may, during any one period, manually control the rotor speed, power, or thrust while taking data to check performance. For engines with augmented takeoff power ratings that involve increases in turbine inlet temperature, rotor speed, or shaft power, this period of running at takeoff must be at the augmented rating. For engines with augmented takeoff power ratings that do not materially increase operating severity, the amount of running conducted at the augmented rating is determined by the FAA. In changing the power setting after each period, the power-control lever must be moved in the manner prescribed in paragraph (b)(5) of this section.

(2) *Rated maximum continuous and takeoff power or thrust.* Thirty minutes at—

(i) Rated maximum continuous power or thrust during fifteen of the twenty-five 6-hour endurance test cycles; and

(ii) Rated takeoff power or thrust during ten of the twenty-five 6-hour endurance test cycles.

(3) *Rated maximum continuous power or thrust.* One hour and 30 minutes at rated maximum continuous power or thrust.

(4) *Incremental cruise power or thrust.* Two hours and 30 minutes at the successive power lever positions corresponding to at least 15 approximately equal speed and time increments between maximum continuous engine rotational speed and ground or minimum idle rotational speed. For engines operating at constant speed, the thrust and power may be varied in place of speed. If there is significant peak vibration anywhere between ground idle and maximum continuous conditions, the number of increments chosen may be changed to increase the amount of running made while subject to the peak vibrations up to not more than 50 percent of the total time spent in incremental running.

(5) *Acceleration and deceleration runs.* 30 minutes of accelerations and decelerations, consisting of six cycles from idling power or thrust to rated takeoff power or thrust and maintained at the takeoff power lever position for 30 seconds and at the idling power lever position for approximately four and one-half minutes. In complying with this paragraph, the power-control lever must be moved from one extreme position to the other in not more than one second, except that, if different regimes of control operations are incorporated necessitating scheduling of the power-control lever motion in going from one extreme position to the other, a longer period of time is acceptable, but not more than two seconds.

(6) *Starts.* One hundred starts must be made, of which 25 starts must be preceded by at least a two-hour engine shutdown. There must be at least 10

false engine starts, pausing for the applicant's specified minimum fuel drainage time, before attempting a normal start. There must be at least 10 normal restarts with not longer than 15 minutes since engine shutdown. The remaining starts may be made after completing the 150 hours of endurance testing.

(c) *Rotorcraft engines for which a 30-minute OEI power rating is desired.* For each rotorcraft engine for which a 30-minute OEI power rating is desired, the applicant must conduct the following series of tests:

(1) *Takeoff and idling.* One hour of alternate 5-minute periods at rated takeoff power and at idling power. The developed powers at takeoff and idling conditions and their corresponding rotor speed and gas temperature conditions must be as established by the power control in accordance with the schedule established by the applicant. During any one period, the rotor speed and power may be controlled manually while taking data to check performance. For engines with augmented takeoff power ratings that involve increases in turbine inlet temperature, rotor speed, or shaft power, this period of running at rated takeoff power must be at the augmented power rating. In changing the power setting after each period, the power control lever must be moved in the manner prescribed in paragraph (c)(6) of this section.

(2) *Rated maximum continuous and takeoff power.* Thirty minutes at—

(i) Rated maximum continuous power during fifteen of the twenty-five 6-hour endurance test cycles; and

(ii) Rated takeoff power during ten of the twenty-five 6-hour endurance test cycles.

(3) *Rated maximum continuous power.* One hour at rated maximum continuous power.

(4) *Rated 30-minute OEI power.* Thirty minutes at rated 30-minute OEI power.

(5) *Incremental cruise power.* Two hours and 30 minutes at the successive power lever positions corresponding with not less than 15 approximately equal speed and time increments between maximum continuous engine rotational speed and ground or minimum idle rotational speed. For engines operating at constant speed, power may be varied in place of speed. If there are significant peak vibrations anywhere between ground idle and maximum continuous conditions, the number of increments chosen must be changed to increase the amount of running conducted while subject to peak vibrations up to not more than 50 percent of the total time spent in incremental running.

(6) *Acceleration and deceleration runs.* Thirty minutes of accelerations and decelerations, consisting of six cycles from idling power to rated takeoff power and maintained at the takeoff power lever position for 30 seconds and at the idling power lever position for approximately 4½ minutes. In complying with this paragraph, the power control lever must be moved from one extreme position to the other in not more than one second. If, however, different regimes of control operations are incorporated that necessitate scheduling of the power control lever motion from one extreme position to the other, then a longer period of time is acceptable, but not more than two seconds.

(7) *Starts.* One hundred starts, of which 25 starts must be preceded by at least a two-hour engine shutdown. There must be at least 10 false engine starts, pausing for the applicant's specified minimum fuel drainage time, before attempting a normal start. There must be at least 10 normal restarts not more than 15 minutes after engine shutdown. The remaining starts may be made after completing the 150 hours of endurance testing.

(d) *Rotorcraft engines for which a continuous OEI rating is desired.* For each rotorcraft engine for which a continuous OEI power rating is desired, the applicant must conduct the following series of tests:

(1) *Takeoff and idling.* One hour of alternate 5-minute periods at rated takeoff power and at idling power. The developed powers at takeoff and idling conditions and their corresponding rotor speed and gas temperature conditions must be as established by the power control in accordance with the schedule established by the applicant. During any one period the rotor speed and power may be controlled manually

while taking data to check performance. For engines with augmented takeoff power ratings that involve increases in turbine inlet temperature, rotor speed, or shaft power, this period of running at rated takeoff power must be at the augmented power rating. In changing the power setting after each period, the power control lever must be moved in the manner prescribed in paragraph (d)(6) of this section.

(2) *Rated maximum continuous and takeoff power*. Thirty minutes at—

(i) Rated maximum continuous power during fifteen of the twenty-five 6-hour endurance test cycles; and

(ii) Rated takeoff power during ten of the twenty-five 6-hour endurance test cycles.

(3) *Rated continuous OEI power*. One hour at rated continuous OEI power.

(4) *Rated maximum continuous power*. One hour at rated maximum continuous power.

(5) *Incremental cruise power*. Two hours at the successive power lever positions corresponding with not less than 12 approximately equal speed and time increments between maximum continuous engine rotational speed and ground or minimum idle rotational speed. For engines operating at constant speed, power may be varied in place of speed. If there are significant peak vibrations anywhere between ground idle and maximum continuous conditions, the number of increments chosen must be changed to increase the amount of running conducted while being subjected to the peak vibrations up to not more than 50 percent of the total time spent in incremental running.

(6) *Acceleration and deceleration runs*. Thirty minutes of accelerations and decelerations, consisting of six cycles from idling power to rated takeoff power and maintained at the takeoff power lever position for 30 seconds and at the idling power lever position for approximately 4½ minutes. In complying with this paragraph, the power control lever must be moved from one extreme position to the other in not more than 1 second, except that if different regimes of control operations are incorporated necessitating scheduling of the power control lever motion in going from one extreme position to the other, a longer period of time is acceptable, but not more than 2 seconds.

(7) *Starts*. One hundred starts, of which 25 starts must be preceded by at least a 2-hour engine shutdown. There must be at least 10 false engine starts, pausing for the applicant's specified minimum fuel drainage time, before attempting a normal start. There must be at least 10 normal restarts with not longer than 15 minutes since engine shutdown. The remaining starts may be made after completing the 150 hours of endurance testing.

(e) *Rotorcraft engines for which a 2½-minute OEI power rating is desired*. For each rotorcraft engine for which a 2½-minute OEI power rating is desired, the applicant must conduct the following series of tests:

(1) *Takeoff, 2½-minute OEI, and idling*. One hour of alternate 5-minute periods at rated takeoff power and at idling power except that, during the third and sixth takeoff power periods, only 2½ minutes need be conducted at rated takeoff power, and the remaining 2½ minutes must be conducted at rated 2½-minute OEI power. The developed powers at takeoff, 2½-minute OEI, and idling conditions and their corresponding rotor speed and gas temperature conditions must be as established by the power control in accordance with the schedule established by the applicant. The applicant may, during any one period, control manually the rotor speed and power while taking data to check performance. For engines with augmented takeoff power ratings that involve increases in turbine inlet temperature, rotor speed, or shaft power, this period of running at rated takeoff power must be at the augmented rating. In changing the power setting after or during each period, the power control lever must be moved in the manner prescribed in paragraph (b)(5), (c)(6), or (d)(6) of this section, as applicable.

(2) The tests required in paragraphs (b)(2) through (b)(6), or (c)(2) through (c)(7), or (d)(2) through (d)(7) of this section, as applicable, except that in one of the 6-hour test sequences, the last 5 minutes of the 30 minutes at takeoff power test period of paragraph

(b)(2) of this section, or of the 30 minutes at 30-minute OEI power test period of paragraph (c)(4) of this section, or of the 1 hour at continuous OEI power test period of paragraph (d)(3) of this section, must be run at 2½-minute OEI power.

(f) *Rotorcraft Engines for which 30-second OEI and 2-minute OEI ratings are desired*. For each rotorcraft engine for which 30-second OEI and 2-minute OEI power ratings are desired, and following completion of the tests under paragraphs (b), (c), (d), or (e) of this section, the applicant may disassemble the tested engine to the extent necessary to show compliance with the requirements of § 33.93(a). The tested engine must then be reassembled using the same parts used during the test runs of paragraphs (b), (c), (d), or (e) of this section, except those parts described as consumables in the Instructions for Continued Airworthiness. Additionally, the tests required in paragraphs (f)(1) through (f)(8) of this section must be run continuously. If a stop occurs during these tests, the interrupted sequence must be repeated unless the applicant shows that the severity of the test would not be reduced if it were continued. The applicant must conduct the following test sequence four times, for a total time of not less than 120 minutes:

(1) *Takeoff power*. Three minutes at rated takeoff power.

(2) *30-second OEI power*. Thirty seconds at rated 30-second OEI power.

(3) *2-minute OEI power*. Two minutes at rated 2-minute OEI power.

(4) *30-minute OEI power, continuous OEI power, or maximum continuous power*. Five minutes at whichever is the greatest of rated 30-minute OEI power, rated continuous OEI power, or rated maximum continuous power, except that, during the first test sequence, this period shall be 65 minutes. However, where the greatest rated power is 30-minute OEI power, that sixty-five minute period shall consist of 30 minutes at 30-minute OEI power followed by 35 minutes at whichever is the greater of continuous OEI power or maximum continuous power.

(5) *50 percent takeoff power*. One minute at 50 percent takeoff power.

(6) *30-second OEI power*. Thirty seconds at rated 30-second OEI power.

(7) *2-minute OEI power*. Two minutes at rated 2-minute OEI power.

(8) *Idle*. One minute at flight idle.

(g) *Supersonic aircraft engines*. For each engine type certificated for use on supersonic aircraft the applicant must conduct the following:

(1) *Subsonic test under sea level ambient atmospheric conditions*. Thirty runs of one hour each must be made, consisting of—

(i) Two periods of 5 minutes at rated takeoff augmented thrust each followed by 5 minutes at idle thrust;

(ii) One period of 5 minutes at rated takeoff thrust followed by 5 minutes at not more than 15 percent of rated takeoff thrust;

(iii) One period of 10 minutes at rated takeoff augmented thrust followed by 2 minutes at idle thrust, except that if rated maximum continuous augmented thrust is lower than rated takeoff augmented thrust, 5 of the 10-minute periods must be at rated maximum continuous augmented thrust; and

(iv) Six periods of 1 minute at rated takeoff augmented thrust each followed by 2 minutes, including acceleration and deceleration time, at idle thrust.

(2) *Simulated supersonic test*. Each run of the simulated supersonic test must be preceded by changing the inlet air temperature and pressure from that attained at subsonic condition to the temperature and pressure attained at supersonic velocity, and must be followed by a return to the temperature attained at subsonic condition. Thirty runs of 4 hours each must be made, consisting of—

(i) One period of 30 minutes at the thrust obtained with the power control lever set at the position for rated maximum continuous augmented thrust followed by 10 minutes at the thrust obtained with the power control lever set at the position for 90 percent of rated maximum continuous augmented thrust. The end of this period in the first five runs must be made with the induction air temperature at the limiting condition of transient overtemperature, but need not be repeated

during the periods specified in paragraphs (g)(2)(ii) through (iv) of this section;

(ii) One period repeating the run specified in paragraph (g)(2)(i) of this section, except that it must be followed by 10 minutes at the thrust obtained with the power control lever set at the position for 80 percent of rated maximum continuous augmented thrust;

(iii) One period repeating the run specified in paragraph (g)(2)(i) of this section, except that it must be followed by 10 minutes at the thrust obtained with the power control lever set at the position for 60 percent of rated maximum continuous augmented thrust and then 10 minutes at not more than 15 percent of rated takeoff thrust;

(iv) One period repeating the runs specified in paragraphs (g)(2)(i) and (ii) of this section; and

(v) One period of 30 minutes with 25 of the runs made at the thrust obtained with the power control lever set at the position for rated maximum continuous augmented thrust, each followed by idle thrust and with the remaining 5 runs at the thrust obtained with the power control lever set at the position for rated maximum continuous augmented thrust for 25 minutes each, followed by subsonic operation at not more than 15 percent or rated takeoff thrust and accelerated to rated takeoff thrust for 5 minutes using hot fuel.

(3) *Starts.* One hundred starts must be made, of which 25 starts must be preceded by an engine shutdown of at least 2 hours. There must be at least 10 false engine starts, pausing for the applicant's specified minimum fuel drainage time before attempting a normal start. At least 10 starts must be normal restarts, each made no later than 15 minutes after engine shutdown. The starts may be made at any time, including the period of endurance testing.

[Doc. No. 3025, 29 FR 7453, June 10, 1964, as amended by Amdt. 33–3, 32 FR 3737, Mar. 4, 1967; Amdt. 33–6, 39 FR 35468, Oct. 1, 1974; Amdt. 33–10, 49 FR 6853, Feb. 23, 1984; Amdt. 33–12, 53 FR 34220, Sept. 2, 1988; Amdt. 33–18, 61 FR 31328, June 19, 1996; Amdt. 33–25, 73 FR 48123, Aug. 18, 2008; Amdt. 33–30, 74 FR 45311, Sept. 2, 2009; Amdt. 33–32, 77 FR 22187, Apr. 13, 2012]

§ 33.88 Engine overtemperature test.

(a) Each engine must run for 5 minutes at maximum permissible rpm with the gas temperature at least 75 °F (42 °C) higher than the maximum rating's steady-state operating limit, excluding maximum values of rpm and gas temperature associated with the 30-second OEI and 2-minute OEI ratings. Following this run, the turbine assembly must be within serviceable limits.

(b) In addition to the test requirements in paragraph (a) of this section, each engine for which 30-second OEI and 2-minute OEI ratings are desired, that incorporates a means for automatic temperature control within its operating limitations in accordance with § 33.28(k), must run for a period of 4 minutes at the maximum power-on rpm with the gas temperature at least 35 °F (19 °C) higher than the maximum operating limit at 30-second OEI rating. Following this run, the turbine assembly may exhibit distress beyond the limits for an overtemperature condition provided the engine is shown by analysis or test, as found necessary by the FAA, to maintain the integrity of the turbine assembly.

(c) A separate test vehicle may be used for each test condition.

[Doc. No. 26019, 61 FR 31329, June 19, 1996, as amended by Amdt. 33–25, 73 FR 48124, Aug. 18, 2008; Amdt. 33–26, 73 FR 48285, Aug. 19, 2008]

§ 33.89 Operation test.

(a) The operation test must include testing found necessary by the Administrator to demonstrate—

(1) Starting, idling, acceleration, overspeeding, ignition, functioning of the propeller (if the engine is designated to operate with a propeller);

(2) Compliance with the engine response requirements of § 33.73; and

(3) The minimum power or thrust response time to 95 percent rated takeoff power or thrust, from power lever positions representative of minimum idle and of minimum flight idle, starting from stabilized idle operation, under the following engine load conditions:

(i) No bleed air and power extraction for aircraft use.

(ii) Maximum allowable bleed air and power extraction for aircraft use.

(iii) An intermediate value for bleed air and power extraction representative of that which might be used as a maximum for aircraft during approach to a landing.

(4) If testing facilities are not available, the determination of power extraction required in paragraph (a)(3)(ii) and (iii) of this section may be accomplished through appropriate analytical means.

(b) The operation test must include all testing found necessary by the Administrator to demonstrate that the engine has safe operating characteristics throughout its specified operating envelope.

[Amdt. 33–4, 36 FR 5493, Mar. 24, 1971, as amended by Amdt. 33–6, 39 FR 35469, Oct. 1, 1974; Amdt. 33–10, 49 FR 6853, Feb. 23, 1984]

§ 33.90 Initial maintenance inspection test.

Each applicant, except an applicant for an engine being type certificated through amendment of an existing type certificate or through supplemental type certification procedures, must complete one of the following tests on an engine that substantially conforms to the type design to establish when the initial maintenance inspection is required:

(a) An approved engine test that simulates the conditions in which the engine is expected to operate in service, including typical start-stop cycles.

(b) An approved engine test conducted in accordance with § 33.201 (c) through (f).

[Doc. No. FAA–2002–6717, 72 FR 1877, Jan. 16, 2007]

§ 33.91 Engine system and component tests.

(a) For those systems or components that cannot be adequately substantiated in accordance with endurance testing of § 33.87, the applicant must conduct additional tests to demonstrate that the systems or components are able to perform the intended functions in all declared environmental and operating conditions.

(b) Temperature limits must be established for those components that require temperature controlling provisions in the aircraft installation to assure satisfactory functioning, reliability, and durability.

(c) Each unpressurized hydraulic fluid tank may not fail or leak when subjected to a maximum operating temperature and an internal pressure of 5 p.s.i., and each pressurized hydraulic fluid tank must meet the requirements of § 33.64.

(d) For an engine type certificated for use in supersonic aircraft, the systems, safety devices, and external components that may fail because of operation at maximum and minimum operating temperatures must be identified and tested at maximum and minimum operating temperatures and while temperature and other operating conditions are cycled between maximum and minimum operating values.

[Doc. No. 3025, 29 FR 7453, June 10, 1964, as amended by Amdt. 33–6, 39 FR 35469, Oct. 1, 1974; Amdt. 33–26, 73 FR 48285, Aug. 19, 2008; Amdt. 33–27, 73 FR 55437, Sept. 25, 2008; Amdt. 33–27, 73 FR 57235, Oct. 2, 2008]

§ 33.92 Rotor locking tests.

If continued rotation is prevented by a means to lock the rotor(s), the engine must be subjected to a test that includes 25 operations of this means under the following conditions:

(a) The engine must be shut down from rated maximum continuous thrust or power; and

(b) The means for stopping and locking the rotor(s) must be operated as specified in the engine operating instructions while being subjected to the maximum torque that could result from continued flight in this condition; and

(c) Following rotor locking, the rotor(s) must be held stationary under these conditions for five minutes for each of the 25 operations.

[Doc. No. 28107, 61 FR 28433, June 4, 1996]

§ 33.93 Teardown inspection.

(a) After completing the endurance testing of § 33.87 (b), (c), (d), (e), or (g) of this part, each engine must be completely disassembled, and

(1) Each component having an adjustment setting and a functioning characteristic that can be established independent of installation on the engine must retain each setting and functioning characteristic within the limits

that were established and recorded at the beginning of the test; and

(2) Each engine part must conform to the type design and be eligible for incorporation into an engine for continued operation, in accordance with information submitted in compliance with § 33.4.

(b) After completing the endurance testing of § 33.87(f), each engine must be completely disassembled, and

(1) Each component having an adjustment setting and a functioning characteristic that can be established independent of installation on the engine must retain each setting and functioning characteristic within the limits that were established and recorded at the beginning of the test; and

(2) Each engine may exhibit deterioration in excess of that permitted in paragraph (a)(2) of this section, including some engine parts or components that may be unsuitable for further use. The applicant must show by inspection, analysis, test, or by any combination thereof as found necessary by the FAA, that structural integrity of the engine is maintained; or

(c) In lieu of compliance with paragraph (b) of this section, each engine for which the 30-second OEI and 2-minute OEI ratings are desired, may be subjected to the endurance testing of §§ 33.87 (b), (c), (d), or (e) of this part, and followed by the testing of § 33.87(f) without intervening disassembly and inspection. However, the engine must comply with paragraph (a) of this section after completing the endurance testing of § 33.87(f).

[Doc. No. 26019, 61 FR 31329, June 19, 1996, as amended by Amdt. 33–25, 73 FR 48124, Aug. 18, 2008]

§ 33.94 Blade containment and rotor unbalance tests.

(a) Except as provided in paragraph (b) of this section, it must be demonstrated by engine tests that the engine is capable of containing damage without catching fire and without failure of its mounting attachments when operated for at least 15 seconds, unless the resulting engine damage induces a self shutdown, after each of the following events:

(1) Failure of the most critical compressor or fan blade while operating at maximum permissible r.p.m. The blade failure must occur at the outermost retention groove or, for integrally-bladed rotor discs, at least 80 percent of the blade must fail.

(2) Failure of the most critical turbine blade while operating at maximum permissible r.p.m. The blade failure must occur at the outermost retention groove or, for integrally-bladed rotor discs, at least 80 percent of the blade must fail. The most critical turbine blade must be determined by considering turbine blade weight and the strength of the adjacent turbine case at case temperatures and pressures associated with operation at maximum permissible r.p.m.

(b) Analysis based on rig testing, component testing, or service experience may be substitute for one of the engine tests prescribed in paragraphs (a)(1) and (a)(2) of this section if—

(1) That test, of the two prescribed, produces the least rotor unbalance; and

(2) The analysis is shown to be equivalent to the test.

(Secs. 313(a), 601, and 603, Federal Aviation Act of 1958 (49 U.S.C. 1354(a), 1421, and 1423); and 49 U.S.C. 106(g) Revised, Pub. L. 97–449, Jan. 12, 1983)

[Amdt. 33–10, 49 FR 6854, Feb. 23, 1984]

§ 33.95 Engine-propeller systems tests.

If the engine is designed to operate with a propeller, the following tests must be made with a representative propeller installed by either including the tests in the endurance run or otherwise performing them in a manner acceptable to the Administrator:

(a) Feathering operation: 25 cycles.

(b) Negative torque and thrust system operation: 25 cycles from rated maximum continuous power.

(c) Automatic decoupler operation: 25 cycles from rated maximum continuous power (if repeated decoupling and recoupling in service is the intended function of the device).

(d) Reverse thrust operation: 175 cycles from the flight-idle position to full reverse and 25 cycles at rated maximum continuous power from full forward to full reverse thrust. At the end of each cycle the propeller must be operated in reverse pitch for a period of 30 seconds at the maximum rotational

speed and power specified by the applicant for reverse pitch operation.

[Doc. No. 3025, 29 FR 7453, June 10, 1964, as amended by Amdt. 33–3, 32 FR 3737, Mar. 4, 1967]

§ 33.96 Engine tests in auxiliary power unit (APU) mode.

If the engine is designed with a propeller brake which will allow the propeller to be brought to a stop while the gas generator portion of the engine remains in operation, and remain stopped during operation of the engine as an auxiliary power unit (''APU mode''), in addition to the requirements of § 33.87, the applicant must conduct the following tests:

(a) Ground locking: A total of 45 hours with the propeller brake engaged in a manner which clearly demonstrates its ability to function without adverse effects on the complete engine while the engine is operating in the APU mode under the maximum conditions of engine speed, torque, temperature, air bleed, and power extraction as specified by the applicant.

(b) Dynamic braking: A total of 400 application-release cycles of brake engagements must be made in a manner which clearly demonstrates its ability to function without adverse effects on the complete engine under the maximum conditions of engine acceleration/deceleration rate, speed, torque, and temperature as specified by the applicant. The propeller must be stopped prior to brake release.

(c) One hundred engine starts and stops with the propeller brake engaged.

(d) The tests required by paragraphs (a), (b), and (c) of this section must be performed on the same engine, but this engine need not be the same engine used for the tests required by § 33.87.

(e) The tests required by paragraphs (a), (b), and (c) of this section must be followed by engine disassembly to the extent necessary to show compliance with the requirements of § 33.93(a) and § 33.93(b).

[Amdt. 33–11, 51 FR 10346, Mar. 25, 1986]

§ 33.97 Thrust reversers.

(a) If the engine incorporates a reverser, the endurance calibration, operation, and vibration tests prescribed in this subpart must be run with the reverser installed. In complying with this section, the power control lever must be moved from one extreme position to the other in not more than one second except, if regimes of control operations are incorporated necessitating scheduling of the power-control lever motion in going from one extreme position to the other, a longer period of time is acceptable but not more than three seconds. In addition, the test prescribed in paragraph (b) of this section must be made. This test may be scheduled as part of the endurance run.

(b) 175 reversals must be made from flight-idle forward thrust to maximum reverse thrust and 25 reversals must be made from rated takeoff thrust to maximum reverse thrust. After each reversal the reverser must be operated at full reverse thrust for a period of one minute, except that, in the case of a reverser intended for use only as a braking means on the ground, the reverser need only be operated at full reverse thrust for 30 seconds.

[Doc. No. 3025, 29 FR 7453, June 10, 1964, as amended by Amdt. 33–3, 32 FR 3737, Mar. 4, 1967]

§ 33.99 General conduct of block tests.

(a) Each applicant may, in making a block test, use separate engines of identical design and construction in the vibration, calibration, endurance, and operation tests, except that, if a separate engine is used for the endurance test it must be subjected to a calibration check before starting the endurance test.

(b) Each applicant may service and make minor repairs to the engine during the block tests in accordance with the service and maintenance instructions submitted in compliance with § 33.4. If the frequency of the service is excessive, or the number of stops due to engine malfunction is excessive, or a major repair, or replacement of a part is found necessary during the block tests or as the result of findings from the teardown inspection, the engine or its parts must be subjected to any additional tests the Administrator finds necessary.

(c) Each applicant must furnish all testing facilities, including equipment

and competent personnel, to conduct the block tests.

[Doc. No. 3025, 29 FR 7453, June 10, 1964, as amended by Amdt. 33–6, 39 FR 35470, Oct. 1, 1974; Amdt. 33–9, 45 FR 60181, Sept. 11, 1980]

Subpart G—Special Requirements: Turbine Aircraft Engines

SOURCE: Docket No. FAA–2002–6717, 72 FR 1877, Jan. 16, 2007, unless otherwise noted.

§ 33.201 Design and test requirements for Early ETOPS eligibility.

An applicant seeking type design approval for an engine to be installed on a two-engine airplane approved for ETOPS without the service experience specified in part 25, appendix K, K25.2.1 of this chapter, must comply with the following:

(a) The engine must be designed using a design quality process acceptable to the FAA, that ensures the design features of the engine minimize the occurrence of failures, malfunctions, defects, and maintenance errors that could result in an IFSD, loss of thrust control, or other power loss.

(b) The design features of the engine must address problems shown to result in an IFSD, loss of thrust control, or other power loss in the applicant's other relevant type designs approved within the past 10 years, to the extent that adequate service data is available within that 10-year period. An applicant without adequate service data must show experience with and knowledge of problem mitigating design practices equivalent to that gained from actual service experience in a manner acceptable to the FAA.

(c) Except as specified in paragraph (f) of this section, the applicant must conduct a simulated ETOPS mission cyclic endurance test in accordance with an approved test plan on an engine that substantially conforms to the type design. The test must:

(1) Include a minimum of 3,000 representative service start-stop mission cycles and three simulated diversion cycles at maximum continuous thrust or power for the maximum diversion time for which ETOPS eligibility is sought. Each start-stop mission cycle must include the use of take-off, climb, cruise, descent, approach, and landing thrust or power and the use of thrust reverse (if applicable). The diversions must be evenly distributed over the duration of the test. The last diversion must be conducted within 100 cycles of the completion of the test.

(2) Be performed with the high speed and low speed main engine rotors independently unbalanced to obtain a minimum of 90 percent of the recommended field service maintenance vibration levels. For engines with three main engine rotors, the intermediate speed rotor must be independently unbalanced to obtain a minimum of 90 percent of the recommended production acceptance vibration level. The required peak vibration levels must be verified during a slow acceleration and deceleration run of the test engine covering the main engine rotor operating speed ranges.

(3) Include a minimum of three million vibration cycles for each 60 rpm incremental step of the typical high-speed rotor start-stop mission cycle. The test may be conducted using any rotor speed step increment from 60 to 200 rpm provided the test encompasses the typical service start-stop cycle speed range. For incremental steps greater than 60 rpm, the minimum number of vibration cycles must be linearly increased up to ten million cycles for a 200 rpm incremental step.

(4) Include a minimum of 300,000 vibration cycles for each 60 rpm incremental step of the high-speed rotor approved operational speed range between minimum flight idle and cruise power not covered by paragraph (c)(3) of this section. The test may be conducted using any rotor speed step increment from 60 to 200 rpm provided the test encompasses the applicable speed range. For incremental steps greater than 60 rpm the minimum number of vibration cycles must be linearly increased up to 1 million for a 200 rpm incremental step.

(5) Include vibration surveys at periodic intervals throughout the test. The equivalent value of the peak vibration level observed during the surveys must meet the minimum vibration requirement of § 33.201(c)(2).

(d) Prior to the test required by paragraph (c) of this section, the engine must be subjected to a calibration test

to document power and thrust characteristics.

(e) At the conclusion of the testing required by paragraph (c) of this section, the engine must:

(1) Be subjected to a calibration test at sea-level conditions. Any change in power or thrust characteristics must be within approved limits.

(2) Be visually inspected in accordance with the on-wing inspection recommendations and limits contained in the Instructions for Continued Airworthiness submitted in compliance with § 33.4.

(3) Be completely disassembled and inspected—

(i) In accordance with the applicable inspection recommendations and limits contained in the Instructions for Continued Airworthiness submitted in compliance with § 33.4;

(ii) With consideration of the causes of IFSD, loss of thrust control, or other power loss identified by paragraph (b) of this section; and

(iii) In a manner to identify wear or distress conditions that could result in an IFSD, loss of thrust control, or other power loss not specifically identified by paragraph (b) of this section or addressed within the Instructions for Continued Airworthiness.

(4) Not show wear or distress to the extent that could result in an IFSD, loss of thrust control, or other power loss within a period of operation before the component, assembly, or system would likely have been inspected or functionally tested for integrity while in service. Such wear or distress must have corrective action implemented through a design change, a change to maintenance instructions, or operational procedures before ETOPS eligibility is granted. The type and frequency of wear and distress that occurs during the engine test must be consistent with the type and frequency of wear and distress that would be expected to occur on ETOPS eligible engines.

(f) An alternative mission cycle endurance test that provides an equivalent demonstration of the unbalance and vibration specified in paragraph (c) of this section may be used when approved by the FAA.

(g) For an applicant using the simulated ETOPS mission cyclic endurance test to comply with § 33.90, the test may be interrupted so that the engine may be inspected by an on-wing or other method, using criteria acceptable to the FAA, after completion of the test cycles required to comply with § 33.90(a). Following the inspection, the ETOPS test must be resumed to complete the requirements of this section.

APPENDIX A TO PART 33—INSTRUCTIONS FOR CONTINUED AIRWORTHINESS

A33.1 GENERAL

(a) This appendix specifies requirements for the preparation of Instructions for Continued Airworthiness as required by § 33.4.

(b) The Instructions for Continued Airworthiness for each engine must include the Instructions for Continued Airworthiness for all engine parts. If Instructions for Continued Airworthiness are not supplied by the engine part manufacturer for an engine part, the Instructions for Continued Airworthiness for the engine must include the information essential to the continued airworthiness of the engine.

(c) The applicant must submit to the FAA a program to show how changes to the Instructions for Continued Airworthiness made by the applicant or by the manufacturers of engine parts will be distributed.

A33.2 FORMAT

(a) The Instructions for Continued Airworthiness must be in the form of a manual or manuals as appropriate for the quantity of data to be provided.

(b) The format of the manual or manuals must provide for a practical arrangement.

A33.3 CONTENT

The contents of the manual or manuals must be prepared in the English language. The Instructions for Continued Airworthiness must contain the following manuals or sections, as appropriate, and information:

(a) *Engine Maintenance Manual or Section*. (1) Introduction information that includes an explanation of the engine's features and data to the extent necessary for maintenance or preventive maintenance.

(2) A detailed description of the engine and its components, systems, and installations.

(3) Installation instructions, including proper procedures for uncrating, deinhibiting, acceptance checking, lifting, and attaching accessories, with any necessary checks.

(4) Basic control and operating information describing how the engine components, systems, and installations operate, and information describing the methods of starting, running, testing, and stopping the engine and its parts including any special procedures and limitations that apply.

(5) Servicing information that covers details regarding servicing points, capacities of tanks, reservoirs, types of fluids to be used, pressures applicable to the various systems, locations of lubrication points, lubricants to be used, and equipment required for servicing.

(6) Scheduling information for each part of the engine that provides the recommended periods at which it should be cleaned, inspected, adjusted, tested, and lubricated, and the degree of inspection the applicable wear tolerances, and work recommended at these periods. However, the applicant may refer to an accessory, instrument, or equipment manufacturer as the source of this information if the applicant shows that the item has an exceptionally high degree of complexity requiring specialized maintenance techniques, test equipment, or expertise. The recommended overhaul periods and necessary cross references to the Airworthiness Limitations section of the manual must also be included. In addition, the applicant must include an inspection program that includes the frequency and extent of the inspections necessary to provide for the continued airworthiness of the engine.

(7) Troubleshooting information describing probable malfunctions, how to recognize those malfunctions, and the remedial action for those malfunctions.

(8) Information describing the order and method of removing the engine and its parts and replacing parts, with any necessary precautions to be taken. Instructions for proper ground handling, crating, and shipping must also be included.

(9) A list of the tools and equipment necessary for maintenance and directions as to their method of use.

(b) *Engine Overhaul Manual or Section.* (1) Disassembly information including the order and method of disassembly for overhaul.

(2) Cleaning and inspection instructions that cover the materials and apparatus to be used and methods and precautions to be taken during overhaul. Methods of overhaul inspection must also be included.

(3) Details of all fits and clearances relevant to overhaul.

(4) Details of repair methods for worn or otherwise substandard parts and components along with the information necessary to determine when replacement is necessary.

(5) The order and method of assembly at overhaul.

(6) Instructions for testing after overhaul.

(7) Instructions for storage preparation, including any storage limits.

(8) A list of tools needed for overhaul.

(c) *ETOPS Requirements.* For an applicant seeking eligibility for an engine to be installed on an airplane approved for ETOPS, the Instructions for Continued Airworthiness must include procedures for engine condition monitoring. The engine condition monitoring procedures must be able to determine prior to flight, whether an engine is capable of providing, within approved engine operating limits, maximum continuous power or thrust, bleed air, and power extraction required for a relevant engine inoperative diversion. For an engine to be installed on a two-engine airplane approved for ETOPS, the engine condition monitoring procedures must be validated before ETOPS eligibility is granted.

A33.4 airworthiness limitations section

The Instructions for Continued Airworthiness must contain a section titled Airworthiness Limitations that is segregated and clearly distinguishable from the rest of the manual.

(a) For all engines:

(1) The Airworthiness Limitations section must set forth each mandatory replacement time, inspection interval, and related procedure required for type certification. If the Instructions for Continued Airworthiness consist of multiple documents, the section required under this paragraph must be included in the principal manual.

(2) This section must contain a legible statement in a prominent location that reads: ''The Airworthiness Limitations section is FAA approved and specifies maintenance required under §§43.16 and 91.403 of Title 14 of the Code of Federal Regulations unless an alternative program has been FAA approved.''

(b) For rotorcraft engines having 30-second OEI and 2-minute OEI ratings:

(1) The Airworthiness Limitations section must also prescribe the mandatory post-flight inspections and maintenance actions associated with any use of either 30-second OEI or 2-minute OEI ratings.

(2) The applicant must validate the adequacy of the inspections and maintenance actions required under paragraph (b)(1) of this section A33.4.

(3) The applicant must establish an in-service engine evaluation program to ensure the continued adequacy of the instructions for mandatory post-flight inspections and maintenance actions prescribed under paragraph (b)(1) of this section A33.4 and of the data for §33.5(b)(4) pertaining to power availability. The program must include service engine

tests or equivalent service engine test experience on engines of similar design and evaluations of service usage of the 30-second OEI or 2-minute OEI ratings.

[Amdt. 33–9, 45 FR 60181, Sept. 11, 1980, as amended by Amdt. 33–13, 54 FR 34330, Aug. 18, 1989; Amdt. 33–21, 72 FR 1878, Jan. 16, 2007; Amdt. 33–25, 73 FR 48124, Aug. 18, 2008]

APPENDIX B TO PART 33—CERTIFICATION STANDARD ATMOSPHERIC CONCENTRATIONS OF RAIN AND HAIL

Figure B1, Table B1, Table B2, Table B3, and Table B4 specify the atmospheric concentrations and size distributions of rain and hail for establishing certification, in accordance with the requirements of §33.78(a)(2). In conducting tests, normally by spraying liquid water to simulate rain conditions and by delivering hail fabricated from ice to simulate hail conditions, the use of water droplets and hail having shapes, sizes and distributions of sizes other than those defined in this appendix B, or the use of a single size or shape for each water droplet or hail, can be accepted, provided that applicant shows that the substitution does not reduce the severity of the test.

FIGURE B1 - Illustration of Rain and Hail Threats. Certification concentrations are obtained using Tables B1 and B2.

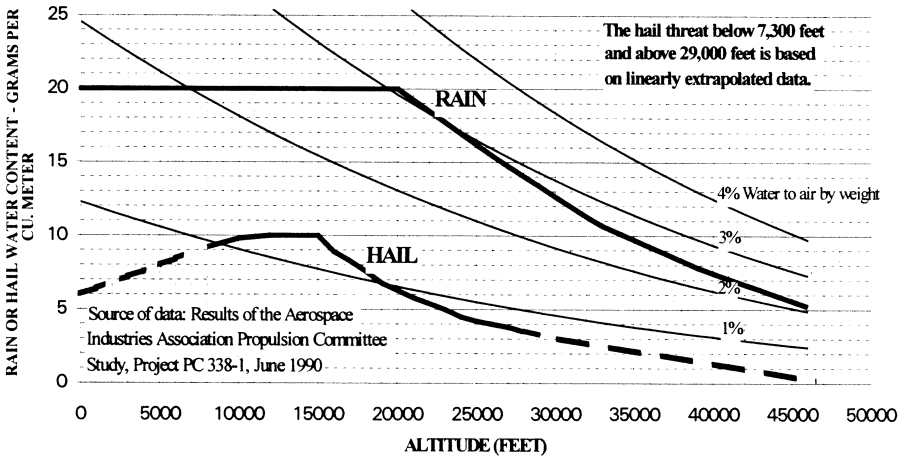


TABLE B1—CERTIFICATION STANDARD ATMOSPHERIC RAIN CONCENTRATIONS

Altitude (feet)	Rain water content (RWC) (grams water/meter^3 air)
0	20.0
20,000	20.0
26,300	15.2
32,700	10.8
39,300	7.7
46,000	5.2

RWC values at other altitudes may be determined by linear interpolation.

NOTE: Source of data—Results of the Aerospace Industries Association (AIA) Propulsion Committee Study, Project PC 338–1, June 1990.

TABLE B2—CERTIFICATION STANDARD ATMOSPHERIC HAIL CONCENTRATIONS

Altitude (feet)	Hail water content (HWC) (grams water/meter^3 air)
0	6.0
7,300	8.9
8,500	9.4
10,000	9.9
12,000	10.0
15,000	10.0
16,000	8.9
17,700	7.8
19,300	6.6
21,500	5.6
24,300	4.4
29,000	3.3
46,000	0.2

HWC values at other altitudes may be determined by linear interpolation. The hail threat below 7,300 feet and above 29,000 feet is based on linearly extrapolated data.

NOTE: Source of data—Results of the Aerospace Industries Association (AIA Propulsion Committee (PC) Study, Project PC 338–1, June 1990.

TABLE B3—CERTIFICATION STANDARD ATMOSPHERIC RAIN DROPLET SIZE DISTRIBUTION

Rain droplet diameter (mm)	Contribution total RWC (%)
0–0.49	0
0.50–0.99	2.25
1.00–1.49	8.75
1.50–1.99	16.25
2.00–2.49	19.00
2.50–2.99	17.75
3.00–3.49	13.50
3.50–3.99	9.50
4.00–4.49	6.00
4.50–4.99	3.00
5.00–5.49	2.00
5.50–5.99	1.25
6.00–6.49	0.50
6.50–7.00	0.25
Total	100.00

Median diameter of rain droplets in 2.66 mm

NOTE: Source of data—Results of the Aerospace Industries Association (AIA Propulsion Committee (PC) Study, Project PC 338–1, June 1990.

TABLE B4—CERTIFICATION STANDARD ATMOSPHERIC HAIL SIZE DISTRIBUTION

Hail diameter (mm)	Contribution total HWC (%)
0–4.9	0
5.0–9.9	17.00
10.0–14.9	25.00
15.0–19.9	22.50
20.0–24.9	16.00
25.0–29.9	9.75
30.0–34.9	4.75
35.0–39.9	2.50
40.0–44.9	1.50
45.0–49.9	0.75
50.0–55.0	0.25
Total	100.00

Median diameter of hail is 16 mm

NOTE: Source of data—Results of the Aerospace Industries Association (AIA Propulsion Committee (PC) Study, Project PC 338–1, June 1990.

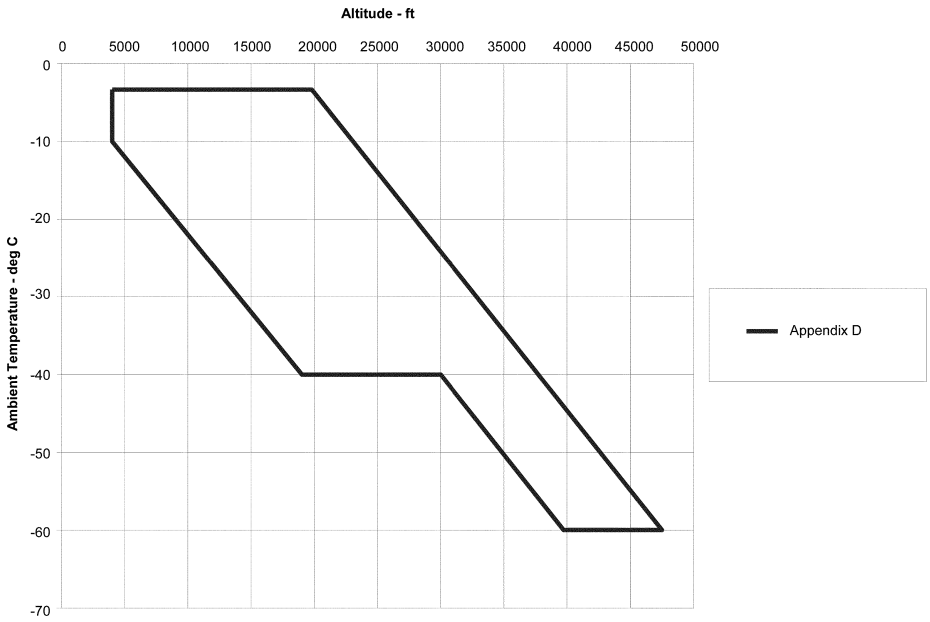
[Doc. No. 28652, 63 FR 14799, Mar. 26, 1998]

APPENDIX C TO PART 33 [RESERVED]

APPENDIX D TO PART 33—MIXED PHASE AND ICE CRYSTAL ICING ENVELOPE (DEEP CONVECTIVE CLOUDS)

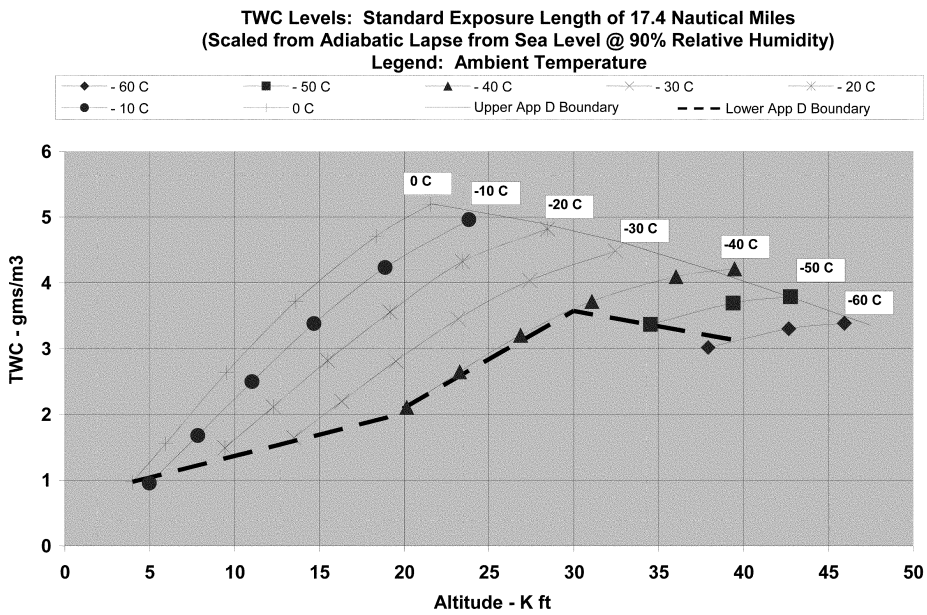
The ice crystal icing envelope is depicted in Figure D1 of this Appendix.

FIGURE D1 — Convective Cloud Ice Crystal Envelope



Within the envelope, total water content (TWC) in g/m³ has been determined based upon the adiabatic lapse defined by the convective rise of 90% relative humidity air from sea level to higher altitudes and scaled by a factor of 0.65 to a standard cloud length of 17.4 nautical miles. Figure D2 of this Appendix displays TWC for this distance over a range of ambient temperature within the boundaries of the ice crystal envelope specified in Figure D1 of this Appendix.

FIGURE D2 — Total Water Content



Ice crystal size median mass dimension (MMD) range is 50–200 microns (equivalent spherical size) based upon measurements near convective storm cores.

The TWC can be treated as completely glaciated (ice crystal) except as noted in the Table 1 of this Appendix.

TABLE 1—SUPERCOOLED LIQUID PORTION OF TWC

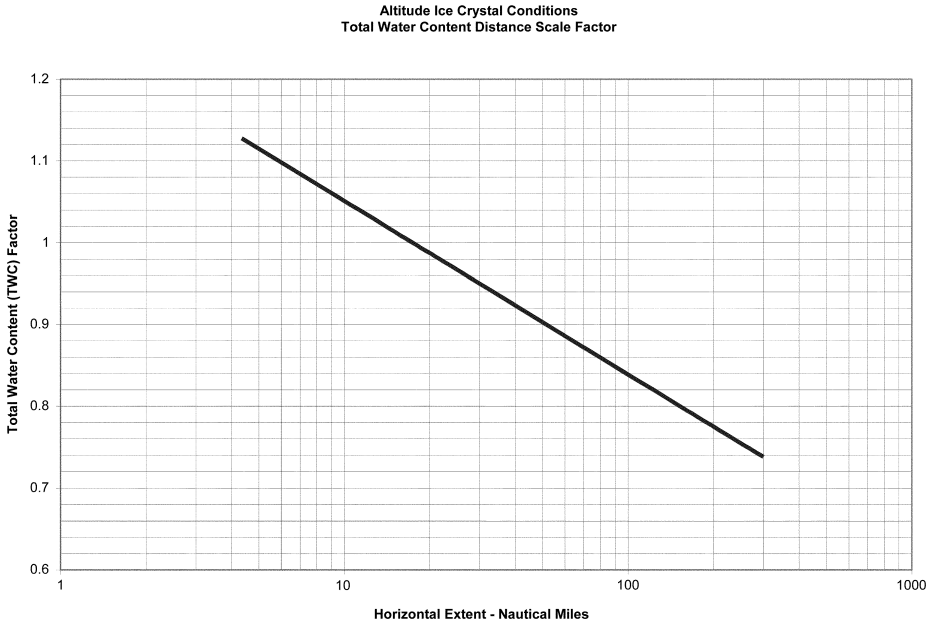
Temperature range—deg C	Horizontal cloud length—nautical miles	LWC—g/m³
0 to −20	≤50	≤1.0

TABLE 1—SUPERCOOLED LIQUID PORTION OF TWC—Continued

Temperature range—deg C	Horizontal cloud length—nautical miles	LWC—g/m³
0 to −20	Indefinite	≤0.5
< −20		0

The TWC levels displayed in Figure D2 of this Appendix represent TWC values for a standard exposure distance (horizontal cloud length) of 17.4 nautical miles that must be adjusted with length of icing exposure.

FIGURE D3 — Exposure Length Influence on TWC



[Amdt. 33–34, 79 FR 65538, Nov. 4, 2014]

PART 34—FUEL VENTING AND EXHAUST EMISSION REQUIREMENTS FOR TURBINE ENGINE POWERED AIRPLANES

Subpart A—General Provisions

Sec.
34.1 Definitions.
34.2 Abbreviations.
34.3 General requirements.
34.4 [Reserved]
34.5 Special test procedures.
34.6 Aircraft safety.
34.7 Exemptions.
34.9 Exceptions.

Subpart B—Engine Fuel Venting Emissions (New and In-Use Aircraft Gas Turbine Engines)

34.10 Applicability.
34.11 Standard for fuel venting emissions.

Subpart C—Exhaust Emissions (New Aircraft Gas Turbine Engines)

34.20 Applicability.
34.21 Standards for exhaust emissions.
34.23 Exhaust Emission Standards for Engines Manufactured on and after July 18, 2012.

Subpart D—Exhaust Emissions (In-Use Aircraft Gas Turbine Engines)

34.30 Applicability.
34.31 Standards for exhaust emissions.

Subpart E—Certification Provisions

34.48 Derivative engines for emissions certification purposes.

Subpart F [Reserved]

Subpart G—Test Procedures for Engine Exhaust Gaseous Emissions (Aircraft and Aircraft Gas Turbine Engines)

34.60 Introduction.
34.61–34.71 [Reserved]

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SOURCE: Docket No. 25613, 55 FR 32861, Aug. 10, 1990, unless otherwise noted.