U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: CALIBRATION TEST, ENDURANCE TEST AND TEARDOWN INSPECTION FOR TURBINE ENGINE CERTIFICATION (§§ 33.85/87/93)

Date: Draft
Initiated By: ANE-110

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Change:

1. PURPOSE**.** This advisory circular (AC) provides information and guidance on acceptable methods, but not the only methods, of compliance with the test requirements of § 33.85 (calibration test), § 33.87 (endurance test), and § 33.93 (teardown inspection) of Title 14 of the Code of Federal Regulations (14 CFR).

2. APPLICABILITY.

a. The guidance provided in this AC is directed to engine manufacturers, foreign regulatory authorities, all applicants for engine type design approval, and Federal Aviation Administration (FAA) engine type certification engineers and their designees. The AC applies to type certification endurance testing of all classes of turbine engines under 14 CFR part 33.

b. This document is neither mandatory nor regulatory in nature and does not constitute a regulation. It describes acceptable means, but not the only means, for demonstrating compliance with the applicable regulations. The FAA will consider other methods of demonstrating compliance that an applicant may elect to present. Terms such as “should,” “shall,” “may,” and “must” are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance in this document is used. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. On the other hand, if the FAA becomes aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation as the basis for finding compliance.

c. This material does not change, create any additional, authorize changes in, or permit deviations from existing regulatory requirements.

3. RELATED REGULATIONS AND DOCUMENTS

a. Related Regulations

(1) Part 21, §§ 21.31and 21.33

(2) Part 33, §§ 33.4, 33.5 33.7, 33.8, 33.82, 33.83, 33.85, 33.93, and 33.99

b. Related Documents

1. FAA Order 8110.4B, Type Certification Process

2. AC 33-2B, Aircraft Engine Type Certification Handbook

4. DISCUSSION

a. The Civil Air Regulation 13 (CAR-13) adopted the original rules for the turbine engine calibration test, endurance test and teardown inspection in 1952. The new 14 CFR part 33 was issued in 1965 to replace the airworthiness standards contained in the CAR-13. The regulations in part 33 were revised through numerous amendments (Amendment 20) over the past four decades. The most significant changes to these rules were in Amendments 6 and 10. These two amendments upgraded the requirements of the engine tests and teardown inspection to accommodate the increasing complexity of modern turbine engines and the interface between engines and airframes.

b. In recent years, several engine manufacturers have proposed more service representative engine tests in place of the endurance cycle defined in § 33.87. However, the intent of § 33.87 is not to simulate in-service operation, but to require an accelerated durability test to demonstrate a minimum level of operability and durability of an engine within its ratings and operating limitations. In addition, a review of past test data shows that the FAA has at times accepted alternative approaches that deviate too much from the rule and, therefore, can no longer be accepted. This AC provides guidance to establish a uniform approach to demonstrate compliance with the test requirements of §§ 33.85, 33.87, and 33.93.

c. The general endurance test requirements specified in § 33.82, the calibration test in § 33.85, the endurance test in § 33.87, the teardown inspection in § 33.93, and the general conduct of block test requirements in § 33.99 form integral parts of the endurance testing of the engine. In addition, for those systems that cannot be adequately substantiated by endurance testing in accordance with the provisions of § 33.87, applicants must conduct additional test(s) under the component test requirements specified in § 33.91 to establish that the components are able to function reliably in all certificated operating conditions.

d. The guidance material in this AC is presented in three chapters corresponding to the regulations in §§ 33.85, 33.87, and 33.93. The contents in each chapter are arranged in accordance with the order of the paragraphs in the regulation. The general testing requirements contained in §§ 33.82 and 33.99 are included in these three chapters whenever applicable. The Appendixes provide background information for the guidance material, documentation requirements for the calibration and endurance tests and teardown inspection, and requirements for special applications, such as multiple engine tests for endurance test, substantiation for engineering changes by endurance testing, and two-minute transient over-temperature approval. The guidance in this AC is derived from extensive FAA and industry experience in determining compliance with §§ 33.85, 33.87, and 33.93. However, if the FAA determines that testing performed in accordance with the guidance this AC would still not result in complete compliance with the regulations, then additional substantiation may be required as the basis for finding compliance.

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CHAPTER 1. GENERAL

1-1. Background.

a. The Civil Aeronautics Board adopted the original rules for turbine engine certification tests in CAR-13 on January 8, 1952. The test requirements included a general block test, calibration tests, a 150-hour endurance test, and a teardown inspection.

b. The following paragraphs describe briefly the major changes made over 40 years through amendments to the regulations and test requirements of endurance test and related rules:

(1) CAR-13.

(a) The calibration test specified in CAR-13 was similar to that of § 33.85(a), except that CAR-13 did not address compressor air bleed for the test. The endurance test in CAR-13 consisted of only a test schedule that resembles the current § 33.87(b). The teardown inspection paragraph in CAR-13 required a complete disassembly and a detailed inspection of the tested engine to check for fatigue and wear.

(b) The FAA adopted the endurance test schedule for "30-minute power for helicopter turbine engines" or rated 30-minute One-Engine-Inoperative (OEI) power in CAR 13-5, effective on February 12, 1963. The FAA adopted the test schedule for "2½-minute power for helicopter turbine engines" or "rated 2½-minute OEI power" in CAR 13-6, effective on April 22, 1964. This was the last amendment to the CAR-13 regulation prior to the FAA recodification that introduced 14 CFR part 33.

(2) 14 CFR part 33.

a. The FAA issued the new part 33 on February 1, 1965 to replace the airworthiness standards contained in part CAR 13. The technical contents of calibration, endurance, teardown, and general conduct of block tests in CAR 13-6 were the same in the new part 33.

b. In response to the increasing complexity of airframes, engines, and their interfaces, the FAA adopted Amendment 6 to part 33 on October 31, 1974. This amendment was a major revision to the endurance test and related regulations. It added a new § 33.82, and in § 33.87(a) the FAA added an endurance test schedule for supersonic aircraft engines. The FAA also introduced § 33.87(a)(3) to address the allowance for multiple engine tests when all engine parameters could not be held simultaneously at the 100 percent level that was to be certified. The FAA made this change based on its certification experience with high bypass large turbofan engine certifications since 1969. Amendment 6 also changed § 33.99 "General conduct of block tests," by adding requirements for engine service, malfunction, and stoppage during endurance testing. Finally, the FAA also revised §§ 33.85(a), 33.85(b), 33.87(a), and 33.93(a).

c. In 1977, the FAA announced the Aircraft Engine Regulatory Review Program. As part of this initiative, the FAA solicited rule change proposals from the aviation and general communities and conducted a review conference. This conference gave the public the opportunity to discuss outdated regulations and appropriate measures to deal with new technology. The conference resulted in Amendment 10 to part 33, effective on March 26, 1984. This amendment revised § 33.87(a) and added the rated 2½-minute OEI power test schedule to the current requirements.

d. The FAA adopted Amendment 12, effective October 3, 1988, which provided a new test schedule for rated continuous OEI power to the endurance test for rotorcraft turbine engines. Amendment 18, effective August 19, 1996, implemented new 30-second OEI and 2-minute OEI ratings applicable to rotorcraft turbine engines. In this amendment, the FAA revised the calibration test and teardown inspection by adding new paragraphs to cover specific requirements for the ratings. The FAA revised the endurance test by adding a new 2-hour test schedule for the ratings in addition to the 150-hour endurance test required in the existing § 33.87.

e. In summary, the endurance test cycles and conditions are intended to demonstrate engine durability and reliability at extreme operating limits. The basic requirements in § 33.87 regarding test cycles and testing at maximum thrust/power/torque, redline rotor speeds, and engine turbine gas temperatures have not changed substantially since the Amendment 2 version of CAR 13 was issued in 1958, despite numerous regulatory reviews. The requirements for compliance with § 33.87 constitute an inseparable part of the engine durability and operability certification process in part 33 that has provided an acceptable level of safety for aircraft gas turbine engines for more than five decades.

1-2. Definitions.

The following terms have the meaning listed when used in this AC:

Continued airworthiness. The engine is airworthy when it conforms to its type certificate and is in condition for safe operation. See Appendix 10 for an additional discussion of continued airworthiness as related to the teardown inspection criteria.

Engine component. Components, systems, and accessories that are part of the engine type design.

Engine Pressure Ratio (EPR). The ratio between engine exhaust and inlet pressures.

False start. The engine rotor is accelerated by means of a starter and fuel is supplied to the combustors, but the ignition system is not activated.

Flight idle. The steady state engine operation at the minimum rotor speed and thrust or power allowed in flight.

Germane or primary hardware. Germane or primary hardware is the hardware that directly impacts the pass/fail criteria for the given test objectives. Germane hardware should be identified in the test plan submitted for approval to the Aircraft Certification Office/Engine Certification Office (ACO or ECO) or their designees when authorized.

Ground idle. The steady state engine operation on the ground at the minimum rotor speed and thrust or power.

Maximum permissible speed or gas temperature. The highest physical rotor speed or gas temperature that may not be exceeded in operation at any steady-state rating.

Rating power or thrust. The rated takeoff power or thrust at sea level standard day conditions for each rating presented for approval that is also the engine rating power or thrust prescribed in the Type Certificate Data Sheet (TCDS). The takeoff rating power or thrust must be included on the engine identification plate.

Power characteristics. The relationship between engine thrust or power and the engine primary control parameters, typically EPR or the power turbine rotor speed or fan speed (N1).

Rating speed or gas temperature. The rotor speed or gas temperature under the expected conditions that provide the rated thrust or power. The gas temperature must be measured at the location specified in the type design of the engine.

Redline conditions. The engine operating limitations in terms of rotor speeds and gas temperature that are established under part 33. These limitations are commonly referred to as maximum permissible speeds and temperatures in the TCDS for an approved engine rating.

Standard 150-hour endurance test. An endurance test that has complied with § 33.87(a) and completed the series of test runs specified in paragraphs § 33.87(b), (c), (d), (e), (f), or (g).

Start (normal start). The transient process of accelerating a rotor from a stationary condition to idling speed. The starting time and other parameters must be maintained within the engine starting limits specified in the TCDS.

Steady-state condition. The engine operating condition during which its parameters do not vary with time. Parameter variations within the tolerance specified in the operating instructions are permitted.

Test hardware. The parts and components to be certificated and that are assembled to the test engine. Whenever a given piece of hardware deviates from the type design, the applicant should provide a comparison in the test plan of the tested hardware compared to the type design. This comparison is frequently referred to as reconciliation. The applicant must substantiate that the non-type design hardware is still representative of the type design part, and that it will not affect the functioning of any other part or system that depends on the proper functioning of the non-type design part. Applicants may use non-type design parts that are less capable than type design parts in withstanding the rigors of the testing environment, but parts that are more capable than a typical type design part may not be used. The ACO or ECO must approve all non-type design hardware used in a certification test.

Transient. The condition in which engine parameter(s) vary with time between two steady-state conditions. Starting, acceleration, deceleration, and shutdown are examples of transient operation between two steady-state operating conditions.

Transient rotor shaft over-speed or transient gas over-temperature. Transient speed or gas temperature condition at rating during acceleration from idle to rating thrust or power.

Type design hardware. Engine hardware that is presented for certification to comply with the requirements of § 21.31(a), (b), (c), and (e). It is the production engine hardware for which the applicant is seeking 14 CFR part 33 certification.

Vibration signature survey. The vibration survey conducted during pre- and post-endurance tests that records vibration amplitude(s) as a function of engine speed. Engine accelerometers mounted on the engine cases record the vibration characteristics. The data are used to confirm that the vibration levels of the engine and rotors are within acceptable limits specified in the engine installation manual, and that the vibratory signature has not changed significantly from the endurance test.

CHAPTER 2. CALIBRATION TEST.

2-1. Power Characteristics.

a. The power characteristics of the endurance test engine that represent the type design must be established by engine test at sea level standard day conditions. Power characteristics are the relationship between engine thrust or power and the primary control parameters which are typically the engine inlet-to-exhaust pressure ratio (EPR), the exhaust gas temperature, or the power turbine rotor speed (N1).

2-2. General Requirements, § 33.85(a), § 33.85(b), and § 33.85(c).

a. The calibration tests required by § 33.85 establish the engine power characteristics in the type design configuration over its entire operating range of speeds, pressures, and temperatures, and measure any deterioration of the engine caused by the endurance test.

b. To identify the engine thrust or power changes that may occur during the engine endurance test of § 33.87, applicants must establish the thrust or power characteristics of the test engine before and after this endurance test, except for the 30-second and 2-minute ratings (see § 33.85(d)). The engine power characteristics should be determined at sea level pressure and rating temperatures, with no air bleed for aircraft services and with only those accessories installed which are essential for engine functioning, unless the TCDS defines other conditions that are used to determine the engine ratings.

c. Applicants should run the calibration test with a clean inlet and exhaust, and with slave facility hardware similar to a production test cell (e.g., engine cowling, bell mouth, and normal engine control schedules), but without special test equipment such as an inlet screen, pre-swirler or mixer screen. However, this special test equipment may be necessary to run the endurance test itself. The power settings must include the highest power or thrust rating capability of the engine on initial and final power calibrations.

d. The calibration test data must show that following completion of the endurance test the engine is capable of producing its rated power or thrust without exceeding any speed, gas temperature, or operating limits specified in the TCDS.

e. The calibration test measurements may be recorded only when the engine operating condition stabilizes at each rating condition. The only exception is the recording of data at the 30-second and 2-minute OEI rating conditions described in § 33.85(d), during which the gas temperature may not be stabilized at the end of the rating time limit.

2-3. Provisions for 30-second and 2-minute OEI Ratings, § 33.85(d).

a. The extended engine operation at the 30-second OEI and 2-minute OEI ratings during the calibration testing could possibly increase the hardware deterioration beyond what would be demonstrated by the endurance test for the ratings alone. Therefore, the data recorded during the OEI power segments in § 33.87(f) can satisfactorily substantiate the calibration test requirements of these two ratings. However, this data should be recorded during the first and last test cycle to properly represent the pre-test and post-test performance capability of the engine. The following paragraphs in this section provide guidance on how the data from § 33.87 may be used to support the applicant's compliance with § 33.85.

b. The applicant must determine the power characteristics of the 30-second and 2-minute OEI ratings. These power characteristics should include the deterioration determined from the pre-test calibration prior to the endurance test of § 33.87(f) up to and including the third test sequence of 30-second rated power. The power deterioration through the third test sequence should be the best indicator of the worst-case power deterioration that could occur during actual usage of the rating. This data must be included in the Installation Manual to define performance characteristics of the engine.

c. If power deterioration exceeds 10 percent at the 30-second rating over the course of the 2-hour test in § 33.87(f), the applicant must evaluate the mode of deterioration to ensure that the availability of 30-second rated power in service will not be compromised by deterioration variability.

d. In addition to the calibration data from § 33.85(d), any available information from tests in § 33.88, and § 33.90 should also be used to establish the engine characteristics throughout the engine operating envelope.

CHAPTER 3. ENDURANCE TEST.

3-1. General Requirements in § 33.87(a).

a. What is an endurance test? The endurance test is not a simulation of expected in-service operation, but an accelerated severity test intended to demonstrate a minimum level of engine operability and durability within the approved engine ratings and limitations.

(1) The test requirements are to demonstrate that, at the end of the test, the engine is in an airworthy condition and is safe for continued safe operation. This determination must be based on the inspection and maintenance requirements that are defined in the Instructions for Continued Airworthiness (ICA) submitted in compliance with § 33.4. To demonstrate this minimum level of durability and operability, the engine must:

(a) Produce rated takeoff and maximum continuous thrust or power, and OEI rating power for rotorcraft engines, within the engine operating limits.

(b) Demonstrate the engine's: (1) operability from minimum to rated takeoff power or thrust without over temperature, surge, stall or other detrimental occurrences to the engine; and (2) durability while operating up to rated thrust or power or torque, redline rotor speeds and gas temperature, and applying limit loads on accessory drives and mounting attachments.

(c) Demonstrate the maximum compressor bleed air capability for engine and aircraft service use.

(d) Demonstrate satisfactory engine operation at maximum and minimum fuel and hydraulic fluid pressure limit conditions.

(e) Demonstrate satisfactory engine operation at the maximum and minimum lubrication oil pressure limit and temperature limit conditions.

(f) Demonstrate engine starting capability, drainage or expulsion of unwanted fluids in the engine or fuel accumulated after a false start.

(2) The data and results from the endurance test may also be used to show compliance to other part 33 regulations. These regulations may include, but are not limited to:

(a) Engine power and thrust settings in § 33.8(b).

(b) Fluid drainage demonstration in § 33.17(e).

(c) Accessory attachments, § 33.25.

(d) Bleed air systems, § 33.66, and bleed and power extraction in § 33.89.

(e) Adequacy of fuel system in § 33.67(a) and (b), and lubrication system, § 33.71(a) and (b).

(f) Hydraulic actuating systems, § 33.72.

(g) Power or thrust response, § 33.73; and acceleration time in § 33.89(a).

(h) Engine-propeller system tests for turbopropeller engines in § 33.95.

(i) Thrust reverser test in § 33.97.

(j) Fuel venting emissions in Subpart B of Part 34.

(3) The general endurance test requirements specified in § 33.82, the calibration test in § 33.85, the endurance test in § 33.87, the teardown inspection in § 33.93, and the general conduct of block test requirements specified in § 33.99 form integral parts of the endurance testing of the engine. However, some systems cannot be adequately substantiated by endurance testing in accordance with the requirements of § 33.87. Applicants must complete additional component tests for those systems under the requirements defined in § 33.91 to establish that the components are able to function reliably in all normally anticipated engine operating and atmospheric conditions. For example, the main accessory gearbox normally requires both an endurance rig test and the engine endurance test to demonstrate its operability and durability. The gearbox must be rig tested at the maximum rating pad loads and power extraction loads. Test conditions must be maintained at the extreme operating and environmental conditions to be approved for engine operation. These extreme conditions are normally outside of the range of engine endurance test conditions.

(4) The endurance test must include at least 150 hours of testing in accordance with the series of test schedules specified in § 33.87(b), (c), (d), (e), and (g), depending upon the type and contemplated use of the engine. The prescribed 6-hour test sequence must be conducted 25 times to complete the required 150 hours of operation, unless a different test sequence is approved by the ACO or ECO. For engines seeking the 30-second OEI and 2-minute OEI ratings, applicants must conduct an additional 2-hour test in accordance with the test schedule in § 33.87(f), for a total test time of at least 152 hours. Appendix 13 presents the graphical skylines of endurance test schedules specified in § 33.87(b), (c), (d), (e), and (f).

(5) The limits included in the engine TCDS as required by § 33.7 must be less than or equal to those demonstrated during the endurance test for each engine rating condition evaluated.

b. Endurance test plan requirements.

(1) The applicant must prepare a test plan for the endurance test. This test plan must be submitted early enough to allow the ACO or ECO time to review and approve the plan prior to the start of the test. At a minimum, the plan should contain:

(a) the applicable part 33 section or sections;
(b) a description of the germane or primary hardware to be tested;
(c) a description of properly calibrated test equipment necessary to conduct the test;
(d) conformity requirements of the test item(s) and test setup;
(e) the test procedure with sufficient detail to fully describe the method of compliance; and
(f) a definition of the pass/fail criteria.

(2) See Appendix 8 for additional information about test plan requirements.

c. Test engine configuration.

(1) The configuration of the test engine must substantially conform to the final type design. The applicant must disclose all non-type design hardware, software, and components, and provide acceptable evidence that it will not adversely affect the outcome of the test. The standard type design configuration of certain type of engines (e.g., large turbofan engines) may preclude simultaneous operation at maximum permissible rotor speeds and gas temperatures while maintaining maximum rated thrust, power, or torque as required by § 33.87(a)(3). Modification of certain test equipment, engine configurations, and test sequences may be necessary to run the test at simultaneous triple redline conditions. The applicant must provide a technical substantiation that, with any such modifications, the test engine still properly represents the operability and durability characteristics of a typical type design engine and complies with the § 33.87 requirements.

(2) Appendix 4 shows some methods that may be employed for matching engine speeds and temperatures for the desired test conditions.

(3) The certifying ACO or ECO issues a Type Inspection Authorization (TIA) that authorizes the conformity inspection to ensure that the test engine conforms to the type design to be certificated. It is the responsibility of the certifying office to identify the test engine configuration, germane hardware for the test, approved non-type design hardware, and the parts that should be subject to detailed inspection. Certain test hardware may be subject to pre-assembly conformity inspection as applicable. The extent of the pre-assembly inspections and the data recording is determined by the ACO or ECO.

(4) The applicant must provide information on aircraft supplied components that will be mounted on or driven by the engine, and that are not part of engine type design. These components may affect the operation of the engine and thus affect the outcome of the endurance test. An example of this type of information is the load imposed by each accessory. The applicant may install the component or simulating loading device on the test engine when approved by the ACO or ECO.

(5) Some engine components such as large integrated starter generators may require high levels of horsepower extraction from the engine core rotor through the gearbox. High levels of horsepower extraction from the engine core have the potential to stall the engine at some engine power levels, such as flight idle or lower, and also possibly during transient operations. To determine the level of horsepower extraction appropriate for the various segments of the endurance test, the applicant must consider 1) the effects of high levels of horsepower extraction on engine stability, operating characteristics, and the durability of the power extraction hardware; and 2) the effects of electrical load transients at critical engine operating conditions (including idle).

(6) See Appendix 5 for more information on conformity inspections.

d. Engine component and test equipment calibrations.

(1) The adjustment setting and functioning characteristic of each engine component that can be adjusted independently of installation on the engine must be established and recorded before and after the endurance test as required by § 33.82 and § 33.93(a)(1), respectively. These components may include, but are not limited to, the control system, pumps, actuators, heat exchangers, and valves. During the endurance test, all components must operate in a manner consistent with both the type design and the engine operating instructions.

(2) All test equipment and measuring instrumentation necessary to operate and monitor the engine and the test facility should be calibrated to FAA approved standards prior to and after the tests. All engine components should be calibrated per their component calibration schedules.

e. Pre- and post-endurance testing.

(1) Section 33.63, Vibration, and § 33.4, Instruction for Continued Airworthiness, require that any engine part be free from excessive stress caused by excessive vibration throughout its operating life. The substantiation that the engine is free from excessive vibration over its operating range can be conveniently accomplished during the endurance testing by obtaining vibration surveys, and we recommend it. For these tests, applicants must conduct and record a pre-endurance vibration signature survey over the entire engine operating range including transient and steady state operations to determine if the engine vibration is within the allowable limits specified in the engine Installation Manual (IM). Applicants must also conduct and record a post-endurance vibration survey to verify that the engine vibration characteristics are still at or below the allowable limits in the IM. The post-test vibration signatures should not show a significant change from the data recorded during the pre-endurance test survey. Applicants must satisfactorily address any change in the engine vibration characteristics.

(2) Fuel, oil, and hydraulic fluid that will be used during the endurance test must be consistent with those fluids that will be specified in the TCDS. The actual fuel, oil and hydraulic fluids used for the endurance test, including any additives, must be justified if they are different in any way from those specified for certification. Applicants must conduct a pre-test analysis of fuel and oil to verify that those fluids meet the appropriate specifications. Oil consumption must be monitored during the test and must be within allowable limits prescribed in the engine operating document. Applicants must make a post-test analysis of engine fuel and oil to verify that these fluids adhered to the appropriate specifications throughout the testing.

f. Servicing and repairs during the endurance test.

(1) During the endurance tests, only servicing and minor repairs may be permitted in accordance with the service and maintenance instructions contained in the ICA. Repairs that are normally required to aid in the engine reassembly after overhaul, such as drive shaft or stub shaft mating surface plating for assembly, may be considered minor repairs. If the frequency of service or the number of stops due to engine malfunction is excessive, or if a major repair or replacement of a part is found necessary during the endurance test or as the result of findings from the teardown inspection, the applicant must subject the engine or its parts to additional test(s) or penalty test run(s) that the ACO or ECO finds necessary. If an engine part fails during the test, the applicant must determine the cause of failure and must assess the effect on the durability and operability of the engine. Any corrective actions must be determined and substantiated prior to resuming the test.

g. Endurance test report requirements.

(1) The certification test report(s) must contain sufficient data (for example, plots and tabulations) and discussion to substantiate that the engine has successfully demonstrated compliance to all requirements of the calibration testing, endurance testing, and the teardown inspection regulations. In addition to test results and analyses of data, the report must contain a listing of engine faults and a complete description of all hardware distress; including any corrective actions that were implemented or are planned for implementation after the test.

(2) The report must also provide comparative tabulations (test results versus the § 33.87 requirements) of (a) the total time spent at each test cycle part and power condition, and (b) the minimum certificated parameter values obtained during each of those test cycle parts.

(3) Applicants should include a trace of one "typical" non-bleed cycle § 33.87(b)(1) segment and one § 33.87(b)(5) segment to show engine stabilization at or above the required operating parameter values to be certificated. Applicants must document and substantiate any deviations or exceptions to the test requirements.

(4) Appendix 11 provides additional information on test report requirements.

3-2. Specific Requirements in § 33.87(a)(1) through (a)(8).

a. Test sequence, § 33.87(a)(1). Applicants should follow the 6-hour test cycle sequence prescribed in § 33.87(b) through (f). However, due to the recognized difficulty with readjusting the engine and test facility configuration to run all test segments sequentially, the ACO or ECO may allow test segments to be run out of their normal sequence. In this case the applicant must provide sufficient technical justification substantiating that any changes to the published test sequences do not lessen the severity of the prescribed §33.87 sequences.

b. Automatic control of the engine, § 33.87(a)(2). Any automatic engine control that is part of the engine must control the engine operation during the endurance test except for operations where manual, instead of automatic control, is permitted or where manual control is otherwise specified for a particular test run.

c. Endurance test at redline conditions, § 33.87(a)(3).

(1) During the endurance test, the engine thrust or power, gas temperature, and rotor shaft rotational speed(s) must simultaneously maintain at least 100 percent of the values associated with the particular engine operation being tested. This means that applicants must run the endurance test to the maximum permissible rotor speeds, gas temperature, and rated power or thrust values that will be included in the engine TCDS. These parameters must achieve steady-state operating values with minimal fluctuations or cyclic type variations, where any minimum variations remain at or above the 100 percent value.

(2) However, the requirements for power or thrust, or rotor speeds, may be less than 100 percent during the maximum air bleed test as permitted under § 33.87(a)(5). When all engine parameters (thrust, power, or torque, speeds, and gas temperature) cannot be held at redline conditions during the endurance test, applicants may conduct more than one test on the same set of engine hardware that is to be presented for certification. See Appendix 2 for additional information on an acceptable endurance test cycle for multiple engine tests.

(3) The test engine must maintain rated power or thrust, which is the minimum physical power or thrust meeting the definition in part 1.1 and the requirements of § 33.7(a) and (c) and § 33.8(b) at each rating condition during the endurance test. The rated power or thrust value that is specified in the TCDS and marked on the engine data plate is normally determined at sea level, static, standard day pressure (14.696 psia or 101.3254 kilopascals) and rating air temperature, with no customer bleed or horsepower extraction, an ideal inlet (100 percent ram recovery), and engine inlet and exhaust test hardware as specified in the TCDS. However, other rating reference conditions may be acceptable provided that the applicant provides proper substantiation and defines those conditions in the TCDS.

(4) If the minimum physical thrust requirement cannot be achieved, then the applicant must provide a rationale or data justifying that any difference between a reduced thrust level that can be achieved and the rating power or thrust is inconsequential to a demonstration of the durability of those engine parts that are subject to thrust loads.

(5) The power or thrust or rotor speed reduction permitted under § 33.87(a)(5) during maximum bleed air test runs must not be more than the effect due to the air bleed used. However, the gas temperature must always be maintained at least 100 percent of the maximum permissible value to be certified.

(6) The normal operating characteristics of certain turbine engines may preclude simultaneous operation at multiple redline conditions and rated power or thrust. In this case, the applicant may propose more than one endurance test on the same engine build to satisfy the requirement of § 33.87(a)(3).

(7) In the case where the applicant proposes more than one endurance test, the second test should be run at the rated thrust, with at least two redline conditions maintained simultaneously.

(8) Appendix 2 presents an example of a two-part test that is acceptable to the FAA.

(9) For turbopropeller and turboshaft engines, the approval of torque and output shaft speed limits will be based on those limits demonstrated simultaneously during the endurance test.

d. Fuel and lubricating oil for endurance test, § 33.87(a)(4).

(1) The fuel, lubricating oil, and hydraulic fluid used for the endurance test must conform to the requirements that are defined in the TCDS and IM.

(2) Applicants must monitor oil consumption during the endurance test and summarize the results in the certification report. Applicants must take oil samples during the test and analyze these samples to evaluate oil property degradation and the presence of any metallic particles and contamination that may indicate a deterioration of one or more parts. Any evidence of oil property degradation or metallic particles must be disclosed in the test report. The oil consumption rate should be consistent with the limit in the operating manual.

(3) Applicants should take fuel samples from the fuel supply line during the initial and final power or thrust calibration runs and at least once during the endurance test. The fuel analysis should include at least specific gravity, heating value, and viscosity. The fuel characteristics must be consistent throughout the test, and must conform to the fuel type specifications.

e. Maximum air bleed testing, § 33.87(a)(5).

(1) Section 33.87(a)(3) requires the engine thrust or power, gas temperature, and rotor shaft rotational speed(s) to be maintained at least at 100 percent of their redline values simultaneously. But during the maximum air bleed test runs, § 33.87(a)(5) permits the power, thrust, or rotor speeds to be less than their 100 percent redline values. Gas temperature, however, must still be maintained at the 100 percent redline value. Any power or thrust or rotor shaft rotational speed reduction must not exceed reductions that would be due to bleed extraction if the engine were in the type design configuration.

(2) Applicants must specify in the test plan the total compressor bleed flow rate limit and the proportional split from each compressor bleed port (on engines having multiple bleed ports). Examples of aircraft service bleed uses are wing/cowling anti-ice, aircraft environmental control systems (e.g., air conditioning packs), and engine cross-bleed starting. The maximum allowable bleed flow rate and the individual bleed port flow limits that are specified in the TCDS and in the § 33.5 manual, respectively, must be demonstrated during the endurance test.

(3) The maximum permissible total air bleed from the engine must be used during at least 20 percent of the endurance test runs (e.g., 5 of the 25 prescribed 6-hour test sequences). On engines with multiple bleed ports, the bleed flows from each port must be extracted simultaneously at rates consistent with normal engine operation and design intent, and the combined extraction must equal the total bleed flow limit at the rating condition being tested.

(4) During the test runs with maximum air bleed, the power or thrust and/or the rotor speed(s) may be less than 100 percent of the value associated with the test condition provided the following conditions are met:

(a) Any power or thrust or rotor shaft rotational speed reduction must not exceed reductions that would be due to bleed extraction if the engine were in the type design configuration.

(b) The gas temperature must be maintained at least at 100 percent of the redline value at each power level to be certified.

(5) The secondary airflow system, including the amount of air bleed for internal engine hardware cooling, should function as specified in the type design.

f. Accessory drive and mounting attachment loadings, § 33.87(a)(6).

(1) Each accessory drive and mounting attachment must be loaded throughout the tests, either with the equipment listed in the applicant's assembly drawing or with slave units of a similar type.

(2) For any accessory drive and mounting attachments that cannot be adequately loaded or substantiated by the endurance test, applicants must conduct additional component test(s) on a rig in accordance with § 33.87(a)(6) and § 33.91 (Component test) to establish that the components can function reliably in all anticipated engine operating and atmospheric conditions. For example, the main accessory gearbox normally requires both gearbox endurance rig testing and the engine endurance testing to show compliance with § 33.87. When a gearbox rig test is necessary, it is generally run at maximum drive-pad loading and at the extreme operating and environmental conditions to be approved. These conditions are normally outside of the engine endurance test set-up capability. In this case, during the engine endurance test, the

gearbox drive position may have actual or non-functioning slave hardware mounted representing the weight and overhung moment.

g. Redline gas temperature or oil temperature exclusion, and fuel, oil, and hydraulic fluid tests, § 33.87(a)(7).

(1) Explanation.

(a) Section 33.87(a)(7) requires the gas temperature and the oil inlet temperature to be maintained at the limiting or redline values to be certificated, except where the test periods are not longer than 5 minutes and do not allow stabilization.

(b) At least one test cycle must be run with fuel, oil, and hydraulic fluid at the minimum pressure limit, and at least one test cycle must be run with fuel, oil, and hydraulic fluid at the maximum pressure limit. During each of these two cycles, the fuel, oil, and hydraulic fluid pressures must be maintained at their maximum or minimum values simultaneously. The fluid temperature may be artificially adjusted by a test facility heat exchanger to achieve the desired value.

(2) Guidance.

(a) Section 33.87(a)(7) provides an exception from the requirement for endurance testing at limiting or redline values for gas temperature or oil inlet temperature at any rated power or thrust where the test periods are not longer than 5 minutes and do not allow stabilization. To satisfy the requirements of this exception, the applicant must substantiate that these are the normal engine operating characteristics in the type design configuration

(b) The term “stabilization” as used in this AC means that engine operating parameters such as oil temperature or gas temperature have achieved steady-state operating values with minimal fluctuations or cyclic type variations, and where any minimum variations remain at or above the 100 percent value to be certificated.

(c) The phrase “*where test periods are not longer than 5 minutes and do not allow stabilization*” means that, at the end of any test period of 5 minutes or less duration, if the type design characteristics of the engine are such that either the oil or exhaust gas temperature are still increasing and have not yet achieved their limiting value, then the parameter is not required to achieve the limiting or 100 percent value during that test period.

(d) The time window for determining whether the parameter has stabilized starts when the throttle is moved from the minimum idle position to the takeoff power position. The throttle must be moved from the minimum idle position to the takeoff power position within one second.

(e) However, the engine gas temperature generally does not require a 5-minute run period to stabilize at the redline value. Therefore, the exclusion from the § 33.87(a)(3) requirement to maintain gas temperature at the 100 percent or redline value to be certificated does not normally apply to the 5 minute or longer runs at takeoff power or thrust during the § 33.87 (b)(1) and (b)(2)(ii) test segments. This means that the gas temperature must be stabilized at or above the 100 percent redline value to be certificated before those 5-minute and 30-minute periods, respectively, can begin.

(f) Before the applicant can utilize the gas temperature stabilization exclusion for the 30-second test run segments in § 33.87 (b)(5), the following conditions apply:

1. The applicant must supply data in the test plan and test report (such as a plot of gas temperature vs. time for a typical non-bleed cycle acceleration from idle to takeoff power or thrust for a type design engine) showing that the time required to achieve gas temperature stabilization at or above the 100 percent value exceeds a 30 second duration in the type design configuration.

2. If this data will not be available until the engine is installed in the endurance test facilities, then the test plan should at least contain a prediction of the engine acceleration characteristics and a statement that the § 33.87(a)(7) exclusion will be sought for the 30-second test run segments of § 33.87 (b)(5). The actual acceleration vs. time plots must then be included in the test report.

3. Even if the gas temperature stabilization exclusion is accepted by the ACO or ECO, applicants must still run the test in its entirety at rated thrust with rotor speeds (i.e., N1 and N2) at or above redline values. Applicants should maintain the same test configuration and acceleration rate of the engine as in the § 33.87(b)(1) and (b)(2)(ii) periods.

(c) If the applicant demonstrates that the gas temperature stabilization exclusion is permitted during the 30-second test run segments in § 33.87 (b)(5), then the total run time that can be claimed at takeoff redline gas temperature must be reduced by the 1.25 hour duration of these segments. Therefore, the total run time that may be claimed in § 33.87(b) at the redline gas temperature condition is reduced to 17.5 hours (which accounts for the § 33.87(b)(1) and (2)(ii) segments only) from 18.75 hours (which would have included the § 33.87 (b)(5) segments).

(d) The engine must be qualified with the same exhaust gas temperature stabilization characteristics that the engine will display in service. The engine must be controlled using the same exhaust gas temperature measurement system that it will use in service.

h. Transient over-speed, over-temperature, and over-torque demonstrations for a maximum period of 30 seconds, §°33.87(a)(8).

(1) Requested transient conditions that are being certified as part of an engine rating limitation must be demonstrated during the acceleration cycles required by § 33.87(b) through (g), as applicable.

(2) AC 33-2B describes a transient as a rotor speed or gas temperature value that exceeds the approved limit for a period of 30 seconds or less for transients associated with the takeoff, maximum continuous, continuous OEI, and 30-minute OEI ratings. Rotor speed or gas temperature transients associated with the 2.5-minute, 2-minute, and 30-second OEI ratings should be limited to very brief periods, on the order of 5 to 10 seconds maximum.

(3) All transient limits may not be used as supplementary limitations, regardless of their duration, for engine power setting purposes. The transient limits of shaft over-speed and gas over-temperature prescribed in § 33.7(c)(14) and (c)(15), respectively, are intended for a transitory overshoot before reaching steady state limit values during engine acceleration in normal operation.

(4) If the number of occurrences of 30-second transient conditions is limited in normal engine operation, then the same number of accelerations required by § 33.87(b) through (g) must be made to the limiting transient conditions during the endurance test. If the number of occurrences of the 30-second transient conditions is not limited in normal engine operation, then at least 50 percent of the required accelerations must be made to the limiting transient conditions. For example, §§ 33.87(b)(1), (b)(2), and (b)(5) require a total of 310 accelerations to take off power or thrust.

(a) Therefore, to certify a 30-second takeoff transient gas temperature rating (in addition to the steady state redline gas temperature rating) for a limited number of excursions, the gas temperature achieved on that same number of accelerations must be equal to or greater than the intended transient limit for a continuous duration of 30 seconds or longer.

(b) Similarly, to certify a 30-second takeoff transient gas temperature rating for an un-limited number of excursions, the gas temperature achieved on a minimum of 155 (half of the 310 total) of the required accelerations to take off power or thrust must be equal to or greater than the intended transient gas temperature limit for a continuous duration of 30 seconds or longer.

(5) We recommend conducting the transient condition test runs during the accelerations to the 5-minute takeoff test segments of § 33.87(b)(1) and during the accelerations to the 30-minute takeoff test segments of § 33.87(b) (2)(ii)). We do not recommend running the transient tests during the 30-second segments of the § 33.87(b)(5) test sequence, unless the transient duration to be certified is extremely short.

(6) The transient shaft over-torque limit is not specified in either § 33.7(c) or § 33.87(a)(8). However, FAA policy, as stated in AC 33-2B, requires that the transient

over-torque limit approval, as with rotor speed and gas temperature limit approvals, must be based on the extent of the transient excursions demonstrated under § 33.87(a)(8) during the endurance test. The approval of the transient over-torque and transient over-speed limits must be based on the limits (value and time) demonstrated simultaneously during the endurance test.

(7) See Appendix 3 for the guidance for 2-minute transient over-temperature approval.

i. Additional test requirements for supersonic aircraft engines, § 33.87(a)(9). We may address the test requirements for supersonic aircraft engines in a future AC.

3-3. <u>Special topics</u>.

a. Endurance test for amended TC and major engineering changes.

(1) The endurance test must be considered as an essential part of all engine type certifications. This test may also be used to substantiate amended TCs, engineering changes, repairs, and PMAs.

(2) See Appendix 1 for guidance on compliance with § 33.87 for amended engine TCs and major engineering changes.

b. Endurance test cycles for multiple engine testing.

(1) When all engine parameters (thrust/ power/torque, speed, and gas temperature) cannot be held at redline conditions simultaneously during the endurance test, then more than one test may be conducted on the same engine hardware to be presented for certification.

(2) Appendix 2 presents an example of a two-part endurance test that may be acceptable to the FAA.

3-4. <u>Endurance Test Schedule, § 33.87(b), for Engines Other Than Certain Rotorcraft Engines</u>.

a. Explanation.

(1) This 6-hour endurance cycle must be performed 25 times for a total of 150 hours of testing on all turbojet, turbofan, and turbopropeller engines. This cycle is also required for rotorcraft turbine engines, except those rotorcraft engines for which the 30-minute OEI rating, continuous OEI rating, or 2½-minute OEI rating are desired. The 150 hours of testing time will accumulate 18.75 hours at takeoff power rating, 45 hours at maximum continuous power rating, 62.5 hours at incremental power step time period, and 23.75 hours at minimum idle condition. This six-hour test cycle for § 33.87(b) is presented graphically in Appendix 13, Figure 1.

(2) The test engine must maintain rated power or thrust, which is the minimum physical power or thrust meeting the rating definition in part 1.1 and the requirements of § 33.7(a) and (c) and § 33.8(b) at each rating condition during the endurance test. The rated thrust or power value that the engine is expected to produce in meeting the above requirements should be based on the following reference conditions: sea level, static, standard day pressure (14.696 psia or 101.3254 kilopascals) and rating air temperature; with customer bleed or horsepower extraction amounts, inlet efficiency, and engine inlet and exhaust test hardware as specified in the TCDS.

(a) The minimum physical power or thrust value required to meet the above requirements may be adjusted from the actual testing conditions to the conditions specified in the TCDS under which the rated power or thrust is determined. However, adjustments to the measured power or thrust to account for losses due to special test hardware that is incidental only to the conduct of the test are not allowed. Special test hardware include, for example, a fan inlet or exit guide vanes, an adjustable fan exhaust nozzle, or an altitude test cell that may be required to achieve simultaneous rated thrust, speed, and gas temperature redline conditions. When the minimum physical power or thrust target cannot be achieved, the applicant must provide substantiating data to justify that any shortfall is inconsequential to a demonstration of the durability of those engine parts that are subject to thrust loads.

(b) For all test conditions, the parameters relevant to the purpose of the test should be agreed to and recorded at appropriate times during the test. Except during transient conditions, the engine should be allowed to stabilize before data are recorded.

(3) The applicable requirements in §§ 33.87(a)(1) through (a)(8) must be complied with in running the test according to this schedule.

b. Guidance. The test must include the following runs defined in §§ 33.87(b)(1) through (b)(6), unless an alternate test sequence is otherwise approved by the ACO or ECO.

(1) Section 33.87(b)(1), Takeoff and idling. The intent of this part is to expose the engine hardware to the maximum cyclic thermal and mechanical stresses associated with accelerations and decelerations between the lowest operating power or thrust condition (i.e., minimum idle) and the maximum operating power or thrust condition (i.e., takeoff). All certifying parameters (such as rated thrust/power and/or rated torque for rotorcraft and turbo-propeller engines, maximum permissible speeds and gas temperature) must reach redline values at takeoff and must be maintained for 5 minutes. Similarly, power or thrust must be maintained at the minimum idle condition for 5 minutes following stabilization.

(a) Applicants must conduct one hour of alternate five-minute periods at rated takeoff power or thrust and at minimum idle power or thrust with the following requirements:

1. Prior to beginning any of the 5-minute takeoff segments, the physical rotor speeds, indicated gas temperature, and physical thrust or power must be at or above the takeoff power values to be certified per § 33.87(a)(3), unless the applicant elects to run more than one 150-hour endurance test. See Appendix 2 for multiple endurance test requirements.

2. Prior to beginning any of the 5-minute minimum idle parts of the test run, the physical rotor speeds, and physical power or thrust must be at or below the minimum idle power operating values to be certified. While the indicated gas temperature may continue to cool after the 5-minute minimum idle part has begun, it must be stabilized at the nominal minimum idle power operating temperature consistent with the ambient test conditions prior to beginning the next acceleration to the takeoff thrust or power level.

(b) For engines with augmented takeoff thrust ratings that involve an increase in turbine inlet temperature, rotor speed, or shaft power, all test runs at takeoff power or thrust must be at the augmented takeoff rating. However, for engines with augmented takeoff thrust ratings that do not materially increase operating severity: (1) if the usage of the rating is not limited, all takeoff runs must be made at the augmented rating; and, (2) if the usage of the rating is limited, the limited number of runs conducted at the augmented rating must be made at the augmented rating thrust.

(c) In complying with § 33.87(b)(1), the power-control lever must be moved from one extreme position to the other in one second or less. However, if different regimes of control operations are incorporated, such as separate stops or detents in the power-control level for another rating which is incorporated between idle and takeoff thrust or power, and which necessitates scheduling of the power-control lever motion in going from one extreme position to the other, then a longer period of time is acceptable, but not more than two seconds.

(d) All accelerations must start from the minimum idle power or thrust, and all decelerations must return to the minimum idle power or thrust.

(2) Section 33.87(b)(2) and (b)(3), Rated maximum continuous and takeoff thrust or power.

(a) In complying with these two paragraphs, the engine must run 15 of the 25 six-hour endurance test cycles at the rated maximum continuous thrust or power for two hours during each cycle. The engine must run the remaining 10 of the 25 six-hour endurance test cycles at the rated takeoff power or thrust for 30 minutes followed immediately by running at maximum continuous power or thrust for1.5 hours during each test cycle.

(b) Prior to beginning the test run at either the maximum continuous rating or the takeoff rating, the physical rotor speeds, indicated gas temperature, and physical thrust or power must be at or above the redline values for each rating to be certificated.

(c) If the applicant does not plan to define redline rotor speeds for the maximum continuous rating, then the takeoff redline rotor speeds will also be the required redline rotor speeds for the maximum continuous rating segments.

(3) Section 33.87(b)(4) Incremental cruise power and thrust.

(a) In complying with this subparagraph, the applicant must run all 25 six-hour test cycles for 2 hours and 30 minutes each, at the successive power lever positions corresponding to at least 15 approximately equal speed and time increments between maximum continuous engine rotational speed and minimum idle rotational speed. However, if the engine exhibits significant peak vibration anywhere between minimum idle and maximum continuous rating conditions, the applicant must increase the number of increments to increase the amount of running time made while subject to the peak vibrations, up to not more than 50 percent of the total time spent in incremental running. For engines operating at constant rotor speed, thrust and power may be varied in place of rotor speed.

1. If the applicant finds any significant resonance within the operating range of the engine, then the relevant parts or components should be subject to sufficient vibration running time at, or close to, the resonance peak speed. The vibration characteristic data for each rotor system may be obtained from the vibration test conducted in compliance with § 33.83. The running time allocated for any peak vibration must be sufficient to accumulate at least minimum vibration cycles for endurance limit, which is material dependent. The recommended minimum number of cycles is 10 million cycles for iron and nickel base ally; 30 million cycles for non-ferrous alloys; and 90 million cycles for titanium alloys. The required dwell time spent at each selected speed depends on the frequency of the vibration resonance. The test time can be calculated by dividing the number of cycles by the frequency.

2. The relevant engine parts or components for vibration dwell consideration under § 33.87(b)(4) should include internal and external components of the engine, such as blades, stators, turbine or compressor assemblies, pumps, and oil tank.

(4) Section 33.87 (b)(5) Thirty minutes of accelerations and deceleration runs.

(a) In complying with this paragraph, all 25 six-hour endurance test cycles must contain one 30-minute run per cycle consisting of alternating 30-second periods at rated takeoff thrust/power immediately followed by 4.5 minutes at idling thrust or power.

1. All accelerations must start from minimum idle thrust or power, and all decelerations must return to minimum idle thrust or power. During runs at rated power or thrust, if the redline gas temperature is expected to stabilize within a 30-second

period, then the physical speeds, indicated gas temperature, and physical thrust or power must be at or above the redline values and must be maintained for at least 30 seconds as required by § 33.87(a)(3). If the redline gas temperature does not stabilize, then only the rated takeoff power or thrust and rotor speeds need be maintained at or above their 100 percent values to be certified during each 30-second period. The power lever control movement requirements specified in paragraph 3-4.b.1(d) of this AC must be followed for all test runs.

2. Prior to beginning any of the 4.5-minute minimum idle parts of the test run, the physical speeds, and physical power or thrust must be at or below the proposed minimum idle power operating level. While the indicated gas temperature may continue to cool after the 4.5-minute minimum idle run part has begun, it must be stabilized at the nominal idle power operating temperature prior to beginning the next acceleration to the takeoff thrust or power level.

(b) Section 33.87(a)(7) permits exclusion of test runs at redline gas temperature or oil inlet temperatures as required by § 33.87(a)(3) for any rated thrust or power condition when the test periods are not longer than 5 minutes and these parameters do not stabilize during the periods. Experience has shown that the gas temperature of certain larger turbine engines does not stabilize during these § 33.87(b)(5) 30-second takeoff runs. The applicant for these engines may elect to comply with this option. However, if this part of the test does not run to redline temperature, then the total steady state run time required at takeoff redline gas temperature will be 17.5 hours.

1. Even if the oil or gas temperature stabilization exclusion in compliance with § 33.87(b)(5) can be substantiated, § 33.87(b)(5) must still be run in its entirety with rotor speeds and thrust or power at or above the 100 percent values to be certificated. Additionally, the engine test configuration and the acceleration rate of the engine are expected to remain the same as during the § 33.87(b)(1) and (b)(2)(ii) periods.

(5) Section 33.87(b)(6) Starts.

(a) The purpose of an engine start demonstration on a full scale engine is to show that normal starts can be accomplished without exceeding the maximum starting temperature limit or causing engine hardware distress following (1) an extended period of engine shutdown; (2) a false start; (3) minimum fuel drainage time or engine motoring time to purge accumulated fuel in the engine; or (4) a short period of engine shutdown.

(b) One hundred engine starts must be conducted to satisfy the requirements of this paragraph. These one hundred starts consist of:

1. Twenty-five normal starts preceded by a minimum two-hour shutdown.

2. A least ten false engine starts, each time pausing for the applicant's specified minimum fuel drainage time before attempting a normal start.

3. Ten normal restarts preceded by a maximum 15-minute shutdown period. These starts are required to demonstrate the engine capability to purge unwanted fuel before energizing the ignition system.

4. Fifty-five additional normal starts.

(c) A normal start is measured from the initial indication of core rotor speed until stable ground idle speed (core rotor) is reached. The normal start must follow the ground start procedure as specified in the engine IM.

(d) A false start is conducted as the engine motors on the starter for the maximum light-off time period, while leaving the igniter deactivated. At the end of this time period, the starter is then disengaged and the power level is commanded to the fuel cutoff position. After the engine comes to a complete stop, a normal engine start is made. Prior to a normal start attempt, the residual fuel in the engine may be purged by motoring or drainage for the minimum time period. The maximum light-off time, maximum core rotor speed for starting, and minimum time required for motoring and fuel drainage used must adhere to the values specified in the IM.

(e) The remaining 55 normal starts in (b)4 above should be preceded by shutdown periods which are greater than 15 minutes but less than 2 hours. These starts may be made anytime both during and after the endurance test.

(f) After each of the starting demonstrations, the engine must show that all following normal starts can be accomplished without any abnormal indications, and without exceeding the maximum starting temperature limit specified in the IM. Any engine hardware distress will be examined as part of teardown inspection. However, if any hardware distress is obvious, or suspected as a result of engine performance checks during test runs, the distress must be investigated before continuing the endurance test.

3-5. Endurance Test Schedule, § 33.87(c), for rotorcraft engines for which a 30-minute OEI power rating is desired.

a. Guidance. This schedule is required for rotorcraft engines for which a 30-minute OEI power rating is desired. The schedule is the same as § 33.87(b), except that the ten 30-minute takeoff power segments in § 33.87(b)(2)(ii) and the fifteen 30-minute maximum continuous power segments in § 33.87(b)(2)(i) are replaced by 25 applications at a 30-minute OEI rating power. The test must include the sequential test runs defined in § 33.87(c)(1) through (c)(6), unless the test sequence is otherwise approved by the ACO or ECO. The required minimum physical power and general endurance test requirements for § 33.87(b) described in paragraphs 3-4.a.(2) and (3) of this AC are applicable to this test schedule.

b. Section 33.87(c)(1), Takeoff and idling. The guidance is identical to that provided for § 33.87(b)(1) under "Guidance" in paragraph 3-4.b.(1) of this AC.

c. Section 33.87(c)(2), Rated 30-minute OEI power.

(1) In complying with this paragraph, 25 six-hour endurance test cycles must be run at rated 30-minute OEI power for 30 minutes each after completing the sixth test sequence at rated takeoff power of § 33.87(c)(1).

(2) The acceleration must start from minimum idle power, and the deceleration must return to maximum continuous power after this test sequence. All limit parameters (rated power, maximum torque, maximum permissible rotor speeds, and gas temperature) must be maintained at 30-minute OEI rating redline values for 30 minutes at the rating.

d. Section 33.87(c)(3) Rated maximum continuous power.

(1) In complying with this paragraph, 25 six-hour endurance test cycles must be run at rated maximum continuous power for 2 hours each after completing the test sequence at rated 30-minute OEI power of § 33.87(c)(2).

(2) All limit parameters (rated power, maximum torque, redline speeds and gas temperature) must be maintained at maximum continuous rating power values for 2 hours.

e. Sections 33.87(c)(4) Incremental cruise power, (c)(5) Acceleration and deceleration runs, and (c)(6), Starts. The guidance for these three paragraphs is identical to that described in §§ 33.87(b)(4), (b)(5) and (b)(6), respectively, except that for the "Incremental cruise power" paragraph the run time and its speed and time increments are 2 hours and not less than 12 increments instead of the 2.5 hours and 15 increments of § 33.87(b)(4).

f. The 150 hours of testing time consists of 13.75 hours at the takeoff power rating, 12.5 hours at the 30-minute OEI power rating, 37.5 hours at the maximum continuous power rating, 62.5 hours at the incremental power step time period, and 23.75 hours at the minimum idle condition.

g. See Figure 3 in Appendix 13 for a graphical presentation of the § 33.87(c) test schedule.

3-6. <u>Endurance Test Schedule, § 33.87(d), for rotorcraft engines for which a continuous OEI rating is desired</u>.

a. Explanation. This schedule is required for rotorcraft engines for which a continuous OEI power rating is desired. The schedule is the same as § 33.87(b), except that a one-hour test run at continuous OEI rating power replaces the one-hour of maximum continuous time in each of the § 33.87(b)(3) test runs. The test must include the sequential runs in § 33.87(d)(1) through (d)(6) sequence unless otherwise approved by the ACO or ECO. The required minimum physical power and general endurance test requirements described for §33.87(b) under “Explanation” in paragraphs 3-4.a.(2) and (3) are applicable to this test schedule.

b. Section 33.87(d)(1), Takeoff and idling, and § 33.87(d)(2), Rated maximum continuous and takeoff power. The guidance is same as that described under “Guidance” in paragraph 3-4.b.(1).

c. Section 33.87(d)(3) Rated continuous OEI power.

(1) In complying with this paragraph, 15 of the 25 six-hour endurance test cycles must be run at rated continuous OEI power for one hour each after completing the § 33.87(d)(2)(i) test sequence at rated maximum continuous power. Ten of the 25 six-hour endurance test cycles must be run at rated continuous OEI power for one hour each after completing the § 33.87(d)(2)(ii) test sequence at rated takeoff power.

(2) All limit parameters (rated power, maximum torque, maximum permissible speeds and gas temperature) must be maintained for one hour at the maximum continuous OEI power.

d. Section 33.87(d)(4) Rated maximum continuous power.

(1) In complying with this paragraph, 25 six-hour endurance test cycles must be run at rated maximum continuous power for one hour each after completing the test sequence at rated continuous OEI rating power of § 33.87(d)(3).

(2) All limit parameters (rated power, rated torque, maximum permissible speeds and gas temperature) must be maintained for one hour at the maximum continuous rating power.

e. Section 33.87(d)(5), Incremental cruise power, § 33.87(d)(6), Acceleration, and deceleration runs, and § 33.87(d)(7), Starts. The guidance for these three paragraphs is identical to that described in §§ 33.87(b)(4), (b)(5) and (b)(6), respectively, except that, the run time and the speed and time increments are 2 hours and not less than12 increments instead of the 2.5 hours and 15 increments of § 33.87(b)(4).

f. The 150 hours of testing time will consists of 18.75 hours at the takeoff rating, 25 hours at the continuous OEI rating, 20 hours at the maximum continuous rating, 62.5 hours at the incremental power step time, and 23.75 hours at the minimum idle condition.

g. See Figures 4 & 5 in Appendix 13 for graphical presentations of the § 33.87(d) test schedule.

3-7. Endurance Test Schedule, § 33.87(e), for rotorcraft engines for which a 2½-minute OEI power rating is desired.

a. Explanation.

(1) The maximum gross weight of a multi-engine rotorcraft is limited by the power available from the remaining operating engine(s) when one engine fails or is shutdown during flight. Analysis of flight performance has shown that in the event of engine failure at the critical point during take-off or landing, a period of higher power, referred as 2½-minute OEI power, is required to lift the aircraft, gain forward speed, clear obstructions in the flight path, and climb out.

(2) Once the aircraft has reached a safe altitude, a longer period at a lower power, which is equal to or higher than maximum continuous power, is required to continue the flight until a suitable landing site is reached. This power level will be either rated maximum continuous, 30-minute OEI, or continuous OEI power depending on the rating structure of the engine. For these reasons, the endurance test schedules for 2½-minute OEI rating are structured to run under one of the following three combinations of ratings:

(a) Rated takeoff, maximum continuous, and 2½-minute OEI
(b) Rated takeoff, maximum continuous, 2½-minute OEI, and 30-minute OEI
(c) Rated takeoff, maximum continuous, 2½-minute OEI, and continuous OEI

(3) See Appendix 6 for more information on rotorcraft operation at 2½-minute OEI condition.

(4) The schedules described in § 33.87(e)(1) and (e)(2) are required for rotorcraft engines for which a 2½-minute OEI power rating is desired. The applicant must select one of the three combinations of ratings in 2(a), 2(b) and 2(c) above for the engine model and their associated test schedules for compliance with endurance test requirements.

(5) See Figures 6 through 10 in Appendix 13 for graphical presentations of the § 33.87(e) test schedules.

b. Guidance. The test must include the runs specified in § 33.87(e)(1) and (e)(2) unless the test sequence is otherwise approved by the ACO or ECO. The required minimum physical power and general endurance test requirements for § 33.87(b) described under "Explanation" in paragraphs 3-4.a.(2) and (3) are applicable to this test schedule.

(1) Section 33.87(e)(1), Takeoff and idling. The guidance is the same as that given for § 33.87(b)(1) under "Guidance" in paragraph 3-4.b.(1) except that, during the

third and sixth takeoff power periods in each of the alternate 5-minute periods, only 2.5 minutes need be conducted at rated takeoff power. The remaining 2.5 minutes should be conducted at rated 2½-minute OEI power.

(2) Section 33.87(e)(2) schedules. In complying with this paragraph, the applicant must select one of options in the following paragraphs (a), (b) and (c) depending on the rating structure of the engine:

(a) For engines with rated takeoff, maximum continuous, and 2½ OEI power ratings:

The guidance is the same as that given for § 33.87(b)(2) through (b)(6) under "Guidance" in paragraph 3-4.b.(2) through b.(5), except that the last 5 minutes of the § 33.87(b)(2)(ii) and the 30 minutes at takeoff power test period in the last one of the twenty-five 6-hour test sequences must be run at the 2½-minute OEI power.

(b) For engines with rated takeoff, maximum continuous, 2½-minute OEI, and 30-minute OEI ratings:

The guidance is the same as that given for § 33.87(c)(2) through (c)(6) in paragraph 3-5.c. through 3-5.e., except that the last 5 minutes of § 33.87(c)(2) and the 30-minute OEI power test period in the last one of the twenty-five 6-hour test sequences must be run at the 2½-minute OEI power.

(c) For engines with rated takeoff, maximum continuous, 2 ½ - minute OEI, and continuous OEI ratings:

The guidance is the same as that given for § 33.87(d)(2) through (d)(6) in described in paragraphs 3-6.b through 3-6.e. of this AC, except that the last 5 minutes of the § 33.87(d)(2)(ii) 30 minutes at continuous OEI power test period in the last one of the twenty-five 6-hour test sequence must be run at the 2½-minute OEI power.

(3) See Appendix 7 for the accumulated testing times for 150 hours of testing to these three schedules.

3-8. Endurance Test Schedule, § 33.87(f), for rotorcraft engines with 30-second OEI and 2-minute OEI ratings.

a. The combined 30-second OEI and 2-minute OEI rating powers enables rotorcraft to perform a mission very similar to that of 2½-minute OEI rating power described in the "Explanation" section of § 33.87(e). However, there are significant differences between these ratings. The use of 30-second OEI and 2-minute OEI ratings is limited to once per flight in service with a mandatory inspection required after each usage. The ratings are intended to safely use available engine design margins for brief periods of exposure. However, such usage may result in component or part deterioration beyond serviceable limits, and may make these components unavailable for further use.

Therefore, the teardown inspection requirement to substantiate the engine 2½-minute OEI rating capability is that all engine parts be in a condition for safe operation in compliance with § 33.93(a)(2). The teardown inspection requirements to substantiate the 30-second OEI and 2-minute OEI ratings capability are that the engine maintains its structural integrity in compliance with § 33.93(b)(2). See Appendix 6 for more information on use of 30-second OEI and 2-minute OEI rating power for rotorcraft.

b. The endurance test for the 30-second and 2-minute ratings must be run following a 150-hour test that was run according to paragraphs § 33.87(b), (c), (d), or (e). The applicant may disassemble the tested engine to the extent necessary to show compliance with the requirements of § 33.93(a). The applicant must then reassemble the tested engine using the same engine parts used for the 150-hour endurance test run of paragraphs § 33.87(b), (c), (d), or (e), except for those parts defined as consumable in the ICA. However, the applicant may also elect to continue the 2-hour test in compliance with § 33.87(f) without intervening disassembly and inspection. If this option is selected, the conditions of engine parts and components after the test must comply with § 33.93(a) instead of § 33.93(b).

c. The required minimum physical power and general endurance test requirements described in items 3 and 4 in the "Explanation" section of § 33.87(b) are applicable to this test schedule.

d. Applicants must conduct the prescribed 2-hour test sequence specified in § 33.87(f)(1) through (f)(8) as follows for a total of four times to complete the required test, unless an alternate test sequence is otherwise approved by the ACO or ECO:

(1) 3 minutes at rated takeoff power;
(2) 30 seconds at rated 30-second OEI power;
(3) 2 minutes at rated 2-minute OEI power;
(4) 5 minutes at rated 30-minute OEI power, rated continuous OEI power, or rated maximum continuous power, whichever is greatest, except that, during the first test sequence, this period shall be 65 minutes;
(5) 1 minute at 50 percent takeoff power;
(6) 30 seconds at rated 30-second OEI power;
(7) 2 minutes at rated 2-minute OEI power; and
(8) 2 minute at minimum idle condition.

e. The accumulated time for 2 hours of testing consists of 4 minutes at 30-second OEI; 16 minutes at 2-minute OEI; 80 minutes at 30-minute OEI, continuous OEI, or maximum continuous power, whichever is greatest power value depending on the rating structure of the engine; 12 minutes at rated takeoff; 4 minutes at 50 percent of takeoff power; and 4 minutes at minimum idle condition.

f. See Figure 11 in Appendix 13 for a graphical presentation of the § 33.87(f) test schedules.

3-9. Endurance Test Schedule, § 33.87(g), Supersonic aircraft engines. We may address the test requirements of supersonic aircraft engines in a future AC.

CHAPTER 4. TEARDOWN INSPECTION.

4-1. Teardown Inspection Requirements for All Endurance Tests (Except for Engines with 30-second OEI and 2-minute OEI Ratings), § 33.93 (a). Each engine must be completely disassembled after completing a 150-hour endurance test of § 33.87(b), (c), (d), (e), or (g). For rotorcraft engines intending to certify 30-second OEI and 2-minute OEI ratings under § 33.87(f), § 33.93(c) allows the applicant the option of completing the endurance testing of § 33.87(b), (c), (d), or (e), and then start the testing of § 33.87(f) without intervening disassembly and inspection. If the applicant chooses this option, the engine teardown inspection must comply with paragraph (a) instead of paragraph (b) of this section after completing the endurance testing of § 33.87(f). The MIDO inspector or the designee, when authorized, must supervise the teardown inspection activities.

a. Section 33.93(a)(1). The adjustment setting and functioning characteristics of each engine component that was established before the endurance test as required by § 33.82 must be calibrated after the test. These components may include, but are not limited to, engine control system components, pumps, actuators, heat exchanger, and valves. The components must retain each setting and functioning characteristic within the limits that were established and recorded at the beginning of the endurance test.

b. Section 33.93(a)(2).

(1) Explanation.

(a) All engine components and parts must be inspected in both “dirty” and “cleaned” conditions in accordance with the applicable ICA manual instructions. All inspection findings must be documented in the certification test report. Appendix 9 provides more detailed guidance for teardown inspections. The engine parts must conform to the type design with allowances for used part condition in accordance with the ICA and applicable information in the TCDS.

(b) The requirements for a dirty inspection after the endurance test is driven by the need to preserve evidence of engine conditions that can be derived from observing oil coked parts, temperature affected parts, metal particles, soot deposits, etc., before these indications are removed by the cleaning process. The dirty inspection may be conducted at the individual part level, partial assembly, or complete assembly level. The degree of dirty layout disassembly largely depends on observations made before and during the disassembly of the engine or components. The applicant should not clean any engine part or complete the disassembly of the test engine until the dirty inspection is completed, unless otherwise authorized by the ACO or ECO.

(c) The clean inspection may include, but is not limited to, the following processes:

1. Visual inspections for indications of unacceptable wear-out, such as galling, distortion, or cracks;

2. Non-destructive inspection for cracks or incipient failures of engine parts;

3. Dimensional inspections for wear, growth, rub or distortion of engine parts, and

4. Visual/bench/teardown inspection of controls, component and accessory hardware.

(d) For the purpose of this subparagraph, the following definitions apply:

1. Type design: The engine part or component that meets the requirements of § 21.31, Type Design, with allowances for used part conditions prescribed in the ICAs and other allowances prescribed in the TCDS.

2. The phrase "an engine" means any engine of the same type design.

3. The phrase "eligible for continued operation" means that the installation of the part will continue to keep the engine in an airworthy condition.

4. For the "information submitted in compliance with § 33.4" phrase, the individual part must meet the limits of the engine manual or overhaul manual as applicable.

(2) Guidance.

(a) Applicants should use the results from the "dirty" and "clean" inspections to determine if the parts conform to the type design and are eligible to be re-installed into the engine for continued safe operation. The manufacturing inspector should check part conformity by witnessing the applicant's inspection. Applicants must use the inspection limits in either the engine manual or the overhaul manual (overhaul, heavy maintenance, shop manual, off-wing manual) as applicable. Any part that no longer conforms to its type design must be documented in the test report.

(b) When an engine part exceeds manual inspection limit(s), the applicant may:

1. Change the manual inspection limit to agree with the inspection result of the endurance test if it is shown that the part will be in an airworthy condition between maintenance periods (inspection, shop visit, and overhaul) of the engine, or

2. Redesign the part to meet the manual limit, or

3. Maintain the manual limit and

a. Modify the frequency and procedures of the engine inspection program in the ICA to assure that the part is inspected and removed from service before reaching the prescribed limit condition, and

b. Identify in the test report any part condition that exceeds manual return-to-service limits, but for which an engineering analysis or service experience from a part of similar type design or inspection results from the endurance test, or the combination thereof, can be used to substantiate that the part at the existing limit is

1. still airworthy;
2. will continue to perform its design functions; and
3. is safe for continued engine operation between maintenance periods (inspection, shop visit, and overhaul) of the engine.

(c) When the applicant specifies a tighter limit in the ICA than the one required under § 33.93, then instructions should be provided in the ICA to remove the part from service before it reaches that limit.

(d) All engine components must pass post-test inspection and functional tests, such as a calibration test or a component acceptance test whenever applicable, to assure that the components are in a condition for continued safe operation and will perform satisfactorily until the next overhaul. Any component that fails the inspection or functional test or is a new component using the § 33.87 test as its sole endurance test must be torn down for inspection. Newly designed components, components with major modifications, or existing components with significantly different operating conditions generally require a separate component test in accordance with § 33.91(a). For the component requiring a separate component test, the post-test teardown inspection after the § 33.87 test may be waived if the applicant can show that the component test condition is more severe than the endurance test and that the teardown inspection will be performed after completing the component test.

(e) Certain repairs may be allowed for the endurance test. These are minor repairs that are normally required to aid in the engine reassembly after overhaul, such as drive shaft or stub shaft mating surface plating for assembly.

4-2. Teardown Inspection Requirements for Engines with 30-second OEI and 2-minute OEI Ratings, § 33.93(b) and (c).

a. After completing the § 33.87(f) test, the adjustment and functional characteristics for components that can be established independent of installation on the engine must be retained within the limits that were established and recorded at the beginning of the test.

b. The § 33.87(f) test for 30-second OEI and 2-minute OEI ratings is run following a 150-hour endurance test under paragraphs § 33.87(b), (c), (d), or (e). The applicant must disassemble the test engine to the extent necessary to show compliance with the requirements of § 33.93(a) before starting the § 33.87(f) test. The pass/fail criteria for § 33.87(f) test are prescribed in § 33.93(b). The conditions of the engine hardware after the test must support this requirement. The applicant must show that no failure of any significant engine component is evident during the test or during the subsequent teardown inspection. In the event that any failure is evident, the failure should be analyzed. Further, the applicant should establish by test, analysis, or both, that the cause of the failure is corrected or that certain limitations are imposed on the engine, as appropriate. For the purpose of this subparagraph, the engine components that are deemed significant are those that can affect structural integrity, including, but not limited to, engine mounts, cases, bearing supports, shafts, and rotors.

c. When the applicant elects not to disassemble the engine after a 150-hour endurance test under paragraphs § 33.87(b), (c), (d), or (e) before starting the § 33.87(f) test, then the engine must comply with the § 33.93(a) requirements for non-30-second OEI and 2-minute OEI ratings after the test.

d. The applicant should document the component or engine part deterioration during the § 33.87(f) test. Such deterioration should not indicate a potentially hazardous condition for the engine. In addition to visible physical damage, non-visible damage should be assessed. Such damage may include, but is not necessarily limited to, the effects of creep, stress rupture, metallurgical effects, or life usage. The applicant should consider this overall evaluation when defining and justifying the inspections and mandatory maintenance actions in the ICA. The ICA should include means for proper identification of these component conditions, and appropriately defined maintenance actions for maintaining the continued airworthiness of the engine.

APPENDIX 1. ENDURANCE TEST FOR ENGINE CERTIFICATION AND SUBSTANTIATION OF ENGINEERING CHANGES.

1. The endurance test must be considered an essential part of all engine type certifications. The test may also be used to substantiate engineering changes, repair, and PMA applications. Acceptable means of compliance with § 33.87 for engine type certification and substantiation of major engineering changes are discussed in the following paragraphs.

a. Engine Certifications.

(1) New Type Certificate. Run the endurance test as prescribed in § 33.87(a) and § 33.87(b) through (g) as applicable (i.e., standard 150-hour endurance test), with no deviations.

(2) Amended Type Certificate. Run the endurance test as prescribed in § 33.87(a) and § 33.87(b) through (g) as applicable, with no deviations, unless one of the following conditions applies:

(a) The engine is a derivative model with no, or minor, design changes and the same or lower ratings or operating limitations, such that the original endurance test is still applicable.

(b) The engine is a derivative model with design changes and the same or lower ratings or operating limitations. These changes, if viewed individually or in combination, would have no impact on engine operability or durability within the approved ratings and limitations. Therefore, the data from the original endurance test would fully substantiate the proposed hardware changes.

(c) The engine is a derivative model with major design changes and the same or lower ratings or operating limitations, and for which the ACO or ECO has determined that a repeat demonstration of the § 33.87 endurance test is needed to substantiate the design change. The endurance test should be run as prescribed in § 33.87(b) through (g), as applicable, with no deviations. Applicants must comply with all subparagraphs of § 33.87(a). The ACO or ECO will determine (1) which subparagraphs of § 33.87(a) are affected by the proposed design changes and require reevaluation by test, and (2) which subparagraphs can be complied with by similarity using existing data from a prior applicable § 33.87 test.

(d) For all other cases, a standard 150-hour endurance test as prescribed in § 33.87, with no deviations, is required.

(e) The above exceptions are based on the assumption that a standard endurance test has been conducted on the original model or subsequent derivative model, in accordance with the requirements of § 33.87, such that the approved data from that previous test would apply.

b. Major Engineering Changes.

(1) When a major design change requires a repeat demonstration of § 33.87, then the applicant must run the endurance test cycle as prescribed in § 33.87(b) through (g), as applicable, with no deviations. Compliance with all subparagraphs of § 33.87(a) is required. The managing ACO or ECO will determine which subparagraphs of § 33.87(a) are affected by the proposed design changes and require reevaluation by test and which subparagraphs have existing data from an applicable § 33.87 test, from which compliance findings by similarity can be made.

APPENDIX 2. ENDURANCE TEST CYCLE FOR MULTIPLE ENGINE TESTS.

1. Regulatory basis for multiple engine tests.

a. Section 33.87(a)(3) allows multiple tests if all the associated limits to the engine operating condition being demonstrated cannot be held at the 100 percent level simultaneously. If the applicant selects multiple tests to comply with the endurance test requirement, then the applicant must run the additional test(s) in accordance with the prescribed test sequence of § 33.87(b) through (g), applicable to all the engine rating conditions (i.e., takeoff, maximum continuous, OEI and other ratings) being demonstrated. The applicant must run these tests on the same engine hardware to be presented for certification.

b. For rotorcraft engines for which 30-second OEI and 2-minute OEI ratings are desired, the applicant must repeat the test sequence defined in § 33.87(f) for a total time of not less than 120 minutes. If a second test is required to demonstrate all the limits associated with the engine operating condition, then the total test time at the desired OEI conditions must not be less than 240 minutes.

c. Section 33.87(a)(3) also states that at least 100 percent of the value of all the parameters associated with a particular engine operating condition must be obtained during the series of runs specified in § 33.87(b) through (g), as applicable. If a parameter (such as speed) for a particular engine rating (such as maximum continuous) is not defined, then the applicant should test the maximum engine “redline” condition as defined in the TCDS.

2. Example of multiple engine tests. The following is an example of an acceptable multiple engine test sequence for a turbofan engine in compliance with § 33.87(b). If the core rotor speed limit and the gas temperature limit have been demonstrated simultaneously during the first test, run the second test at the fan rotor speed limit and the gas temperature limit, simultaneously, in accordance with the test sequences defined in §§ 33.87(b)(1), (b)(2)(ii), and (b)(5). This second demonstration would accumulate an additional 42.5 hours of testing, resulting in a total time of 192.5 hours on the same engine hardware for this endurance test. The applicant may choose to run the test in two parts (on the same set of hardware) as follows:

a. Part One: Run a standard 150 hours endurance test in accordance with § 33.87(b) at the redline core rotor speed, the gas temperature limit, and the rating thrust, simultaneously.

(1) During the takeoff parts of the test.

(a) The fan rotor speed must be maintained at or above the takeoff rating speed*;

(b) The core rotor speed must be maintained at or above the takeoff redline limit;

(c) The gas temperature must be maintained at or above the takeoff redline limits; and

(d) The thrust must be maintained at or above the takeoff rating value.

(2) During the Maximum Continuous parts of the test.

(a) The fan rotor speed must be maintained at or above the maximum continuous rating speed*;

(b) The core rotor speed must be maintained at or above the maximum redline or takeoff redline speed**;

(c) The gas temperature must be maintained at or above the maximum continuous rating limit; and

(d) The thrust must be maintained at or above the maximum continuous rating value.

b. Part Two: Re-run only the takeoff and maximum continuous parts of the cycle in accordance with the test sequences defined in § 33.87(b)(1), (b)(2)(ii), and (b)(5) at fan rotor speed, gas temperature limits, and rating thrust simultaneously. The Part 2 run time is 87.5 hours, which consists of 18.75 hours at takeoff power, 45 hours at maximum continuous, and 23.75 hours at idle.

(1) During the takeoff parts.

(a) The core rotor speed must be maintained at least at takeoff rating speed**;

(b) The fan rotor speed must be maintained at the takeoff redline limit,

(c) The gas temperature must be maintained at the takeoff redline limit; and

(d) The thrust must be maintained at nameplate takeoff rating level.

(2) During the maximum continuous parts of the test:

(a) The fan rotor speed must be maintained at the maximum continuous rating limit or takeoff redline limit**;

(b) The core rotor speed must be maintained at the maximum continuous rating speed*;

(c) The gas temperature must be maintained at the maximum continuous redline limit; and

(d) The thrust must be maintained at the maximum continuous rating level.

c. The total run time for the multiple endurance test runs including Part 1 and Part2 is: 237.5 hours (i.e., 150 hours and 87.5 hours).

*If the maximum permissible rotor speed and gas temperature for the maximum continuous rating are not defined, then the maximum engine rotor speed redline condition, normally engine takeoff, must be tested.

**When the takeoff or maximum continuous fan or core rotor rating speeds are not defined, then these speeds must be maintained at least at the level normally required to produce the rating thrust at the existing ambient conditions during any part of these runs in which redline speeds are not required.

APPENDIX 3. ENDURANCE TESTING FOR A TWO-MINUTE TRANSIENT OVERTEMPERATURE LIMIT APPROVAL.

1. Explanation.

a. Two-minute transient over temperature approval for engine acceleration (reference § 33.87(a)(3)): FAA previously approved a 2-minute transient gas over-temperature rating for engine acceleration within the 5-minute time limit associated with the thrust or power rating, for turbofan engines under § 33.7. This 2-minute approval addresses a condition in which a gas temperature overshoot occurs due to a decrease in engine cycle efficiency caused by a difference in the thermal growth rate of the engine cases and rotors. This condition most often occurs when an engine is accelerated to takeoff from a cold state.

(1) For turbine engines installed on rotorcraft, this temperature excursion could be significant because rotorcraft flight operations often accelerate the engine from a cold state.

(2) For turbine engines installed on large fixed-wing aircraft, such overshoot excursions would not be expected to occur regularly during takeoff operation, due to the time spent from engine start, through push back from the gate and taxi, to takeoff. However, the following are examples of flight conditions where this gas temperature overshoot limit could be used:

(a) Engine acceleration during first takeoff of the day;
(b) Engine acceleration from a cold soak windmilling condition; and
(c) Engine acceleration from low Mach number during hot day conditions, such as certain corner points of the flight envelope or aircraft go-around operations.

b. Within the 5-minute maximum steady state gas temperature limit for the takeoff thrust or power rating, the applicant may propose a gas temperature overshoot time limit greater than 30 seconds and less than or equal to 2 minutes. In reviewing § 33.87(a)(3), the FAA determined that the phrase, “must be at least 100 percent of the value associated with the particular engine operation being tested,” may be applied to cover the proposed gas temperature overshoot. However, since the overshoot is part of the 5-minute steady state temperature limit, a deteriorated engine should be removed from an aircraft for maintenance whenever the engine fails to produce rated takeoff thrust or power for either the overshoot or the 5-minute steady state temperature limits, or both.

2. Guidance.

a. For approval of gas temperature overshoot limits greater than 30 seconds and less than or equal to 2 minutes in compliance with § 33.87(a)(3), the applicant must demonstrate the proposed limit value and duration for all test periods at takeoff thrust or power condition in § 33.87. This should include the running time of all 30-second periods at takeoff power or thrust in § 33.87 unless the exclusion for gas temperature and oil inlet temperature in § 33.87(a)(7) applies. Section 33.87(a)(7) requires test runs at limiting temperature for any rated power or thrust, except where the test periods are not longer than 5 minutes and do not allow stabilization. For example, an applicant may propose a 2-minute gas temperature overshoot limit as part of the 5-minute maximum permissible limit proposed for rated takeoff in compliance with § 33.87(b):

(1) The applicant would then be required to demonstrate 6 hours and 35 minutes out of the 18.75 hours of running time required by §§ 33.87(b)(1), (b)(2)(ii), and (b)(5), at the 2-minute overshoot temperature limit. However, the demonstration required by § 33.87(b)(5) for 30-second periods at takeoff thrust or power may be waived if the exclusion provision in § 33.87(a)(7) is applicable.

(2) The type certificate data sheet would then specify:

(a) A 2-minute overshoot out of a 5-minute maximum permissible gas temperature limit for the takeoff rating as follows:

1. Maximum permissible gas temperature limit for takeoff (5 minutes).
2. Maximum permissible gas temperature limit for takeoff (2-minute overshoot out of a total of 5 minutes).
3. A note that indicates that the engine must produce rated takeoff thrust or power within both the 2-minute overshoot and the 5-minute steady state redline temperature limits.
4. When the engine cannot meet the two requirements in 3, it must be removed from service for maintenance.

Note 1. The proposal of a 2-minute gas temperature overshoot limit would require the demonstration of test requirements of §§ 33.27(c)(1) and 33.88 using the 2-minute gas temperature value as the maximum steady state operating temperature limit.

Note 2. For approval of a gas temperature overshoot limit that exceeds 2 minutes, the applicant must demonstrate the overshoot temperature value for the entire 18.75 hours of running time at takeoff thrust or power, as required by §§ 33.87(b)(1), (b)(2)(ii) and (b)(5).

APPENDIX 4. ENGINE CONFIGURATION AND TEST EQUIPMENT MODIFICATIONS TO ACHIEVE SIMULTANEOUS REDLINE TEST CONDITIONS IN THE ENDURANCE TEST.

1. To run the endurance test at redline conditions simultaneously, i.e., at maximum permissible rotor speeds, gas temperature, and full rated thrust or torque as required by § 33.87(a)(3), the applicant may need to modify the engine configuration or use certain additional facility test equipment. The following methods are commonly employed for matching engine speeds and temperatures to achieve the desired test conditions:

a. Change the inlet airflow and condition by:
   (1) Changing the inlet nozzle area,
   (2) Installing an inlet grid or screen to introduce a pressure drop at the inlet, or
   (3) Heating the inlet air.

b. Variable compressor vane mis-scheduling.

c. Use of cabin bleed from HPC and/ or LPC.

d. Use of a variable area hot section nozzle.

e. Use of a variable area exhaust nozzle area.

2. When one or more of the above methods is chosen, the applicant should provide a technical justification substantiating that the tested configuration does not compromise §^{o}33.87 test requirements or mask stability issues.

3. Operating the engine at triple redline conditions (i.e., at redline rotor speeds and gas temperature, and full rated thrust or torque) frequently requires some non-standard adjustments to the engine designed control and operating characteristics. These adjustments may result in unintended adverse consequences to some engine design features.

a. For example, attaining redline core rotor speeds simultaneously with redline gas temperatures may require off-design point scheduling of the compressor variable stator vanes and other engine hardware. This in turn may reduce the amount of air that can be bled internally from the compressor for pressurization of bearing sump areas and for cooling various high and low-pressure turbine components. This regulation does not require that the engine be tested with an engine system (such as these cooling circuits) reduced in capability or effectiveness below the design intent level at which it would operate if the engine remained in a type design configuration.

b. Therefore, the applicant may propose minor modifications to the engine to mitigate these unintended consequences. For example, the applicant may propose a minor modification to the compressor internal cooling flow circuit, such as increased flow regulating orifice diameters that might increase the cooling effectiveness of the cooling circuit back to what it would be if the engine were operated in a type design configuration.

c. For each such proposed modification, however, the applicant must substantiate that the modification does not improve the capability of either the modified part or any part that may be affected by that modified part to withstand the rigors of the intended test conditions. In the example mentioned above, the applicant must substantiate that (1) modifications to the compressor cooling flow circuit do not improve the capability of the compressor case to withstand the test conditions, and (2) the increased cooling flow does not improve the capability of those hot section parts that are pressurized or cooled by this flow to withstand the rigors of the test. The reconciliation of the acceptability of any such modified (i.e., non-type design) parts should be included in the reconciliation section of the test plan.

d. The intent of the regulation is that the engine configuration to be tested will substantially conform to the final type design and be representative of the durability and capability of a typical type design engine to withstand the rigors of the test.

APPENDIX 5. ENDURANCE TEST CONFORMITY AND TYPE INSPECTION AUTHORIZATION.

1. The germane hardware (primary hardware) is the hardware that directly impacts the pass/fail criteria for engine parts and components in an endurance test. The calibration and endurance test engine must be in the type design configuration, except for non-type design hardware approved by the ACO or ECO that are required to achieve certain specified test conditions. Each applicant must have made all inspections necessary to determine that (1) the parts and components of the engine adequately conform to the drawings and specifications of the type design; and (2) the engine is built to the approved assembly procedures. FAA manufacturing inspection personnel or an FAA designee will conduct pre- and post-test conformity inspections.

2. Certain test hardware must be subject to pre-assembly conformity inspections. This kind of conformity determination may vary depending upon circumstances. Usually only major and critical parts subject to significant temperatures, distortion, cracking, fatigue, creep, and wear are inspected for conformity, giving particular attention to their critical characteristics and dimensions. The FAA pre-test review of the applicant's quality control procedures, experience level of the inspection personnel, and capability of the inspection facilities will help to dictate the extent of the required conformity inspections for the endurance test. The FAA manufacturing inspector or the applicant's FAA-designated inspector should conduct the inspections.

3. The TIA is normally prepared by the ACO or ECO upon the request of the applicant, and is used to authorize conformity inspections to ensure that the test engine hardware conforms to the approved type design for certification. However, the FAA may also issue a TIA requiring special inspections on either the test engine or the test facilities in response to specific concerns. The TIA should identify the test engine configuration, including germane hardware for the test and FAA approved non-type design hardware, and the parts that are subject to pre-assembly inspection. For more information on the request for conformity inspection, TIA, conformity inspection, statement of conformity, Type Inspection Report (TIR) and related instructions, see Chapter 5 of the latest revision of FAA Order 8110.4B, Type Certification.

4. The following list is an example of hardware that is germane to a § 33.87 demonstration required by a redesigned annular combustor. Assume the combustor redesign alters the actual discharge gas temperature profile relative to the gas temperature measured by the turbine temperature assembly. This factor then changes the operating environment of all parts that are affected by a change in the gas temperature characteristics. The objective of the endurance test is to demonstrate that the core engine hardware affected by changes to the gas path environment will satisfactorily pass a 150-hour endurance test at the maximum permissible gas temperature. In this example, the germane hardware is:

   a. Diffuser case

b. Combustor Section, which includes

(1) Fuel nozzles
(2) Inner and outer liners, outer and inner cowls, and domes
(3) Inner and outer support rings
(4) Combustion case

c. HPT Section, which includes
(1) Disks, vanes, blades, and side plates
(2) Air seals and shrouds
(3) Inner and outer supports, and outer case
(4) Cooling air manifold

d. HPT to LPT Transition Duct

e. LPT Section, which includes
(1) Disks, blades, and vanes
(2) Air seals and shrouds
(3) Inner and outer supports, and outer case

f. Exhaust Section, which includes
(1) Turbine exhaust case
(2) Tailpipe
(3) Gas temperature probe assembly

APPENDIX 6. ROTORCRAFT OPERATION WITH 2½-MINUTE OEI, OR 30-SECOND OEI, AND 2-MINUTE OEI RATINGS AND ENDURANCE TEST.

1. Endurance test for 30-second OEI and 2-minute OEI ratings.

a. The maximum gross weight of a multi-engine rotorcraft is limited by the power available from the remaining operating engine(s) when one engine fails or is shutdown during flight.

b. In the event of an engine failure at the critical decision point (CDP) of an aircraft during takeoff or landing, a short burst of very high power, referred as the 30-second OEI power, is required to complete the takeoff, or complete a rejected takeoff, or accomplish a balked landing. This power level should enable the aircraft, at any point at or above CDP, to achieve continued flight, meet obstacle clearance requirements, and gain forward speed for taking off. At any point at an airspeed/altitude up to CDP, this power level should also enable the aircraft to safely complete a rejected takeoff. If the OEI condition occurs during landing, this high power level should be sufficient to lift the aircraft to a safe altitude, clear obstructions in the flight path, and initiate a climb out (balked landing).

c. A somewhat longer period, two minutes and at a lower power level, but still higher than takeoff power (referred as 2-minute OEI power), is required to complete the climb out from takeoff to a safe altitude and obtain desired forward airspeed. Once the aircraft has reached the desired safe altitude and airspeed, a longer period at a lower power (still equal to or higher than maximum continuous power) is required to continue the flight until a suitable landing site is reached. This power level will either be rated maximum continuous, 30-minute OEI, or continuous OEI power depending on the rating structure of the engine. For these reasons, the engine rating structure for a rotorcraft having 30-second OEI and 2-minute OEI is typically selected from one of the following three combinations of ratings:

(1) Maximum continuous, rated takeoff, and 30-second and 2-minute OEI
(2) Maximum continuous, rated takeoff, 30-second and 2-minute OEI, and 30-minute OEI
(3) Maximum continuous, rated takeoff, 30-second and 2-minute OEI, and continuous OEI

d. For the endurance test, the test schedule is prescribed in § 33.87(f) for rotorcraft engines for which 30-second OEI and 2-minute OEI ratings are desired. The intent of this two-hour test runs is to assure that the engine is capable of producing these OEI rating powers in a deteriorated state. Therefore, this is an add-on test conducted separately on the same engine hardware after having completed a 150-hour endurance test in accordance with § 33.87(b), (c), (d), or (e).

2. Endurance test for 2½-minute OEI rating.

a. The 2½-minute OEI rating power is intended for the engine to perform similar functions as 30-second OEI and 2-minute OEI ratings in an OEI flight condition for a rotorcraft, but at a generally lower power level relative to these two ratings. Similarly, the engine rating structure for a rotorcraft having 2½-minute OEI is typically selected from one of the following three combinations of ratings:

(1) Maximum continuous, rated takeoff, and 2½-minute OEI
(2) Maximum continuous, rated takeoff, 2½-minute OEI, and 30-minute OEI
(3) Maximum continuous, rated takeoff, 2½-minute OEI, and continuous OEI

b. The three test schedules for the endurance test as prescribed in § 33.87(e) are designed to substantiate the above rating structures.

3. The difference between the OEI ratings.

a. Thirty-second OEI and 2-minute OEI ratings are intended to perform very similar functions as 2½-minute OEI ratings in rotorcraft operation. However, the significant difference between them is the limited use in service with mandatory inspection/maintenance actions for 30-second OEI and 2-minute OEI powers rating usage. These two higher power ratings are intended to safely use available engine design margin for brief periods of exposure that may result in engine part or component deterioration beyond serviceable limits and therefore possibly unavailable for further use. The purpose of mandatory maintenance action is to restore the safety margin of the engine back to the level required in the airworthiness standards of part 33. Additionally, the teardown inspection standards are different as follows:

b. The requirement for teardown inspection for 2½-minute OEI rating after an endurance test in § 33.93(a) is that each engine part must be eligible for incorporation into an engine for continued operation in accordance with information submitted in compliance with § 33.4.

c. The teardown inspection requirements in § 33.93(b) for 30-second and 2-minute OEI ratings are that each engine part may exhibit deterioration in excess of that permitted in § 33.4 including some engine parts or components that may be unsuitable for further use provided the structural integrity of the engine is maintained.

APPENDIX 7. ACCUMULATED ENDURANCE TESTING TIMES FOR §33.87(E).

1. The endurance tests under paragraph § 33.87(e) for a 2½-minute OEI rating are structured to run in one of the following three combinations of ratings as described in the § 33.87(e) "Guidance" section:

(a) Rated takeoff, maximum continuous, and 2½-minute OEI; or
(b) Rated takeoff, maximum continuous, 2½-minute OEI, and 30-minute OEI; or
(c) Rated takeoff, maximum continuous, 2½-minute OEI, and continuous OEI.

2. The accumulated testing times for 150 hours of testing of these three schedules are summarized as follows:

Time (hours) at Indicated Power Level							
Schedule	2½ Min OEI	30 Min OEI	Cont. OEI	Takeoff	Max. Cont.	Rotor Speed Steps	Idle
a	2.17*			16.58	45	62.50	23.75
b	2.17*	12.41**		11.67	37.5	62.50	23.75
c	2.17*		24.91***	16.67	20	62.50	23.75

Note: *2.17 hours = 2 hours and 10 minutes.
**12.41 hours = 12 hours and 25 minutes.
***24.91 hours = 24 hours and 55 minutes.

APPENDIX 8. ENDURANCE TEST PLAN REQUIREMENTS.

1. The applicant must prepare a test plan for the endurance test that thoroughly defines the test objective, -test engine, germane or primary test hardware, test facility, test procedures, and the pass/fail criteria. The test plan should be submitted early enough to allow ACO or ECO or their designee a sufficient amount of time to review and approve the plan prior to the start of the test.

2. The following paragraphs describe types of information to be included in a test plan for the calibration test, endurance test, and teardown inspection. However, they are neither all inclusive nor mandatory. The information is only intended as a guide to preparing the plan.

a. Description of the Test Objective. List the 14 CFR part 33 paragraphs for which the tests are intended to show compliance. Provide a brief description of how each quoted regulation will be complied with by the test(s).

b. Test engine configuration. The configuration of the test engine must substantially conform to the final type design. However, non-type design hardware and components may be used in the test engine to achieve certain test conditions when approved by the ACO or ECO. For example, modification of certain test equipment, engine configurations, and test sequences may be necessary to run the test at simultaneous triple redline conditions. The test plan must disclose and tabulate all non-type design hardware and components used in the test engine and provide substantiation that the deviations will not adversely affect the outcome of the test.

c. Facility configuration. This includes a list of test equipment necessary to conduct the test, configuration of slave hardware, bleed configuration, oil system modification to achieve maximum oil temperature, etc. All test equipment must be properly calibrated.

d. Conformity. The germane hardware (primary hardware) is the hardware that directly impacts the pass/fail criteria for engine parts and components in an endurance test. Applicants should identify the germane hardware of the test engine in a tabulated format for easier identification. Applicants should also include a list of components that require pre- and post-endurance test bench calibration. Results of hardware conformity inspections should be presented. Appendix 5 provides additional information on the conformity inspection.

e. Test procedure. The test procedure must provide sufficient details to describe the method of compliance. This may include discussions on pre-and post-endurance calibration tests, test cycles/hours, test sequences if they are different from those prescribed in § 33.87 (b) through (g), fuel, oil and hydraulic fluid to be used and sampling intervals, expected oil consumption, and other component testing requirements as applicable.

f. Post test. Following the completion of the endurance test, the engine must be completely disassembled for a dirty inspection and a clean inspection. Applicants should detail the inspection requirements.

g. Success Criteria. Applicants should describe the pass/fail criteria that determine how engine performance characteristics, and/or condition of parts and components meet the requirements of §§ 33.85 and 33.93, respectively.

APPENDIX 9. TEARDOWN INSPECTION REQUIREMENTS - DIRTY INSPECTION AND CLEAN INSPECTION.

1. The FAA manufacturing inspector and the ACO or ECO project engineer, or their designees when authorized, should witness the teardown inspection. The teardown inspection consists of two parts—a dirty and a clean inspection. The dirty inspection is conducted at part level, partial assembly, subassembly, or assembly without cleaning. The degree of disassembly is largely dependent on the findings of the engine and components before, during, or after disassembly.

2. Tear down inspection requirements.

a. Dirty inspection. The applicant should specifically note any abnormal leakage indications in valves, seals or fittings; indications of excessive or lack of lubrication; excessive coking; metal or foreign particles in the oil screens or passages; sticking or breakage of parts; lack of freedom of moving parts; excessive breakaway torques; and any other condition that may not be noticeable after complete disassembly and cleaning. The manufacturing inspector should verify that the applicant carefully notes the appearance of subassemblies during the teardown.

b. Clean inspection**.**

(1) Visual inspection—All engine parts should be thoroughly cleaned and visually inspected for indications of galling, metallic pickup, corrosion, distortion, interference between moving parts, and cracks. These parts should be checked for discoloration that may be due to excessive heat or lack of lubrication. Special attention should be given to bearings, gears, and seals or other rotating parts. Hot section parts should be carefully inspected for indications of cracking, overheating, or burning.

(2) Nondestructive inspection—Those engine parts that are highly stressed should be inspected for crack or incipient failures by suitable nondestructive testing methods such as magnetic particle inspection, x-ray, penetrant, ultrasonic, or eddy current.

(3) All critical engine parts that are subject to wear, growth, rubbing or distortion should be dimensionally inspected to determine the extent of any changes that occurred during the test. Dimensional changes may be accomplished by comparison of pre- and post-test dimensional measurements.

(4) The applicant's inspection report, as verified by the manufacturing inspector, should be submitted to the ACO or ECO project engineer as an attachment to the Conformity Inspection Record FAA Form 8100.1. This report should contain the results of the inspection, giving a comprehensive description of all defects, failures, wear or other unsatisfactory conditions, including photographs as required. The manufacturing inspector should also ensure that questionable parts are identified and retained by the applicant in safe storage for review by ACO or ECO engineering as necessary.

APPENDIX 10. INSTRUCTIONS FOR CONTINUED AIRWORTHINESS AND TEARDOWN INSPECTION CRITERIA.

1. For the purposes of this AC, an aircraft engine is considered “airworthy” when the following two conditions are met:

a. The engine conforms to its type certificate. An engine conforms to its type certificate when the engine configuration is consistent with the type design and other data that is part of the type certificate (TC).

b. The engine is in a condition for safe operation. An engine is in a condition for safe operation when the condition of the engine, considering factors such as wear, damage, and deterioration after the endurance test, does not prevent the engine from demonstrating compliance with those requirements of part 33 that relate to the safe operation of the engine, and does not result in an unsafe condition to the aircraft.

2. The applicant for an aircraft engine TC prepares ICA, which provide information on the proper maintenance of the engine, as part of that the engine type certification process. An aircraft engine, when maintained according to the ICA or other FAA-approved maintenance programs, will be continuously airworthy between maintenance or overhaul periods throughout its operational life. In other words, the engine is in a state of “continued airworthiness.”

3. Section 33.93(a)(2) requires that, following the endurance testing, the engine parts at teardown 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.” Therefore, the ICA are used as standards for pass/fail criteria in compliance with this subparagraph.

APPENDIX 11. ENDURANCE TEST REPORT REQUIREMENTS.

1. The certification test reports must contain sufficient data (for example, plots, tabulations, figures, and photographs) and discussions to substantiate that the engine successfully completed all requirements of the calibration test, endurance test, and teardown inspection. In addition to test results and analyses of data, the reports should include analyses of engine faults, and significant hardware deterioration and corrective actions implemented during, or that will be implemented after, the test. However, the content of the reports should be selective, and should not be used as a data dump.

2. The following paragraphs describe types of data, analysis and other information applicants should include in reports for the calibration test, endurance test, and teardown inspection. These information categories are neither all inclusive nor mandatory. The information categories are intended only as a guide in preparing the reports.

a. Objective. List the 14 CFR part 33 paragraphs for which the test results are intended to show compliance.

b. Success Criteria. Describes the criteria for determining if the engine performance characteristics and the condition of parts and components meet the requirements of § 33.85, and § 33.93, respectively.

c. Engine and facility configuration. This includes descriptions of the engine build, slave hardware, and special test facility hardware required, for example, to accommodate compressor bleed air extraction or to achieve maximum oil temperature.

d. Modifications**.** This includes redline target value changes and hardware changes that are different from the bill of materials contained in the TIA. Applicants must disclose any changes to the germane or principal hardware and must substantiate that these changes will not affect the outcome of the test, and that the changed parts are still representative of the type design part.

e. Test discussions. Results from these areas of the test should be included.

(1) Pre-endurance testing. Discussions should include the results of pre-endurance engine and component test calibrations that were used to substantiate the baseline operating characteristics of the engine.

(2) Endurance testing. Discussions must include, but are not limited to:

(a) A description of any deviations from the prescribed cycle requirements must be disclosed, and the applicant must substantiate that these modified cycles are still in compliance with the regulation.

(b) Descriptions of any penalty runs that were required to make up for cycles that deviated from the regulation requirements.

(c) Comparative tabulations (vs. the § 33.87 requirements) of:

1. The operating time accumulated at each power condition, including any shortfalls in the gas temperature due to the stabilization exception provided by § 33.87(a)(7).

2. The minimum certificated parameter values obtained during each of the cycle segments to substantiate that the lowest of these minimum segment values was still at or above the value to be certificated.

3. A trace of one "typical" non-bleed cycle § 33.87(b)(1) segment and one § 33.87(b)(5) segment (first 5 minutes only), showing stabilization at or above the required values to be certificated prior to starting the timer for each part. This trace will also substantiate the stabilization time for the gas temperature if the stabilization exception provided by § 33.87(a)(7) is utilized.

(d) A substantiation that any shortfall between a reduced thrust level that can be achieved and the required minimum physical thrust is inconsequential to the substantiation of the durability of those engine parts that are subject to thrust loads.

(3) Post-endurance testing. The results of the post-endurance calibration and vibration signature survey. The vibration signature survey must show that the vibration levels did not significantly change and are within the limits specified in the engine IM.

f. Post test. Following the completion of the endurance test, applicants must disassemble the engine into modules, subassemblies, or parts as appropriate for a dirty inspection. After completion of the dirty inspection, the hardware must be disassembled, cleaned, and inspected. Any significant inspection findings of engine parts should be tabulated with the part name, part number, inspection results, known or suspected causes, effects on the operation of the engine, and proposed corrective actions or proposed product improvements. For components, if any parts fail the acceptance test procedure (ATP), any cause and corrective action information and a summary of the ATP results must be described in the test report. Any engine manual airworthiness or return-to-service limits that are affected by the post-test hardware condition must be identified in the test report, and any required changes must be substantiated.

g. Data reporting.

(1) The report should provide test data in either tabulation or graphic formats in sufficient detail to show compliance with applicable requirements of § 33.87(a) and § 33.87(b) through (f). These tables or plots may include, for example, typical gas temperature, rotor speed or thrust/power versus time or power setting parameter, oil temperature versus rotor speed, vibration versus rotor speed.

(2) Photographs showing significant hardware findings from the pre-test and post-test inspections should be included in the test report.

h. Analysis.

(1) Performance data. Applicants should analyze the performance deterioration based on pre- and post-endurance calibrations and determine its acceptability for continued service operation. The calibration test data must show that following completion of the endurance test, the engine is capable of producing its rated power or thrust without exceeding any speed, gas temperature, or other operating limits specified in the TCDS.

(2) Bleed air test results. Describe the maximum air bleed amount tested and its effect on temperature, speed, and thrust/power.

(3) Fault and maintenance messages. Applicants should investigate any component that has an indicated maintenance message recorded during the endurance test. The messages, cause, and comments/corrective action should be included in the report.

(4) Critical dimensions. Applicants must identify the critical dimensions to assess rotor hardware residual plastic growth or deformation. We recommend that applicants include data on critical dimension, new part dimension, manual limits, pre- and post-test dimensions and predicted growth.

(5) Oil pressure/temperature test results. The endurance test must demonstrate that the engine operation with the oil at or beyond the minimum and maximum pressure limits is satisfactory. The test must also show that satisfactory engine operation with the oil temperature at or exceeding both steady state and transient maximum temperature limits has been successfully demonstrated.

(6) Oil sample test results. The test report should describe the procedure or specification under which the pre- and post oil sample were analyzed. The results should clearly show that the samples conform to the specification.

(7) Vibration signature analysis. Applicants must analyze both HPT and LPT related vibrations to assure that the vibration deterioration is acceptable. The post endurance test vibration level should remain below the field maintenance limit.

i. Test plan. The report must include a copy of the approved test plan, with the approval documents attached.

APPENDIX 12. CHRONOLOGICAL REVISIONS OF ENDURANCE TEST REGULATIONS.

1. CAR, part 13 – Aircraft Engine Airworthiness.

a. CAR 13, effective 3/5/1952. The Civil Aeronautics Board adopted this version of CAR 13, which had no amendment, on January 8, 1952. The previously effective part 13 was promulgated in 1941 and had remained substantially unchanged until 1952. One of the significant changes made to this version was that this was the first time the certification of turbine-type engine rules were adopted into the regulation. The general block tests, calibration tests, and 150-hour endurance test for turbine engines were designated as §§ 13.250, 252 and 254, respectively, in the CAR 13 rule. The technical content of the calibration test was basically the same as § 33.85(a), except that it did not address compressor air bleed for the test. The endurance test consisted of 30 periods of runs of 5 hours each as specified by the test schedule. This endurance test resembles the current § 33.87(b)(1), with 91 percent takeoff, and 90 percent and 75 percent maximum continuous power/thrust test runs, instead of § 33.87(b)(2) through § 33.87(b)(4). The teardown inspection paragraph (§ 13.256) required a complete engine disassembly and a detailed inspection of the tested engine to check for fatigue and wear.

b. CAR 13, Amendment 13-1, effective 8/12/1957.

(1) This amendment revised two subparagraphs in the endurance test schedule from “91 percent takeoff” and “90 percent and 75 percent maximum continuous power/thrust” to “Takeoff and idling” and “Incremental cruise power and/or thrust,” respectively, which would make these two essentially the same as § 33.87(b)(2), and § 33.87(b)(4).

(2) Other revisions are as follows: (a) During the endurance test, the engine power/thrust and rotational speeds must be controlled within +/- 3 percent of the specified value; (b) The addition of test requirements for engines with an augmented power or thrust rating; and (c) the addition of maximum gas temperature and oil temperature requirements at all engine rating runs during the test, which is same as the equivalent requirements in § 33.87(a)(7).

c. CAR 13, Amendment 13-2, effective 5/17/1958. This amendment revised the specification of power and/or thrust and of engine rotational speed of a tolerance in the endurance test from “ +/- 3 percent of the specified value” to “at not less than 100 percent of the specified value.”

d. CAR 13, Amendment 13-5, effective 2/12/1963. In this amendment, part 13 was amended by defining and adding a new rating, “30-minute power for helicopter turbine engines”, and adding a new test schedule to § 13.254, Endurance Test, for substantiating this rating power for turbine engine used in rotorcraft. The technical content of this new schedule is essentially the same as § 33.87(c), “30-minute OEI power rating” for rotorcraft engines.

e. CAR 13, Amendment 13-6, effective 4/22/1964. This amendment established a 2½-minute power rating for an OEI event at any instant after the start of takeoff for multi-engine rotorcraft. It was accomplished by defining and adding a new rating, “2½-minute power for helicopter turbine engines”, and adding a new test schedule to § 13.254(c) for an engine with a “2½ power” and a “30-minute power” to substantiate these rating powers. The test requirements for these ratings are essentially same as §33.87(e) except the following:

(1) Section 33.87(e)(2) covers three OEI rating combinations to suit rotorcraft performance needs. These are: (a) 2½ OEI/maximum continuous, (b) 2½ OEI/30-minute OEI, and (c) 2½ OEI/continuous OEI ratings, while § 13.254(c) covered only item (b) above.

(2) Section 33.87(e)(2) requires that the last 5 minutes of the 30-minute OEI in one of the 6-hour test sequence of the endurance test must be run to 2½ OEI power, and § 13.254(c) does not.

Note: Section 13.250, General block tests, § 13.252, Calibration test, and § 13.256, Teardown inspections in CAR 13 rule, remained unchanged through Amendment 13-6.

2. 14 CFR, part 33 – Airworthiness Standards: Aircraft Engines.

a. Part 33, Original, effective 2/1/1965.

(1) The new part 33 to the Federal Aviation Regulations was issued to replace the airworthiness requirements contained in CAR-13 and was part of the FAA recodification program.

(2) Section 33.85, Calibration test, is same as its equivalent paragraph in CAR13-6 except for one additional requirement that the engine power control must be adjusted to produce the maximum allowable gas temperatures and rotor speeds at takeoff operating conditions before the endurance test, and may not be changed during calibration tests and the endurance test.

(3) The contents of § 33.87, Endurance test, and § 33.93, Teardown inspections are the same as their equivalent paragraphs in CAR13-6, except for minor editorial differences.

(4) Section 33.99, General conduct of block tests, was completely revised from its equivalent paragraph in CAR13-6.

b. Part 33, Amendment 6, effective 10/31/1974.

(1) The new § 33.82, General, adopted by this amendment, requires the applicant to establish and record certain adjustment settings and functioning characteristics of engine components before starting the endurance test. This paragraph remains the same as the current (amendment 20) regulation.

(2) Section 33.85(a) of the calibration test was revised by including only the compressor air bleed essential for engine functioning during the test. Section 33.85(b) was completely revised. With these revisions in place, both paragraphs agree with the current regulation.

(3) Section 33.87, Endurance test, was revised by:

(a) Expanding §33.87(a) to the current requirements except the following:

1. The test may be run at reduced power or thrust or rotor speeds below 100 percent value specified in §33.87(a)(3) during maximum air bleed runs; and

2. The testing of accessory drives and mounting attachments may be accomplished on a rig in §33.87(a)(6).

(b) Including the endurance test schedule for supersonic aircraft engine.

(4) Section 33.93(a), Teardown inspection, was completely revised to the current requirements.

(5) Section 33.99, General conduct of block tests, was revised to the current regulation by including requirements on engine service, malfunction, and stoppage during endurance test.

c. Part 33, Amendment 10, effective 3/26/1984.

(1) Section 33.87, Endurance test, was revised as follows:

(a) Sections 33.87(a)(3) and (a)(5) were revised to allow the applicant to reduce power or thrust or rotor speeds below 100 percent value specified in § 33.87(a)(3) during maximum compressor air bleed runs, as it is not always possible to reach redline speeds at takeoff and maximum continuous thrust/power without exceeding gas temperature limits.

(b) Section 33.87(a)(6) was revised to allow separate rig testing of accessory drives and mounting attachments.

(c) A new requirement was added to specify that a 2½-minute OEI rating power must be applied for a 5-minute period at the end of one rated 30-minute power run in 25 of the 6-hour test sequence for the 2½-OEI minute rating test schedule.

(d) The above changes updated §§ 33.87(a)(3), (a)(5), and (a)(6), to the same as the current requirements (Amendment 20 to Part 33).

d. Part 33, Amendment 12, effective 10/3/1988.

(1) In § 1.1, the existing definitions of "2½-minute power" and "30-minute power" were revised to read: "2½-minute OEI power" and "30-minute OEI power" to make these definitions relate more closely to the name of these power ratings with their intended usage. A new definition of "continuous OEI power" was introduced.

(2) In § 33.87, the new test schedule for an engine with a "continuous OEI power" rating was added to the endurance test as § 33.87(d).

e. Part 33, Amendment 18, effective 8/19/1996.

(1) This Amendment adopted new 30-second OEI and 2-minute OEI ratings applicable to rotorcraft turbine engines.

(2) The new definitions of "30-second OEI power" and "2-minute OEI power" ratings were introduced in § 1.1.

(3) Section 33.85 was revised by adding new paragraphs (c) and (d) to cover specific calibration test requirements for these two OEI ratings.

(4) Section 33.87 was revised by adding a new 2-hour test schedule paragraph (f) for the ratings in addition to the 150-hour endurance test required by § 33.87(b) through (e) for the engine.

(5) Section 33.93 was revised by adding new paragraphs (b) and (c) defining teardown inspection requirements after completing the 2-hour endurance test in § 33.87(f).

APPENDIX 13. GRAPHIC SKYLINES OF ENDURANCE TEST SCHEDULES

1. Engines other than certain rotorcraft engines, § 33.87(b).

Test cycle	1-15	Figure 1
Test cycle	16-25	Figure 2

2. Rotorcraft engines with a 30-minute OEI power rating, § 33.87(c).

Test cycle	1-25	Figure 3

3. Rotorcraft engines with a continuous OEI rating, § 33.87(d).

Test cycle	1-15	Figure 4
Test cycle	16-25	Figure 5

4. Rotorcraft engines with a 2½ OEI rating, § 33.87(e).

   a. § 33.87(b) and § 33.87(e)

Test cycle	1-15	Figure 6
Test cycle	16-25	Figure 7

   b. § 33.87(c) and § 33.87(e)

Test cycle	1-25	Figure 8

   c. § 33.87(d) and § 33.87(e)

Test cycle	1-15	Figure 9
Test cycle	16-25	Figure 10

5. Rotorcraft engines with a 30-second and 2-minute OEI ratings, § 33.87(f).

Test cycle	1-4	Figure 11

§ 33.87(b) 150 Hour Endurance Test Cycles 1-15

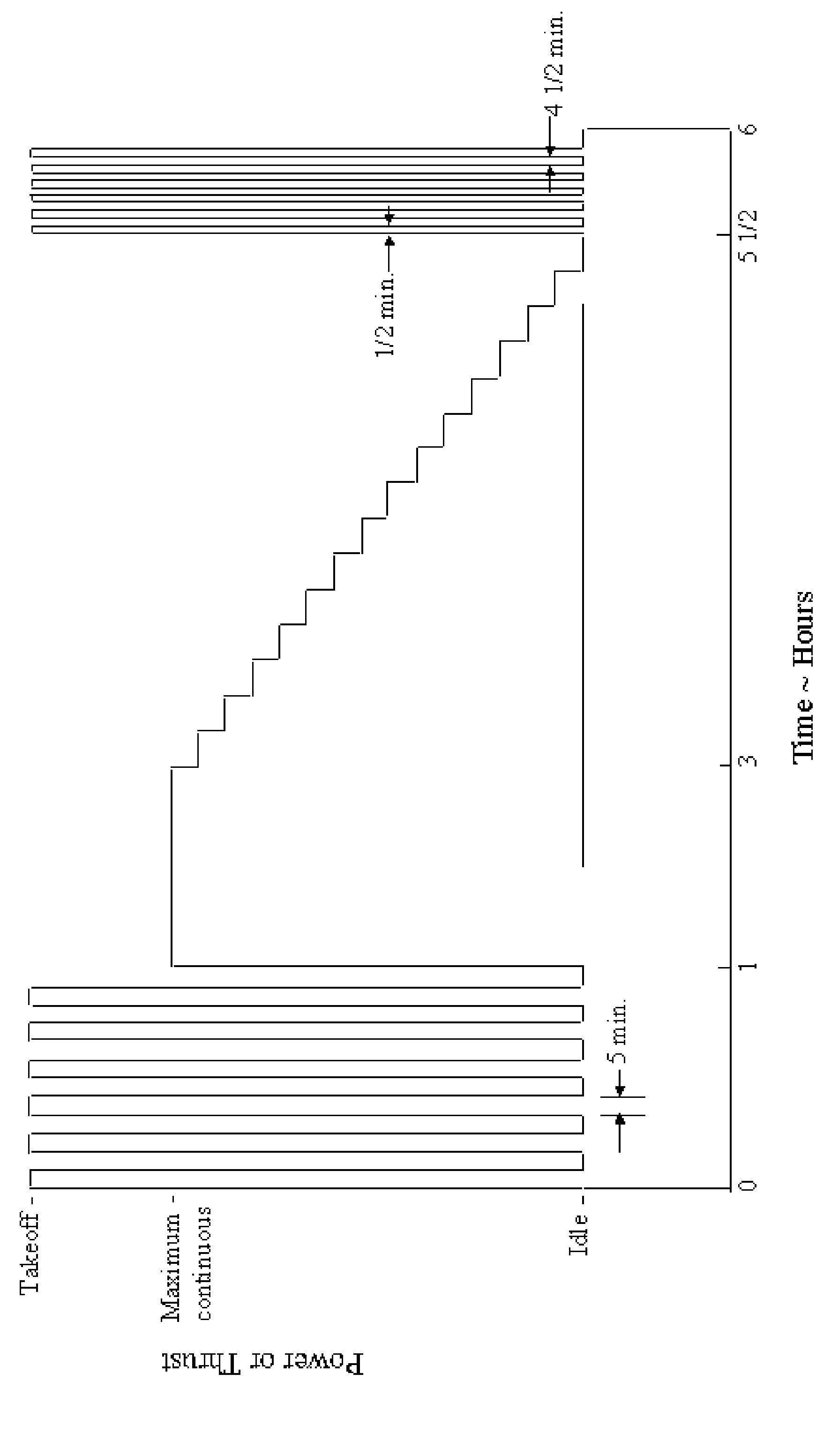

Figure 1

§ 33.87(b) 150 Hour Endurance Test Cycles 16-25

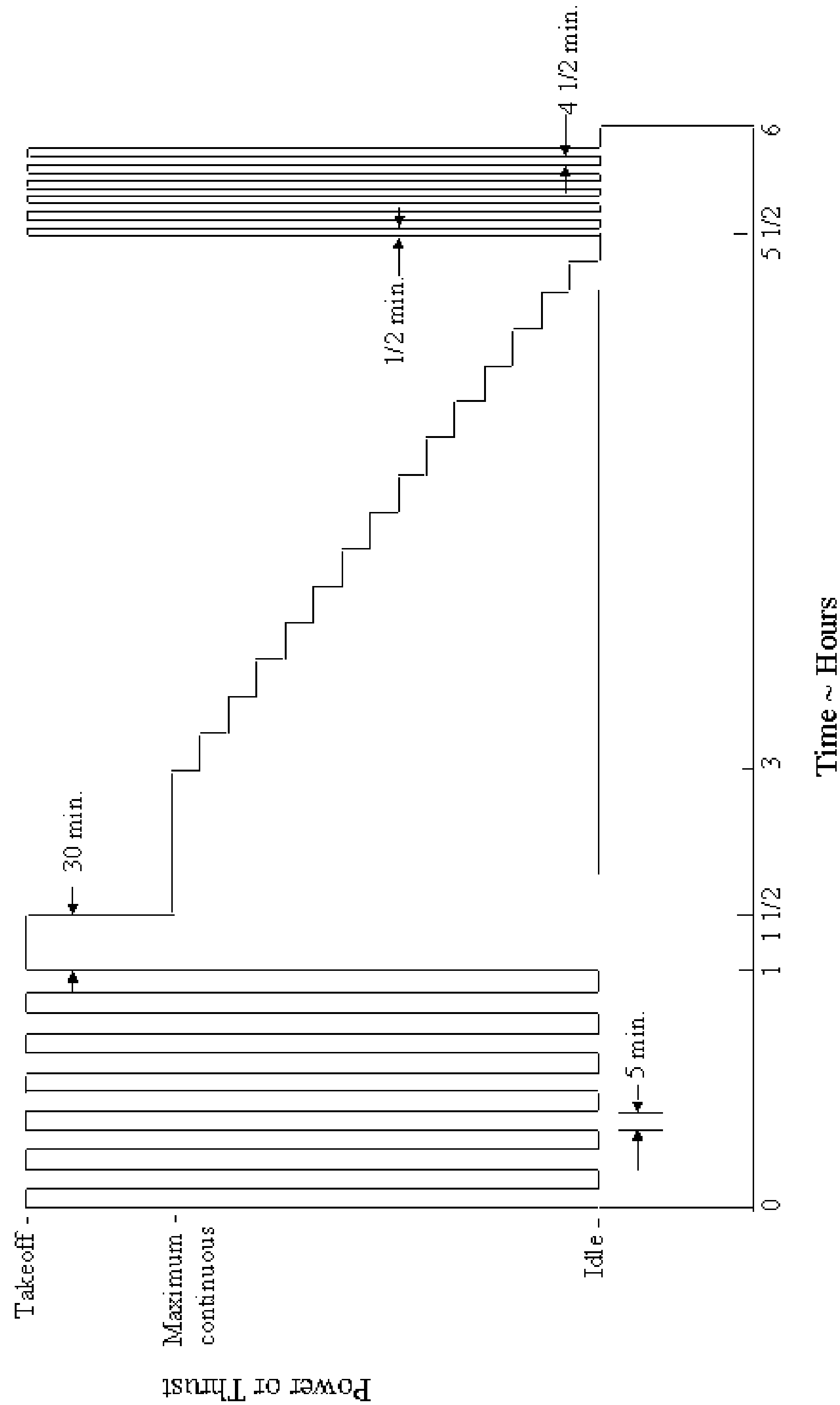

Figure 2

§33.87(c) 150 Hour Endurance Test Cycle 1-25
for Rotorcraft Engine with 30-Minute OEI Power Rating

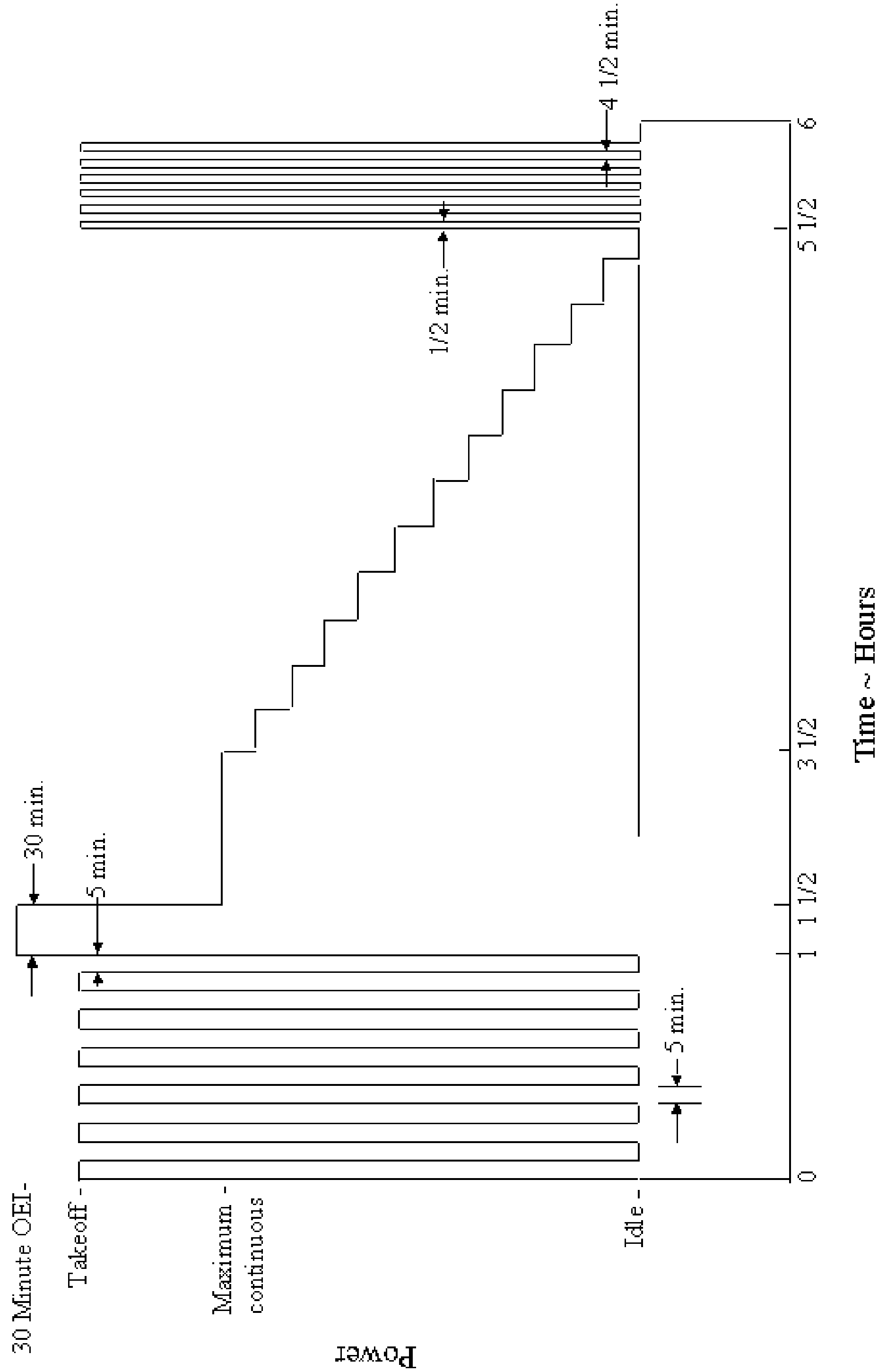

Figure 3

§33.87(d) 150 Hour Endurance Test Cycle 1-15 for Rotorcraft Engine with Continuous OEI Power Rating

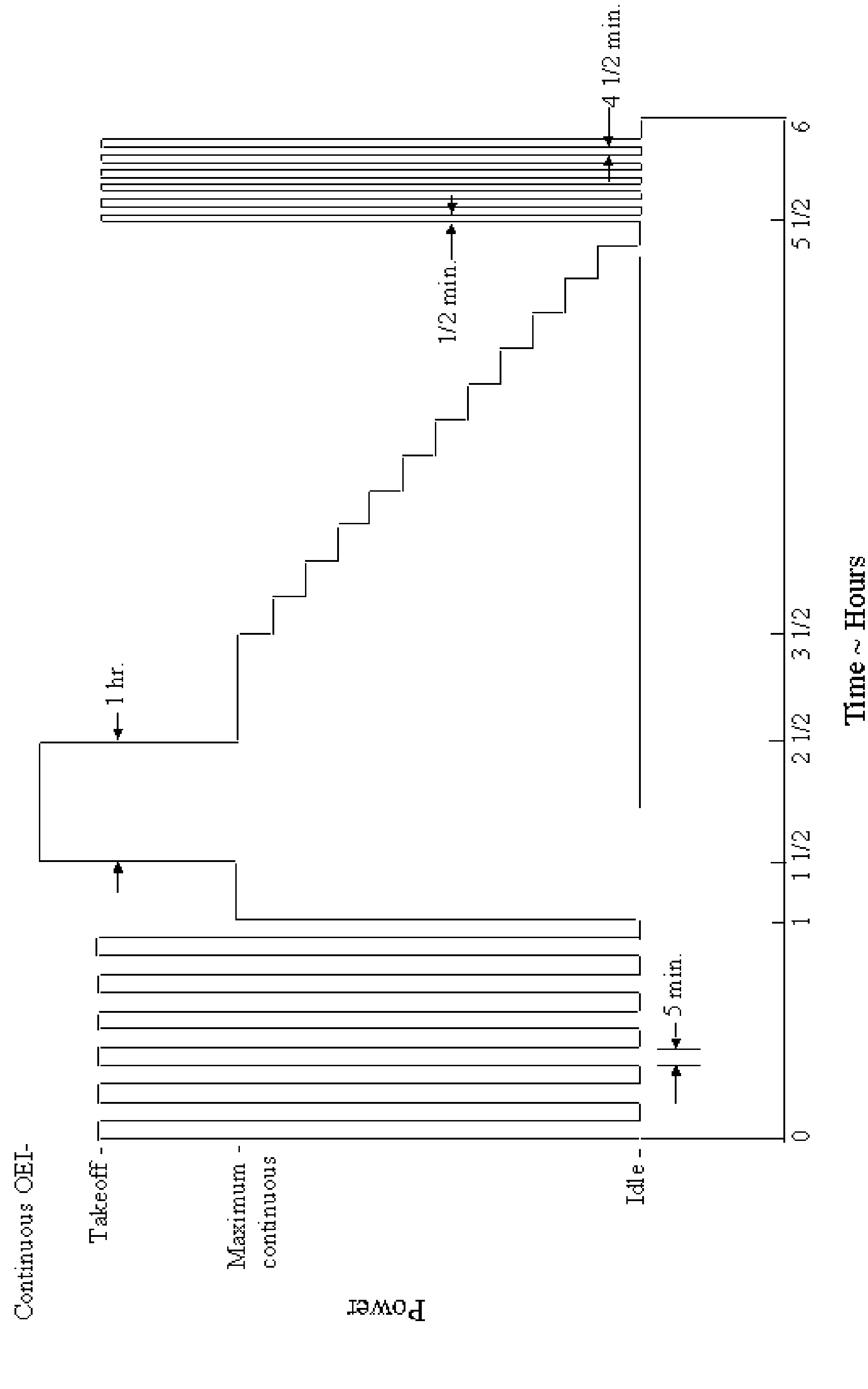

Figure 4

This document does not represent final agency action on this matter and should not be viewed as a guarantee that any final action will follow in this or any other form.

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§33.87(d) 150 Hour Endurance Test Cycle 16-25
for Rotorcraft Engine with Continuous OEI Power Rating

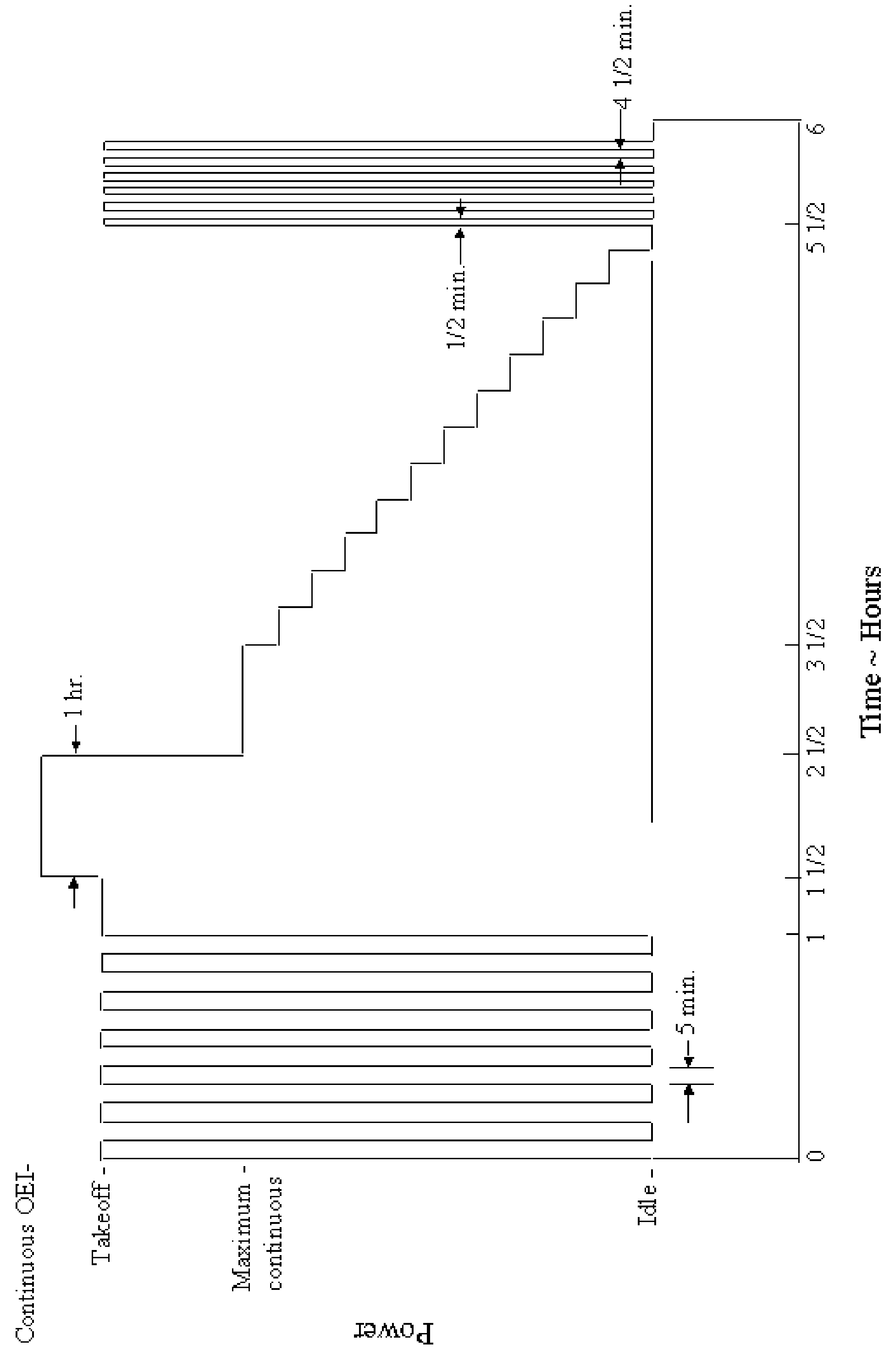

Figure 5

§33.87(e) 150 Hour Endurance Test Cycle 1-15
for Rotorcraft Engine with Rated 2 ½- Minute OEI Power Rating

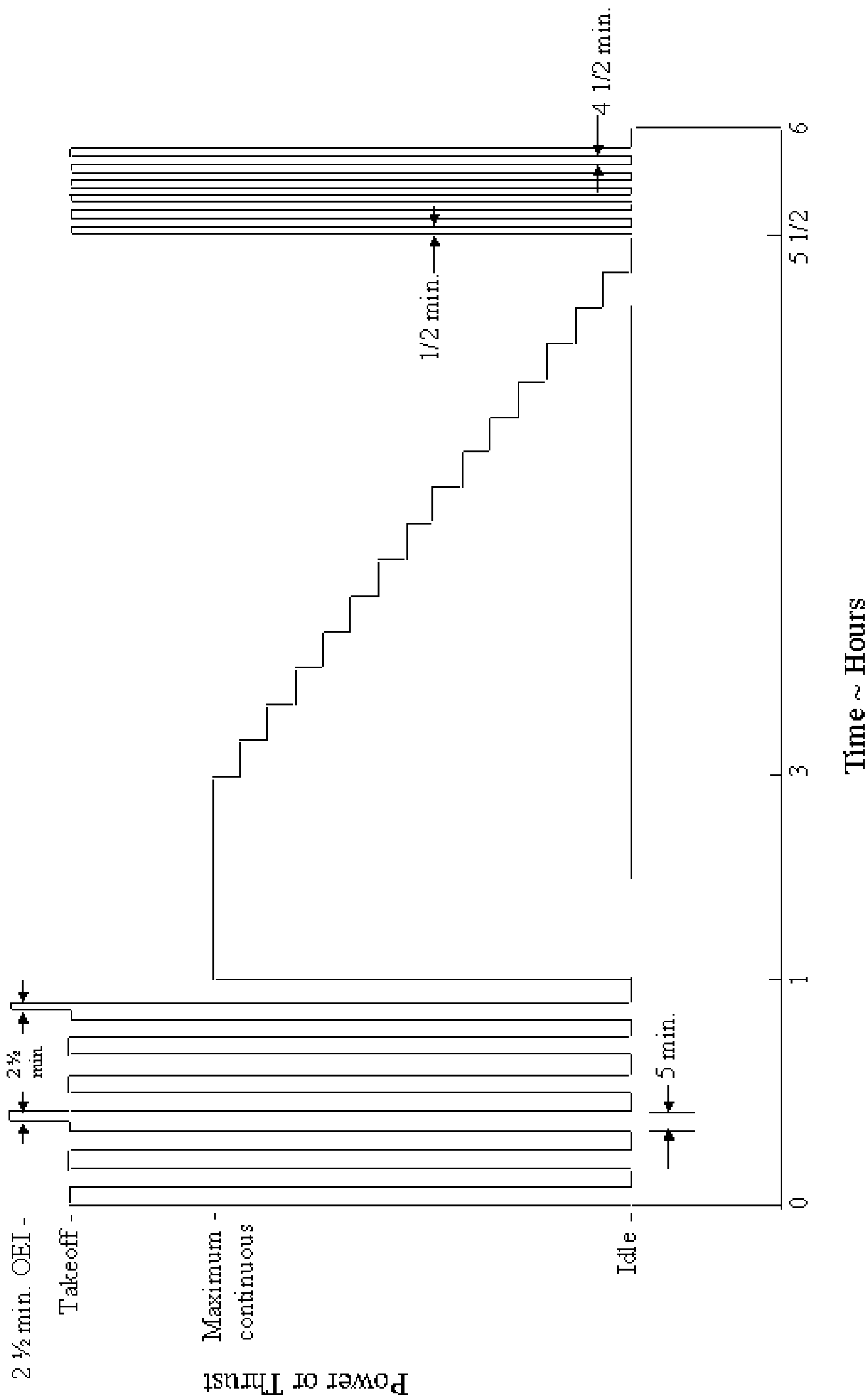

Figure 6

§33.87(e) 150 Hour Endurance Test Cycle 16-25
for Rotorcraft Engine with 2 ½ -Minute OEI Power Rating

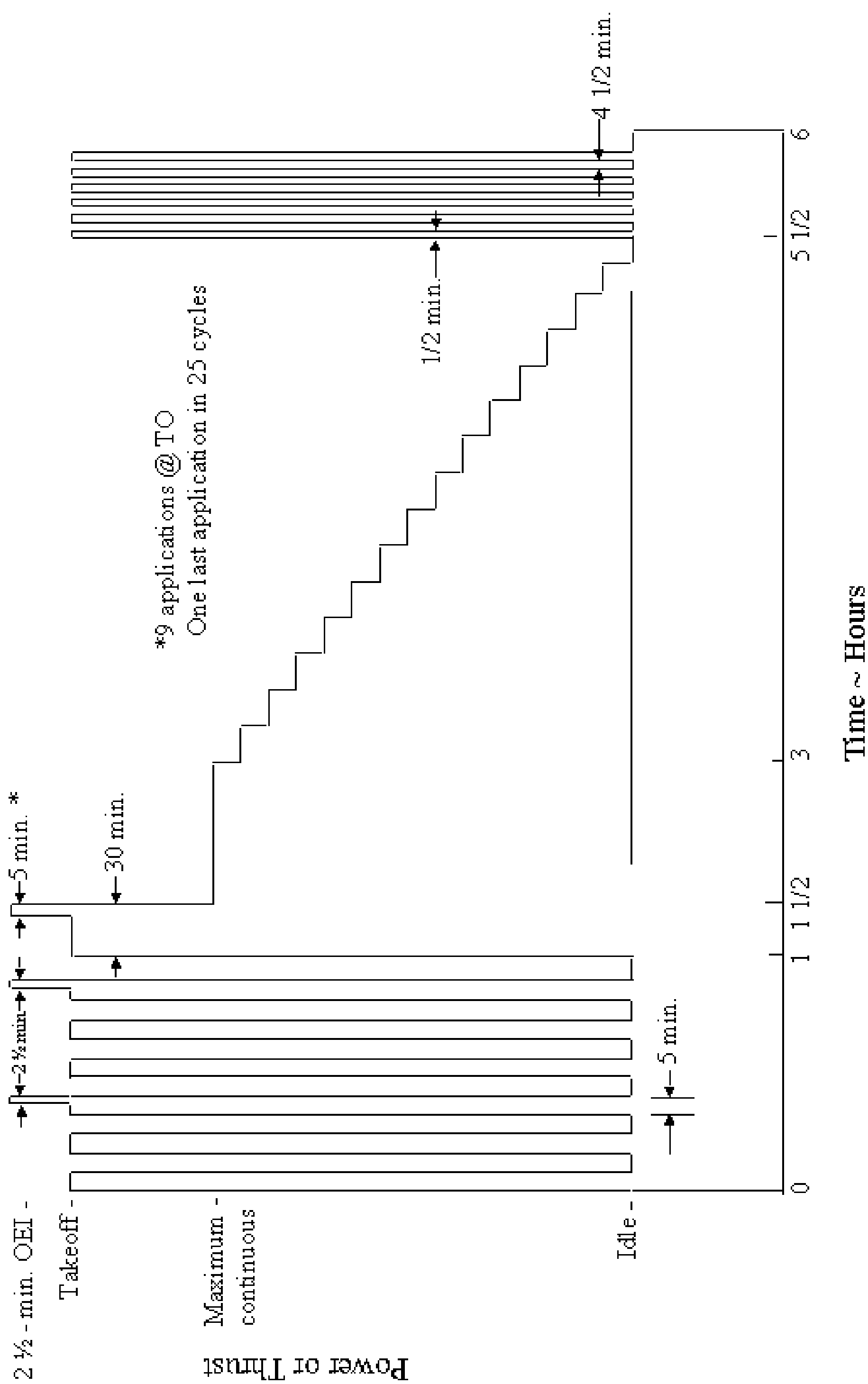

Figure 7

§33.87(e) 150 Hour Endurance Test Cycles 1-25
for Rotorcraft Engine with 2 1/2 Minute and 30-Minute OEI Power Ratings

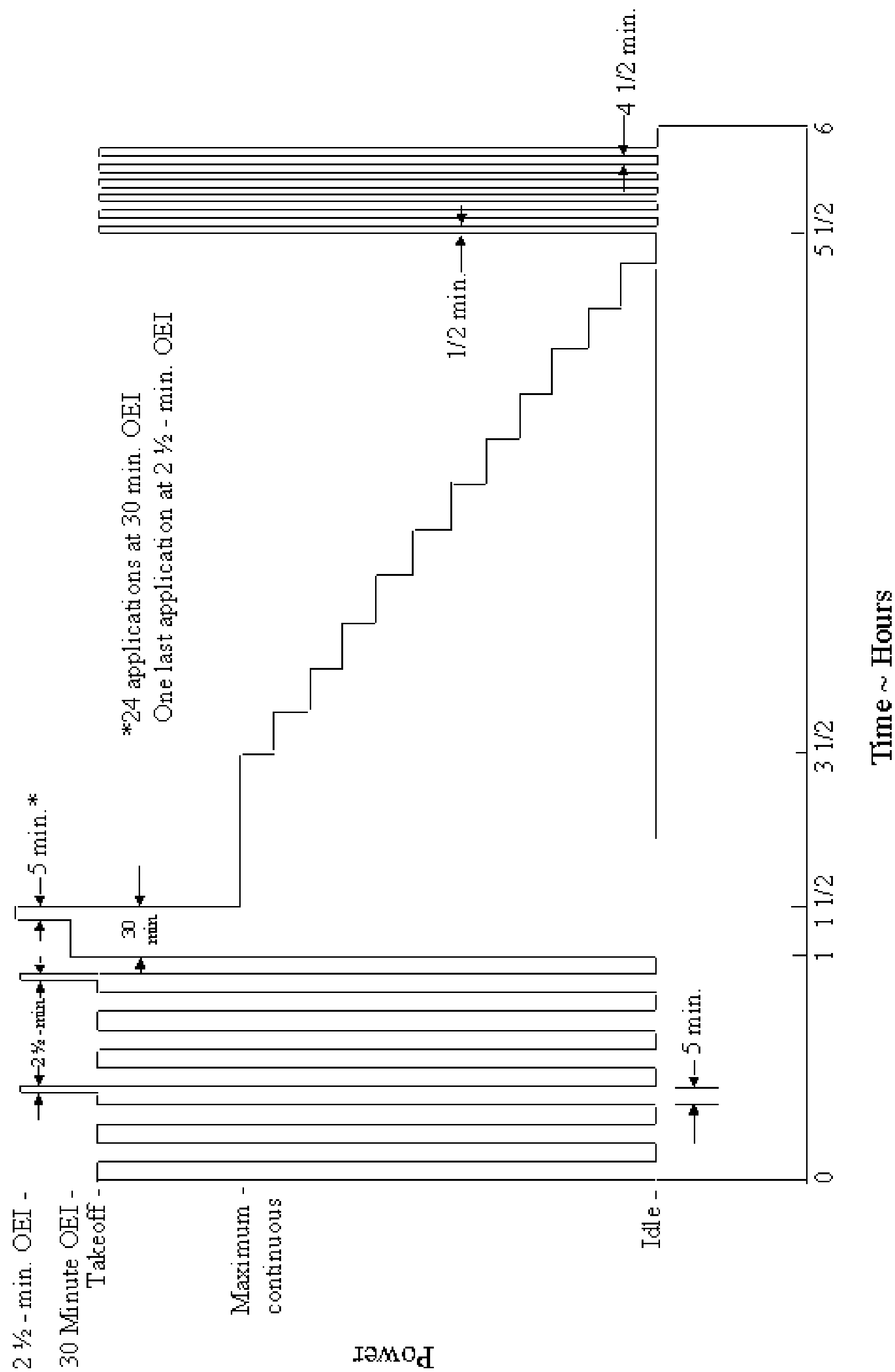

Figure 8

§33.87(e) 150 Hour Endurance Test Cycle 1-15 for Rotorcraft Engine with 2 ½-minute and Continuous OEI Power Rating

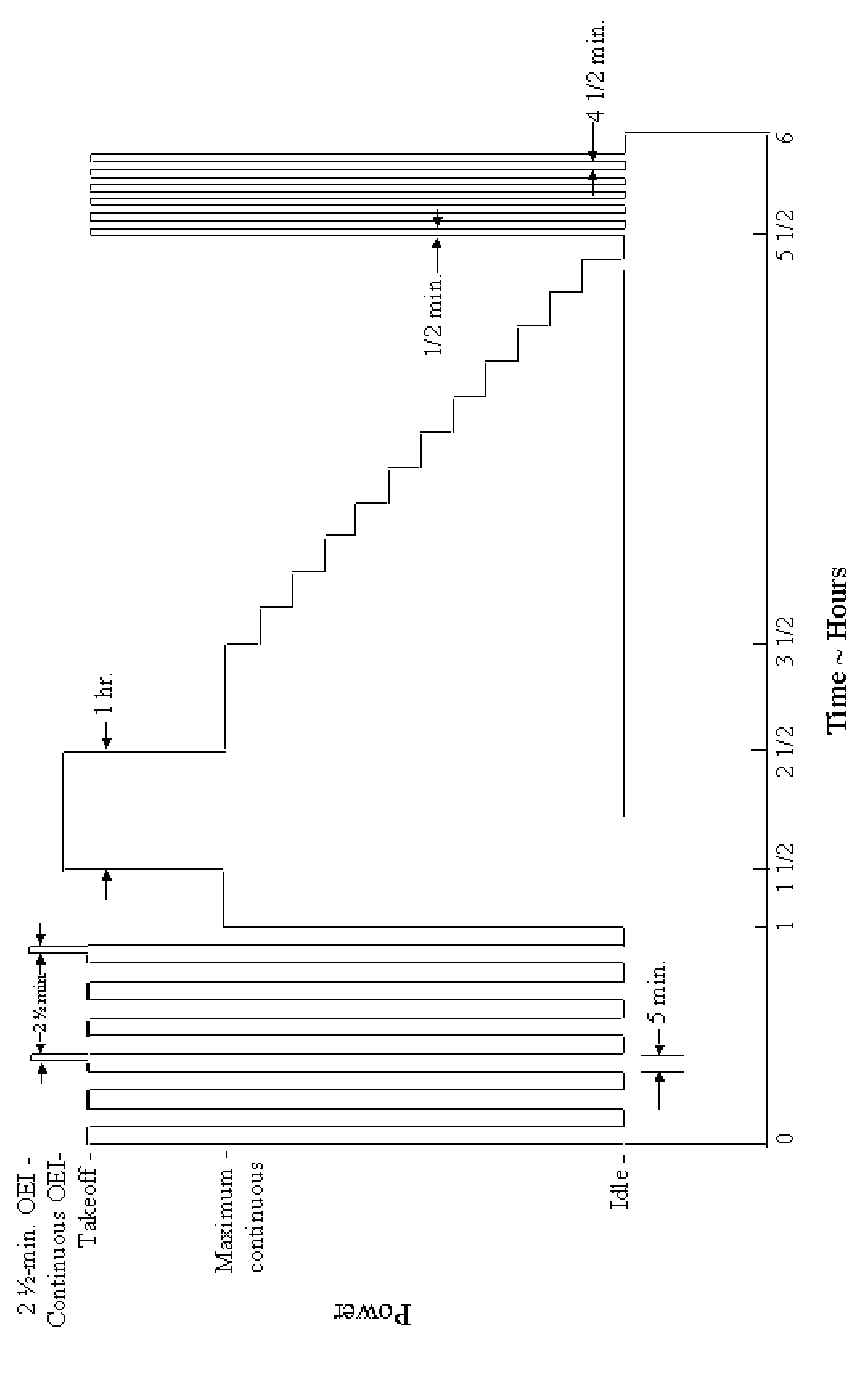

Figure 9

§33.87(e) 150 Hour Endurance Test Cycles 16-25 for Rotorcraft Engine with 2 ½ Minute and Continuous OEI Power Ratings

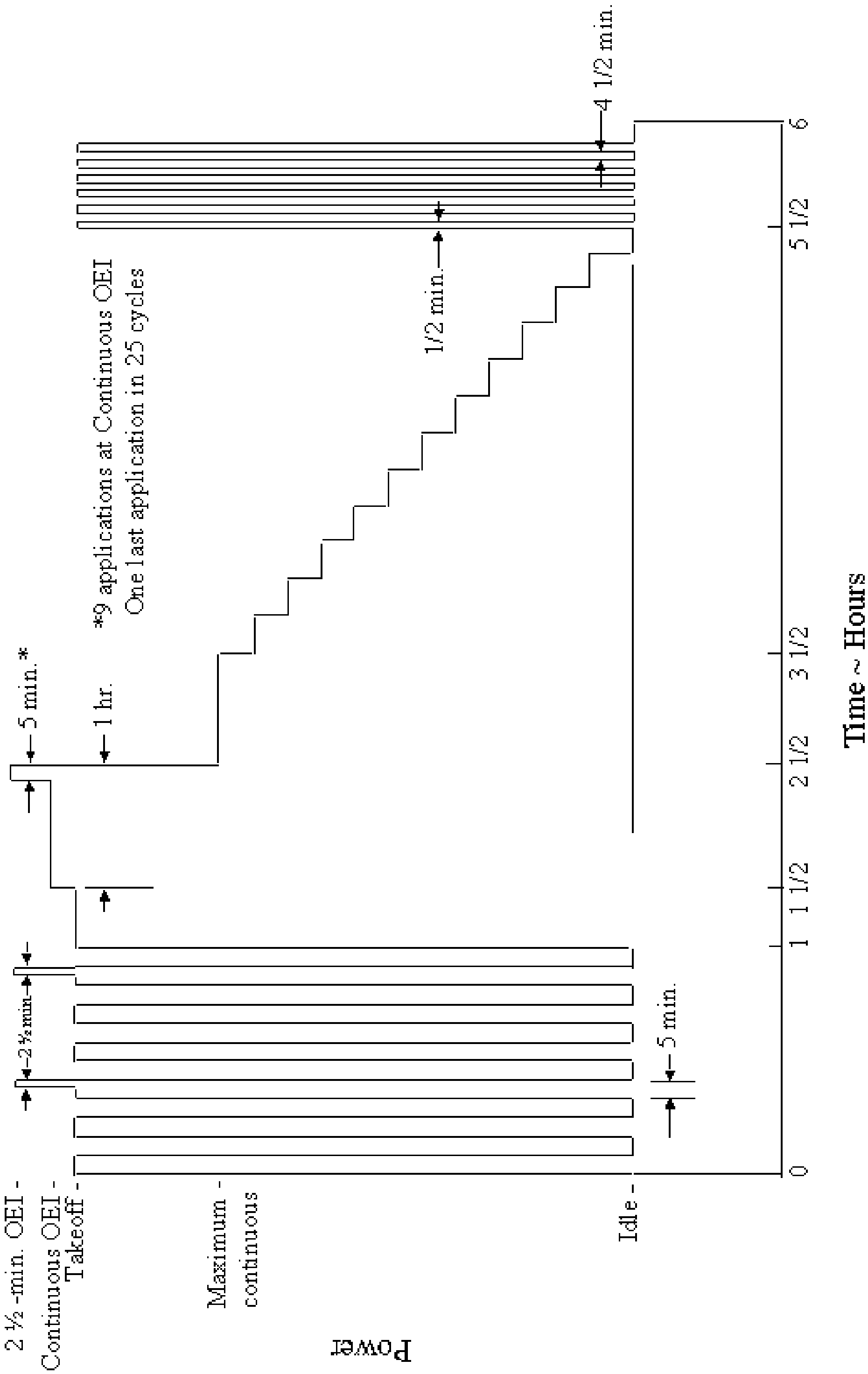

Figure 10

§33.87(f) 2 Hour Supplemental Endurance Test, Cycles 1-4 for Rotorcraft Engine with 2-Minute and 30-Second OEI Ratings

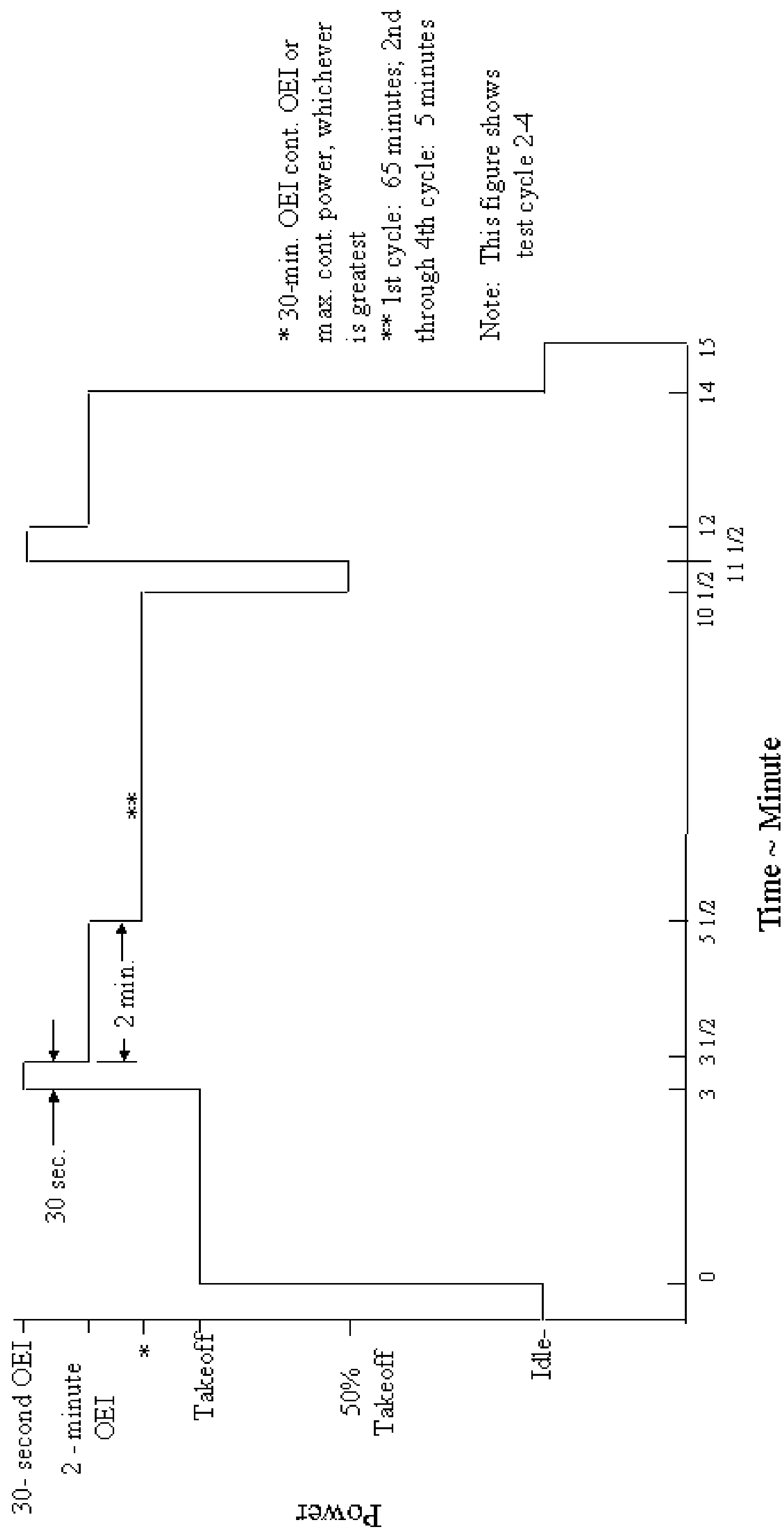

Figure 11