CHAPTER 3. TYPE CERTIFICATION GUIDANCE MATERIAL
SECTION 1. SUBPART A--GENERAL

15. Section 33.3, General.

Section 33.3 General:

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

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Guidance: The INTENT of this section is self-evident.

Incorporations: None.

References: None.

Generally speaking, FAA will approve an applicant's engine within those conditions and limits which are satisfactorily substantiated. The applicant's assumed data and information for the specific engine design, for which type certification is requested, are initially (in part) provided to FAA with submittal of the application for TC. FAA then, and throughout the TC process, evaluates and validates the assumptions by analyses and tests. The conclusions result in statements of ratings, operating limitations, and instructions for continued airworthiness, installing, and operating the engine - all to assure safe operation of the engine in service.

16. Section 33.4, Instructions for Continued Airworthiness.

Section 33.4 Instructions for Continued Airworthiness.

The applicant must prepare Instructions for Continued Airworthiness in accordance with Appendix A to this Part [immediately following] 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.

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 Section 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 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 material 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.

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 document. This 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 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 Sections 43.16 and 91.163 of the Federal Aviation Regulations unless an alternative program has been FAA approved."

***

Guidance: The INTENT of this section is to assure that Instructions for Continued Airworthiness are available prior to service introduction of the engine.

Incorporations: None.

References: None.

The overhaul section, or manual portion of the instructions for continued airworthiness, may not be available at time of type certification of the engine. In such cases, the engine TCDS should incorporate a "NOTE" prohibiting the overhaul of engines until the overhaul instructions are available; and that, meanwhile, the manufacturer may provide rebuilt engines utilizing new engine tolerances. Overhauled engines must deliver, at least, the TC rated powers, or thrusts, within the ratings' associated limitations.

17. Section 33.5, Instruction Manual for Installing and Operating the Engine.

Section 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.

(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.

***

Guidance: The INTENT of this section is to assure that the engine installation and operating instructions are approved by the time the type certificate for the engine is issued.

Incorporations: None.

References: SAE Document ARP 1507, "Helicopter Engine/Airframe Interface Document and Checklist," issued September 1985. This reference offers further guidance on the types and formats of engine installations and operations information. Although this document is oriented to helicopter (turboshaft) engines, it may be useful as additional general guidance to authors of installation and operating instruction manuals.

a. The installation and operating instructions should incorporate all relevant and complete information on the characteristics, performance, and physical interfaces of the engine. A type certificated engine may include some external lines, equipment mountings, diaphragms, or firewalls which do not meet all certification requirements of some installations. Added line shrouding, relocation of fluid lines, or other changes constitute engine type design changes which may be required for the aircraft installation. Such FAA-approved changes are accomplished preferably by the engine type certificate holder, as approval based on engine compatibility and endurance qualification is usually necessary. However, upon achieving satisfactory coordination with the engine type certificate holder, accomplishment of such changes by the aircraft applicant is often acceptable as an alternative.

b. The engine type certificate holder or applicant may elect to incorporate items of equipment or accessories which are oftentimes handled as part of the aircraft installation responsibility. Examples of such items are engine mounted oil tanks, oil coolers, fuel heaters, generators, thrust reversers, inlet and exhaust nozzles, and various fluid pumps.

(1) When the engine manufacturer elects to furnish such accessories, it is basically implied that he will substantiate

them for engine compatibility, and be responsible for dealing with service difficulties.

(2) If the engine type certificate holder elects to establish aircraft installation compliance, he should develop and provide the necessary installation data in accordance with applicable aircraft requirements.

(3) If the engine type certification effort incorporates findings of compliance for aircraft installation items (i.e., to FAR Part 23, 25, 27, or 29 requirements) then such should be identified on the engine TCDS.

c. The engine installation instructions should incorporate information on the means of limiting, and on the quality of engine compressor bleed air available for airframe use. Design bleed air quality, limit(s), and the means of limiting should be verified by the failure modes and effects analysis and by testing, as appropriate. An example of the need for such information is seen in the certification of FAR Part 23 turbine powered aircraft: Turbine engine bleed air systems of turbine powered airplanes must be investigated to determine that, if the bleed air system is used for direct cabin pressurization, it is not possible for hazardous contamination of the cabin air system to occur in the event of lubrication system failure.

d. The engine installation instructions should incorporate statements of instrumentation types, ranges, required precision, and accuracies for those engine parameters required for safe operation. These statements should be based upon the applicant-selected ratings for the specific engine design, as verified and substantiated throughout the type certification process, particularly the block tests.

18. Section 33.7, Engine Ratings and Operating Limitations.

Section 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 Section 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 2-1/2 Minute OEI power;

(vii) Rated Continuous OEI power; and

(viii) 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 over-temperature 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) For engines to be used in supersonic aircraft engine rotor windmilling rotational r.p.m.

***

Guidance: The INTENT of this section is to publicly document the engine ratings and limitations data and other information necessary for safe operation of the engine.

Incorporations: AC 91-33A, "Use of Alternate Grades of Aviation Gasoline for Grade 80/87 and Use of Automotive Gasoline," dated July 1984.

References:

1. RTCA Document DO-160B.

2. SAE Committee Report No. AE4EL.

3. AC 21-6A, "Production Under Type Certificate Only", dated July 1, 1982.

4. AC 21-1B, "Production Certificate", dated May 10 1976.

a. Tests. Specific block tests are conducted to establish the various rated powers and thrusts, and the maximum and minimum operating limitations.

(1) The effects of altitude on engine ratings and operating limitations should be determined acceptably. This may be accomplished by means of altitude chamber testing, flight testing, simulated altitude testing, or analytical data using proven methodology.

(2) The ratings' limiting maximum operating parameters should be qualified by operation as indicated in the 150-hour FAA endurance test. Other limitations may be qualified by testing in which the limiting values may be the average attained for appropriate durations.

(3) Special or additional tests may be necessary, at times, to qualify some limitations for either complex engines, such as turbine engines with several rotor systems when limiting test conditions cannot be easily maintained for all rotors simultaneously, or where limits for components may be tested separately on rig tests. Specific examples are:

(i) Under certain ambient conditions, it may not be possible to simultaneously exercise to its respective speed limitation, each rotor of a multiple rotor engine during endurance test running. In such a case, and if approved by the cognizant FAA project manager or engineer, the test may be replicated as necessary to demonstrate each respective limitation, as also discussed under the "Section 33.87, Endurance Test" paragraph of this AC.

(ii) Engine electronic control devices such as full authority digital electronic controls (FADECs), require substantiation of tolerance to the effects of lightning strikes. This substantiation is interpreted to be necessary under the general requirements of FAR Section 33.91(a). Current practice is to require an installations simulation of the complete engine-furnished FADEC system, including cables and connectors, to be subjected to direct and induced lightning strike tests. This effort is typically conducted in accordance with the guidance information provided in References 1 and 2 above. The primary expected outcomes of this testing are definition of the lightning energy levels which the FADEC system can tolerate without adverse affects, and the level of shielding or other protection which the airframer will need to provide upon installation of the FADEC system in the aircraft.

(4) Military test data and reports may be used for certification purposes, if they are determined by the FAA type certification project manager or engineer to satisfy the criteria of the appropriate FAR Part 33 section, and of the conformity inspection requirements of Section 21.53.

b. Ratings and Limitations. Rated engine powers and thrusts are usually established on the basis of engine operation on a test stand, in its normal operating configuration; but usually with, at least, a test stand inlet in place of the aircraft installation hardware.

(1) Ratings are included on the engine TCDS.

(2) All operating limitations that may be considered by the applicant to affect flight safety, if exceeded, are to be noted in the model description and should include such items as the maximum values of: Engine pressure ratio (EPR); torque; rotorspeeds; powers; gas path temperatures; component temperatures; manifold pressure; vibration levels; fuel and

lubricant pressures and temperatures; time at ratings; and number of excursions at ratings.

c. Production and Overhauled Engines. Although discussion of production engines would normally be considered beyond the scope of type certification, the following information may be useful:

(1) Each engine newly produced under a type certificate (TC) only, or under a production certificate, must be tested to assure that engine output is not less than the TC ratings and within each rating's respective associated operating limitations. (See References 3 and 4 above).

(2) It should be recognized that engine manufacturers and overhaulers will typically deliver engines with some degree of performance margin. This margin is usually based on a business agreement between the engine supplier and the installer or user.

(i) The important point is that there is no regulatory basis for engines to have more than minimum type certificated (specification) power/thrust available at delivery, whether in new or overhauled condition.

(ii) A further point is that in-service engines must always be capable of delivering the type certificate rating minimum performance, again, within the respective rating's operating limitations. Otherwise, the engine must be removed from further service and minimum performance restored before return to service.

(3) There are special cases wherein some in-service engine applications have been approved for subsequent operations to lesser performance levels than established during initial type certification. These cases are known as having deteriorated power operation approvals. Such cases have been approved only following extensive reevaluation of the engine and the aircraft to the deteriorated performance level, against the original type certification basis. This approval is limited to the specific initial operator's route structure.

19. Section 33.8, Selection of Engine Power and Thrust Ratings.

Section 33.8 Selection of engine power and thrust ratings.

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

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

The objective of this requirement is to establish, on a uniform basis, the power or thrust ratings which new engines, and engines restored to new condition, are required to produce. These ratings are used in establishing aircraft performance for which consistent minimum performance is desired. Ratings selected by the applicant are established by FAA block tests. Ratings are typically based on specific atmospheric conditions, for the static case, with no customer bleed, no power extraction, and 100 percent recovery of inlet and exhaust losses. The applicant's experience on the calibrated output of a number of engines, of both the applicable new model and of engines of closely similar design characteristics, should be reviewed to evaluate the range of output expected in all other engines of that type. The selected ratings should be consistent with the output of the lowest output engine anticipated.

SECTION 2. SUBPART B--DESIGN AND CONSTRUCTION; GENERAL

20. Section 33.14, Start-Stop Cyclic Stress (Low-Cycle Fatigue).

Section 33.14 Start-stop cyclic stress (low-cycle fatigue).

By a procedure approved by the FAA, operating limitations must be established which specify the maximum allowable number of start-stop stress cycles for each rotor structural part (such as discs, spacers, hubs, and shafts of the compressors and turbines), the failure of which could produce a hazard to the aircraft. A start-stop stress cycle consists of a flight cycle profile or an equivalent representation of engine usage. It includes starting the engine, accelerating to maximum rated power or thrust, decelerating, and stopping. For each cycle, the rotor structural parts must reach stabilized temperature during engine operation at maximum rated power or thrust and after engine shutdown, unless it is shown that the parts undergo the same stress range without temperature stabilization.

***

Guidance. The INTENT of this section is to establish cyclic life limits using FAA-approved methodology for rotating structural components whose failure could produce a hazard to the aircraft.

Incorporations: AC 33.3, "Turbine and Compressor Rotors Type Certification Substantiation Procedures," dated September 9, 1968.

References: None.

The guidance embodied in the "Incorporations" above, with respect to determination of service life limits, is still considered valid.

a. Some applicants have pre-approved procedures on file with the FAA for establishing initial (and increases of) low cycle fatigue (LCF) lives. Such procedures should be utilized where they exist.

b. The FAA requires the applicant to define the LCF verification test cycle, based on the most severe mission cycle expected in service. The determination of the most severe mission cycle expected in service is based on the concurrence of the FAA engine certification project manager with the applicant's proposed definition.

(1) It is determined logically, based on the type of engine, types of airframe applications, and anticipated service

usage. In rare cases, specific airframe applications during the time of the engine certification program are not known, and, therefore, more speculative, but conservative, approaches may need to be used. In all cases, the FAA's installation office may be consulted to assist in determining the mission cycle.

(2) The test cycle basis should, in part, incorporate some excursions to the redline limits of gas path temperature, rotational speeds, torques, pressures, etc., associated with the maximum ratings used in the mission cycle. Consider such excursions that could reasonably be expected to occur within the extremes of ambient temperature and takeoff altitude conditions encountered during the engine's service life.

(3) The supporting data required for LCF qualification includes mechanical and thermal stress analyses and tests, and material analyses and tests. Since there are various acceptable methods of determining maximum temperature gradients, the FAA does not advocate that any particular methodology be applied for thermal analyses. Test engine rotor structural parts should attain a stabilized temperature for each applied test cycle.

c. Increases in service life limits, similar to the determination of initial life limits, will need to be based on a representative severe operating cycle, identified from service experience. Programs to increase service life limits should be based on further cyclic testing and analysis of in-service parts that have attained a reasonable percentage of their life limits.

d. FAA findings of compliance with existing FAR Section 33.14 are based, in part, on the applicant's definition of the flight cycle profile, or equivalent representation of engine usage. Implementation of this aspect of the rule, in the case of OEI rated engines, requires addressing the use of OEI ratings at a realistic frequency representative of actual (expected) in-service use.

(1) To date, the service experience with OEI rated engines is that use of OEI ratings, following a true case of one engine having failed, is an extremely rare event. Thus, it is considered totally unrealistic to mandate the use of OEI ratings as a constituent of each flight cycle.

(2) However, the applicant is still required, in all cases, to account for low cycle fatigue effects, based on the anticipated usage of OEI ratings during the life of the engine. This could be accomplished, for example, by adding a reasoned finite number of cycles to the expended life of the appropriate components for each OEI power excursion.

21. Section 33.15, Materials.

Section 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.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: AC 33-4, "Design Considerations Concerning the Use of Titanium in Aircraft Turbine Engines," dated July 28, 1983.

References: None.

The applicant should select approved specification materials in the design and construction of the engine to minimize the development of an unsafe condition of the engine. Although the regulations do not specifically address corrosion and deterioration, these factors need to be considered in the type certification process, particularly in the design stage. Examples are proposed use of non-corrosion resistant alloys in corrosion-susceptible areas and proposed use of galvanic materials in contact.

22. Section 33.17, Fire Prevention.

Section 33.17 Fire prevention.

(a) The design and construction of the engine and the materials used must minimize the probability of the occurrence and spread of 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, overheating, or other hazardous conditions.

(b) Except as provided in paragraphs (c), (d), and (e) of this section, each external line, fitting, and other component, which contains or conveys flammable fluid must be fire resistant. Components must be shielded or located to safeguard against the ignition of leaking flammable fluid.

(c) Flammable fluid tanks and supports which are part of and attached to the engine must be fireproof or be enclosed by a fireproof shield unless damage by fire to any non-fireproof part will not cause leakage or spillage of flammable fluid. For a reciprocating engine having an integral oil sump of less than 25-quart capacity, the oil sump need not be fireproof nor be enclosed by a fireproof shield.

(d) For turbine engines type certificated for use in supersonic aircraft, each external component which conveys or contains flammable fluid must be fireproof.

(e) Unwanted accumulation of flammable fluid and vapor must be prevented by draining and venting.

***

Guidance. The INTENT of this section is to assure that design, materials, and construction techniques are used to minimize the occurrence and spread of fire.

Incorporations: AC 33-4, "Design Considerations Concerning the Use of Titanium in Aircraft Turbine Engines", dated July 28, 1983.

References:

1. SAE AS1055B, "Fire Testing of Flexible Hose, Tube Assemblies, Coils, Fittings, and Similar System Components," March 1, 1978.

2. SAE AIR 1377A, "Fire Test Equipment for Flexible Hose and Tube Assemblies," January 1980.

3. FAA Powerplant Engineering Report No. 3A, "Standard Fire Test Apparatus and Procedure," Revised March 1978.

4. FAA Report No. FAA-RD-79-51, "Titanium Combustion in Turbine Engines," dated July 1979; and JAR-E, Section 2, Paragraph ACJE530(c), "Titanium Fires."

5. SAE Report No. 690436, "Ignition of Aircraft Fluids on High Temperature Engine Surfaces," by W.T. Westfield of the FAA.

6. FAA Report No. FAA-RD-75-155, "Ignition and Propagation Rates for Flames in a Fuel Mist," October 1975, by C.E. Polymeropoulos.

7. AC 20-135, "Powerplant Installation and Propulsion System Component Fire Protection Test Methods, Standards and Criteria," dated February 6, 1990.

a. The FAR Part 1 definitions of "fire resistant" and "fire proof" are very broad and are not quantified in terms of flame temperature and time of immersion. For purposes of engine certification, fire resistant should be associated with a test flame temperature of 2000 ^{o}F, for at least a 5-minute duration;

fireproof should be associated with a test flame temperature of 2000 °F, for at least a 15-minute duration.

b. Fire test conditions to be applied should be established consistent with the intended use of the engine component or subsystem being evaluated. Examples of this are: sheet stock designed to be firewalls or fireshrouds; formed parts designed as oil tanks; castings designed as fuel pump bodies; seamless tubing designed as fuel and oil supply lines; etc.

c. The test flame should be applied at the component or subsystem location that is determined by analysis and/or inspection to be most critical to fire susceptibility. Additionally, the operating characteristics of the component or subsystem should be established consistent with those which would normally be expected to exist during actual engine fire conditions.

d. Fire susceptibility means not only the probable location of a fire, but also the specific location of the component or subsystem within the fire zone that may be least likely to survive the effects of a fire. Such a determination should consider, at least, the following potential factors: materials characteristics; parts geometry; local torching effects; joint seals; vibration characteristics; internal fluid levels, pressures, and flows; wicking of surface coatings; engine design requirement for installed engine, through nacelle exhaust ejector driven component cooling airflows; characteristics of probable leakage in forms of sprays, drops, streams; etc.

e. The fire test burner to be used should provide the desired 2000 °F flame temperature of sufficient size, and at an energy level (BTU/hr) appropriate to the geometry of the engine component or subsystem being evaluated. Further general guidance on burner configuration can be found in References 1, 2, and 3 above.

f. In all cases, fire test acceptance criteria should show no support of combustion by the constituent material being tested; no burn-through; no leakage of fluid-carrying or fluid-holding parts sufficient to increase the fire hazard; and fire-protecting parts should be capable of satisfactorily performing the functions for which they were designed.

g. Compliance with the requirements of Section 33.17(a) requires that the design and construction of turbine engines must minimize the probability of the occurrence of an internal fire that could result in structural failure, overheating, or other hazardous conditions. (See also Reference 4 above).

h. Available references relating to hot surface ignition (HSI) criteria for fuels are consistent in that the HSI temperature for JP-type fuels is in the range of 425-500 °F (minimum) for the non-ventilated case. HSI temperature increases dramatically with increasing airflow. It is also influenced by the characteristics of the secondary cooling air and engine surface geometry, ventilation rates of the engine nacelle, direction and changes of direction of the cooling air, and changes in engine power while leakage is occurring. Further information on this topic is available in References 5 and 6 above.

23. Section 33.19, Durability.

Section 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 Section 35.42 of this chapter.

***

Guidance. The INTENT of this section is self-evident

Incorporations:

1. AC 33-4, "Design Considerations Concerning the Use of Titanium in Aircraft Turbine Engines," dated July 28, 1983.

2. AC 33-5, "Turbine Engine Rotor Blade Containment/Durability," dated June 18, 1990.

References: None.

a. This section addresses the generic safety requirement of engines between "overhaul" periods, in addition to specific design requirements for rotor blade containment and for propeller blade pitch control.

(1) The generic requirement is fulfilled by compliance not only to each of the appropriate sections of FAR Part 33, but also to the "grandfather" Sections of 21.33, "Inspection and tests," and 21.16, "Special conditions."

(2) Collectively, these speak to not only the basis for type certification, but more specifically to: (1) materials and products specifications; (2) conformance of parts to the drawings in the type design; (3) specification of manufacturing processes; and (4) construction and assembly specifications in the engine type design (drawings). Each of these items should be traceable in the type certification design documentation from the engine top assembly drawing.

b. This section also addresses the specific design requirements for rotor blade containment, whereas FAR Section 33.94 addresses the demonstration requirements; both are addressed in Incorporation 2. Essentially, the design (analysis) is borne out by testing to substantiate that the potential energy of the containment structure is greater than the kinetic energy of the released rotor blade debris.

24. Section 33.21, Engine Cooling.

Section 33.21 Engine cooling.

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

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

a. Interpretations of this regulation have historically been limited to operating fluid, external engine surface, and component heat rejection considerations, particularly of reciprocating engines. However, inasmuch as the rule applies to "Design and Construction-General," it should be interpreted to apply to both reciprocating and turbine engines, and to all engine cooling considerations.

b. Evaluation of the engine cooling systems design should not only address operating fluid and external component cooling, but also internal flow path cooling of turbochargers, rotors, spacers, nozzles, combustors, cases, etc. Particular attention should be given to ensure that continued safe operation and integrity of the critical structural components, while operating in the intended environment, is maintained throughout the design life and/or time to inspection, as appropriate.

25. <u>Section 33.23, Engine Mounting Attachments and Structure</u>.

Section 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.

***

<u>Guidance</u>. The INTENT of this section is to specify the allowable limit and ultimate loads, as defined, for the engine mounting attachments and related engine structure.

<u>Incorporations</u>: None.

<u>References</u>: None.

a. Engine attachment (mount) limit loads are the maximum loads to be expected in service and include, in combination, static mount loads, operating engine maximum reactive torque loads, gyroscopic loads, and maximum ground and flight loads. Ultimate load capability of the engine attachment mount structure is substantiated by analysis and by limited rig and component testing, which should also serve to validate the applicant's analytical methodology.

b. Engine mounting attachments and structure design should include consideration of deterioration, and corrosion effects expected during the design life of the engine. Suitable methods of detection of pending faults and failures at, or between, inspection intervals to be approved, should also be given consideration.

26. <u>Section 33.25, Accessory Attachments</u>.

Section 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.

***

Guidance. The INTENT of this section is that design and construction of engine accessory drives and their mount pads permit proper engine operation when loaded; prevent contamination and excessive loss of oil; and permit inspection, adjustment, and removal of accessories.

Incorporations: None.

References: None.

If engine accessory drives are designed to protect the engine from potential unsafe conditions, such as those due to accessory seizure overtorque, by designed failure of a drive shaft shear section; then, it should be shown that the shear section will not fail under all normal operating load conditions, or otherwise result in damage or hazard to the engine or its subsequent aircraft installation.

27. Section 33.27, Turbine, Compressor, Fan and Turbosupercharger Rotors.

Section 33.27 Turbine, compressor, fan and turbosupercharger rotors.

(a) Turbine, compressor, fan, and turbosupercharger rotors must have sufficient strength to withstand the test conditions specified in paragraph (c) of this section.

(b) The design and functioning of engine control devices, systems, and instruments must give reasonable assurance that those engine operating limitations that affect turbine, compressor, and turbosupercharger rotor structural integrity will not be exceeded in service.

(c) The most critically stressed rotor component (except blades) of each turbine, compressor, and fan, including integral drum rotors and centrifugal compressors in an engine or turbosupercharger, as determined by analysis or other acceptable means, must be tested for a period of 5 minutes--

(1) At its maximum operating temperature, except as provided in paragraph (c)(2)(iv) of this section; and

(2) At the highest speed of the following, as applicable:

(i) 120 percent of its maximum permissible r.p.m. if tested on a rig and equipped with blades or blade weights.

(ii) 115 percent of its maximum permissible r.p.m. if tested on an engine.

(iii) 115 percent of its maximum permissible r.p.m. if tested on a turbosupercharger driven by a hot gas supply from a special burner rig.

(iv) 120 percent of the r.p.m. at which, while cold spinning, it is subject to operating stresses that are equivalent to those induced at the maximum operating temperature and maximum permissible r.p.m.

(v) 105 percent of the highest speed that would result from failure of the most critical component or system in a representative installation of the engine.

(vi) The highest speed that would result from the failure of any component or system in a representative installation of the engine, in combination with any failure of a component or system that would not normally be detected during a routine preflight check or during normal flight operation.

Following the test, each rotor must be within approved dimensional limits for an overspeed condition and may not be cracked.

***

Guidance. The INTENT of this section is to assure engine rotor structural integrity, by design and functioning of engine control and instrumentation systems, to inhibit exceedances of operating limitations; and, to demonstrate that each engine rotor has sufficient strength to withstand a maximum overspeed condition without cracking.

Incorporations: None.

References: None.

a. If the engine bill-of-material includes instrumentation (including sensors), then such must be designed and must function so as to assure safe operation, (structural integrity of the in-service engine). Note that the rule requires the most critically stressed rotor component (including discs, spacers, cooling plates) of each turbine, compressor, and fan to be tested at a maximum overspeed condition for 5 minutes. Determination of the maximum overspeed condition needs to consider the 6 cases defined in the rule -- including shaft failures which decouple a turbine rotor from its load. Rotor shafts are not considered "prime reliable" in that it is assumed that shaft failures will occur, both as a single failure and in combination with another undetected or dormant failure.

b. A rotor burst test, in lieu of the presently required 5-minute overspeed test, could be found as an acceptable equivalent means of compliance. In the case of output shaft (low) turbines, the rotor burst test would be performed, in conjunction with an abrupt load decouple test, to demonstrate the existence of adequate margin between the peak speed and the burst speed. The actual burst speed must be corrected to account for the effects of gas path temperature (i.e., actual engine at maximum operating temperature versus spin pit temperature at burst), and test specimen actual material properties versus specification minimum material properties. Acceptance criteria must show at least a 5.0 percent speed margin between the abrupt decouple peak speed and the corrected burst speed.

c. The following table, provided as a historical reference, correlates the rotor integrity regulation and its guidance, including significant differences:

TABLE 27-1. ROTOR INTEGRITY REGULATIONS/GUIDANCE

REGULATION & EFFECTIVITY DATE		CORRESPONDING GUIDANCE & ISSUE DATE	SIGNIFICANT GUIDANCE DIFFERENCES
FAR 33-13, FAR 33-12, FAR 33-11, FAR 33-10, FAR 33-9, FAR 33-8, FAR 33-7, FAR 33-6,	08/18/89 10/03/88 04/24/86 03/26/84 10/14/80 05/02/77 02/01/77 10/31/74	AC 33-3, 09/09/68	o POST-TEST ACCEPTANCE CRITERIA OF THE FAR TAKES PRECEDENCE OVER THAT OF THE AC.
FAR 33-5, FAR 33-4,	03/01/74 04/23/71	AC 33-3, 09/09/68	o FAR DOES NOT IDENTIFY POST-TEST ACCEPTANCE CRITERIA.
FAR 33-3, FAR 33-2,	04/03/67 07/06/66	AC 20-26, CH.2 07/08/65	o POST-TEST ACCEPTANCE CRITERIA OF THE AC REVISED BY CH.2. (PARAGRAPH 4C).
FAR 33 & 33-1,	02/01/65	AC 20-26 CH.1, 09/18/64; AC 20-26, 07/22/64	o SUPERSEDES FAA MEMORANDUM OF 02/09/59. o OVERSPEED TEST CONDITION ANALYSIS BASED ON FAILURE(S).
CAR 13-6, CAR 13-5, CAR 13-4, CAR 13-3,	04/22/64 02/12/63 05/03/62 10/01/59	FAA POLICY MEMORANDUM, 02/09/59	o ESTABLISHES REQUIREMENTS FOR SUBSTANTIATION OF TURBINE & COMPRESSOR ROTOR INTEGRITY. NOTE THAT THE OVERSPEED TEST CONDITION TO BE RUN IS BASED ON ANALYSIS OF CONTROL SYSTEM FAILURE(S) AND ON A FACTOR OF TAKEOFF R.P.M., WHICHEVER YIELDS THE GREATEST STRESS. o MUST DEMONSTRATE OVERSTRESS MARGIN, BUT DOES NOT OFFER ACCEPTANCE CRITERIA.
CAR 13-2, CAR 13-1, CAR 13,	05/17/58 08/12/57 06/15/56	NONE	N/A

28. Section 33.29, Instrument Connection.

Section 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.

***

Guidance. The INTENT of this section is to prevent misconnections of engine-required instrumentation, and to provide a drawing location for rotor unbalance sensing.

Incorporations: None.

References: None.

An acceptable method of complying with FAR Section 33.29(b) is to identify, on the engine installation drawing, the flange location for installation of the unbalance indicator transducer. Historically, "turbojet" has been interpreted to also include fan engines.

SECTION 3. SUBPART C--DESIGN AND CONSTRUCTION; RECIPROCATING AIRCRAFT ENGINES

29. Section 33.33, Vibration.

Section 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.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

30. Section 33.35, Fuel and Induction System.

Section 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.

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

31. Section 33.37, Ignition System.

Section 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.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

The engine installation instructions should define the characteristics and interface requirements of all aircraft sources of electrical power required by the engine ignition system.

32. Section 33.39, Lubrication System.

Section 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.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

SECTION 4. SUBPART D--BLOCK TESTS; RECIPROCATING AIRCRAFT ENGINES

33. Section 33.42, General.

Section 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.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

34. Section 33.43, Vibration Test.

Section 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.

***

Guidance. The INTENT of this section is to demonstrate that the engine is free of potentially harmful vibration under all normal operating conditions.

Incorporations: None.

References: None.

When the engine is used to drive a propeller, the engine vibration investigation must be conducted with a representative propeller, including the propeller governor and spinner. A satisfactory finding from the engine vibration survey will serve to permit certification of the engine, as far as its vibration is concerned.

35. Section 33.45, Calibration Tests.

Section 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 Section 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.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

36. Section 33.47, Detonation Test.

Section 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.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: AC 33.47-1, "Detonation Testing in Reciprocating Aircraft Engines," dated June 27, 1988.

References: None.

37. Section 33.49 Endurance Test.

Section 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 of maximum best economy cruising power or maximum recommended cruising power.

(2) A 20-hour run consisting of alternate periods of 1-1/2 hours at rated maximum continuous power with maximum continuous speed, and 1/2 hour at 75 percent rated maximum continuous power and 91 percent maximum continuous speed.

(3) A 20-hour run consisting of alternate periods of 1-1/2 hours at rated maximum continuous power with maximum continuous speed, and 1/2 hour at 70 percent rated maximum continuous power and 89 percent maximum continuous speed.

(4) A 20-hour run consisting of alternate periods of 1-1/2 hours at rated maximum continuous power with maximum continuous speed, and 1/2 hour at 65 percent rated maximum continuous power and 87 percent maximum continuous speed.

(5) A 20-hour run consisting of alternate periods of 1-1/2 hours at rated maximum continuous power with maximum continuous speed, and 1/2 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 1-1/2 hours at rated maximum continuous power with maximum continuous speed, and 1/2 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 2-1/2 hours at rated maximum continuous power with maximum continuous speed, and 2-1/2 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 five minutes at the observed horsepower obtainable with the takeoff critical altitude manifold pressure and takeoff speed, and five 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 of rated maximum continuous power with maximum continuous speed, and 1/2 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 1/2 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 gar 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 and speed.

(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 Section 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 2-1/2 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 2-1/2 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 2-1/2 hours each at 80 percent rated maximum continuous power with takeoff speed, and at 80 percent rated maximum continuous power with 80 to 90 percent maximum continuous speed.

(5) A 25-hour run consisting of alternate periods of 2-1/2 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 portion 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 paragraph (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.

***

Guidance. The INTENT of this section is demonstrate a minimum level of operability of the complete engine, within its (to be) approved ratings, limitations, inspection, and maintenance requirements.

Incorporations: None.

References: None.

38. Section 33.51, Operation Test.

Section 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 multi-speed 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 5 seconds.

***

Guidance. The INTENT of this section is to assure that demonstration of the above characteristics is also conducted.

Incorporations: AC 23.909-1, "Installation of Turbochargers in Small Airplanes With Reciprocating Engines," dated February 3, 1986.

References: None.

The incorporation above primarily addresses small airplane approval procedures for turbocharger installations. It is incorporated herein, however, since it also provides useful guidance for approval of engine modifications to accommodate turbocharger installations.

39. Section 33.53, Engine Component Tests.

Section 33.53 Engine component tests.

(a) For each engine that cannot be adequately substantiated by endurance testing in accordance with Section 33.49, the applicant must conduct additional tests to establish that components are able to function reliably in all normally anticipated flight and atmospheric 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.

***

Guidance. The INTENT of this section is to assure test substantiation of all engine components, functions, and features that would not otherwise have been evaluated by endurance or other testing.

Incorporations: None.

References: None.

40. Section 33.55, Teardown Inspection.

Section 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 Section 33.4.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.

41. Section 33.57, General Conduct of Block Tests.

Section 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 Section 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.

***

Guidance. The INTENT of this section is self-evident.

Incorporations: None.

References: None.