Advisory Circular

Subject: CALIBRATION TEST, ENDURANCE TEST AND TEARDOWN INSPECTION FOR TURBINE ENGINE CERTIFICATION (§§ 33.85, 33.87, 33.93)

Date: 4/13/06

Initiated by: ANE-111

AC No: 33.87-1

1. PURPOSE.

a. 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 Part 33).

b. The guidance in this AC replaces the guidance for § 33.87 contained in the FAA Policy Memorandum, Policy No. ANE-2000-33.87-R3, titled "Policy for 14 CFR § 33.87 Endurance Test." The guidance in this AC also replaces the guidance for §§ 33.85, 33.87, and 33.93 contained in AC 33-2B, Aircraft Engine Type Certification Handbook. This AC applies to part 33 type certification endurance testing of all classes of turbine engines.

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) Aircraft Certification Office (ACO) and Engine Certification Office (ECO) engine type certification engineers. Without specific references to FAA project engineers, certification engineers, project managers, or to an FAA office, the term FAA (or "we") will apply to both FAA personnel and FAA designated representatives for those functions and situations for which the designees have been granted the appropriate authority to act for an ACO or the ECO.

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. We 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 these regulations.

c. While we are providing guidance on what may be considered acceptable methods of compliance under normal circumstances, we acknowledge that no document can provide guidance that will cover all future engine designs, operating characteristics, and unique certification circumstances. Therefore, if we find that the compliance methods defined within this document do not provide acceptable means to show compliance due to some unique engine design or operating characteristics, or other unforeseen circumstances, then we will not be bound to accept these methods. If the applicant chooses to use this AC, the applicant must conform to all aspects of the AC.

d. This guidance does not change, create any additional, authorize changes in, or permit deviations from, the 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, 33.91, 33.93, and 33.99

b. Related Documents

(1) FAA Order 8110.4C, Type Certification.

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

(3) FAA Policy Memorandum, Policy No. ANE-2000-33.87-R3, "Policy for 14 CFR § 33.87 Endurance Test."

4. DISCUSSION.

a. The revision of part 13 of the Civil Air Regulations (14 CFR Part 13) in 1952 created the original rules for the turbine engine calibration test, endurance test, and teardown inspection. The airworthiness standards of part 13 were replaced in 1965 when the new part 33 of the Federal Aviation Regulations (14 CFR Part 33) became effective. Part 33 has been revised since through numerous amendments over the past four decades. The most significant changes were in Amendments 6 and 10, adopted in 1974 and 1977, respectively. These 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. The intent, however, 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 tests 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 these components are able to function reliably in all certificated operating conditions.

d. The guidance material in this AC is presented in Chapters 2, 3, and 4, corresponding to the requirements in §§ 33.85, 33.87, and 33.93, respectively. The contents of each chapter are arranged in accordance with the order of the paragraphs in the respective regulation. The general testing requirements contained in §§ 33.82 and 33.99 are included in these chapters wherever applicable. The appendices provide background information for the guidance material; define documentation requirements for the calibration, endurance tests, teardown inspection; and define testing requirements for special applications.

e. The guidance in this AC is derived from extensive FAA and industry experience in determining the basis of compliance to §§ 33.85, 33.87, and 33.93. If, however, we determine that testing performed in accordance with the guidance in this AC would still not result in complete compliance with these regulations, we may require additional substantiation or testing to determine compliance.

//*signed by FAF on 4/13/06*//
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CHAPTER 1. GENERAL

1-1. Background.

a. The Civil Aeronautics Board adopted the original rules for turbine engine certification tests when it revised part 13 of the Civil Air Regulations (CAR) on January 8, 1952. The test requirements for turbine engines included a general block test, calibration tests, a 150-hour endurance test, and a teardown inspection.

b. In the following paragraphs we briefly describe the major changes made over the past 50 plus years through amendments to the regulations for the endurance test and to related rules. The chronological revisions of the endurance test regulations from the original issuance of part 13 of the CAR to the latest version of part 33 of the Federal Aviation Regulations are presented in Appendix 12. This information may be helpful in reviewing the endurance test requirements of derivatives of previously certified engines.

(1) Part 13 of the CAR.

(a) The calibration test specified in part 13 was similar to that of § 33.85(a), except that part 13 did not address compressor air bleed for the test. The endurance test in part 13 consisted of only a test schedule that resembles the current § 33.87(b) schedule. The teardown inspection paragraph in part 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 Amendment 13-5, effective on February 12, 1963. We adopted the test schedule for “2½-minute power for helicopter turbine engines” or “rated 2½-minute OEI power” in Amendment 13-6, effective on April 22, 1964. This was the last amendment to part 13 prior to the FAA recodification that introduced part 33.

(2) 14 CFR Part 33.

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

b. In response to the increasing complexity of airframes, engines, and their interfaces, the FAA adopted Amendment 6 to part 33, effective on October 31, 1974. This amendment substantially revised the endurance test and related regulations. In this amendment, we added a new § 33.82 and, in § 33.87(a), an endurance test schedule for supersonic aircraft engines. We 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. We made this change based on our certification experience with high-bypass large turbofan engine certifications. Amendment 6 also changed § 33.99 “General conduct of block tests," by adding requirements for engine service, malfunction, and stoppage during endurance testing.

c. In 1977, as part of the Aircraft Engine Regulatory Review Program, the FAA solicited rule change proposals from the aviation and general communities and conducted a review conference. As a result, we issued Amendment 10 to part 33, effective March 26, 1984, which revised § 33.87(a) and the rated 2½-minute OEI power test schedule to the current requirements.

d. We adopted Amendment 12, effective October 3, 1988, which provided a new test schedule for rated continuous OEI power for rotorcraft turbine engines. In Amendment 18, effective on August 19, 1996, we provided a 2-hour endurance test schedule in § 33.87(f) for the new 30-second OEI and 2-minute OEI ratings in addition to the existing 150-hour endurance tests required in § 33.87. We also revised the calibration test and teardown inspection by adding new paragraphs to cover specific requirements for these two ratings.

e. The basic requirements in § 33.87 regarding test cycles and testing at maximum thrust, power, or torque, redline rotor speeds, and engine turbine gas temperatures have remained substantially the same, despite several regulatory reviews, since their introduction in 1958 through Amendment 2 of part 13 of the CAR. These endurance test requirements 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.

f. The endurance test cycle was not designed to represent a typical in-service flight cycle. Instead, it was created to represent an accelerated demonstration of durability, operability, and reliability with the engine operating at the limits of power, thrust or torque, rotor speeds, and gas temperature to which it will be certificated.

1-2. Definitions.

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

Continued airworthiness. The engine is in a state of continued airworthiness when it conforms to its type certificate and is in a condition for continued safe operation.

Engine component. 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. Occurs when 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 with the engine power control lever set at the position representing the least power or thrust that is allowed in flight.

Germane or primary hardware. The certification hardware that directly impacts the pass/fail criteria for the given test objectives. Applicants should identify germane hardware in the certification test plan submitted to the FAA for approval.

Ground idle. The steady state engine operation on the ground with the engine power control lever set at the position representing the least power or thrust that is allowed on the ground.

Maximum permissible speed or gas temperature or output shaft torque (see also "Redline conditions"). The highest physical rotor speed, gas temperature, or output shaft torque, including transients, which may not be exceeded in operation at any applicable rating. These limitations are also referred to as the redline rotor speeds, output shaft torque, and gas temperature that are prescribed in the Type Certificate Data Sheet (TCDS) for each approved engine rating.

Power characteristics. The relationship during both steady-state and transient operations between engine thrust, power, or output shaft torque and the engine primary control parameters, which are typically the EPR or the power turbine rotor speed, output shaft speed, or fan speed.

Rated power or thrust. The takeoff power or thrust referenced to sea level standard day pressure, rated air temperature, and specific engine configuration conditions for each rating presented for approval. This is also the engine rated power or thrust prescribed in the TCDS.

Rated 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 same location specified in the type design of the engine.

Rating. A specific engine operating power condition at which an engine must be certified to operate. Some examples of engine ratings are takeoff, climb, maximum continuous, and cruise.

Redline conditions. The engine operating limitations in terms of the maximum allowable rotor speeds, output shaft torque (for turboprop or turboshaft engines), and gas temperature that are established for each engine rating condition under part 33. These limitations are also referred to as the maximum permissible rotor speeds, output shaft torque, and gas temperature that are prescribed in the TCDS for each 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), as appropriate to the model being tested.

Start (normal start). The transient process of motoring the engine on the starter while simultaneously supplying ignition and fuel to accelerate the engine from a shutdown condition to a ground idling condition. The starting time and other parameters must be maintained within the engine starting limits that will be specified in the TCDS and in the Instructions for Continued Airworthiness (ICA).

Steady-state condition. The engine operating condition during which its parameters such as power or thrust or torque do not significantly vary with time.

Test hardware. The parts and components to be certificated and that are assembled to or, if remotely located, are still part of the test engine. Whenever a given piece of hardware deviates from the type design, the applicant should provide a comparison in the test plan, frequently referred to as a "reconciliation," of the tested hardware compared to the type design hardware. The applicant must substantiate that any non-type design hardware is still representative of the capabilities, durability, and operating characteristics of the type design part. Further, the non-type design part must not adversely affect the functioning of any other part or system. Applicant may use non-type design parts that are less capable than type design parts in withstanding the rigors of the testing environment, but may not use parts that are more capable than a typical type design part. The FAA must approve all non-type design hardware used in a certification test.

Transient. A condition in which engine parameter(s) vary with time between two steady-state conditions. Examples of transients include starting, acceleration, and deceleration.

Transient rotor shaft overspeed, or output shaft overtorque, or transient gas overtemperature. Temporary transient rotor shaft speed, output shaft torque, or gas temperature condition following a rapid acceleration from idle to rated 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 seeks part 33 certification.

Vibration signature survey. The vibration measurements conducted during pre- and post-endurance tests that record vibration amplitude(s) as a function of engine rotor speed. Engine accelerometers mounted on the engine cases record the vibration data.

CHAPTER 2. CALIBRATION TESTS.

2-1. Power Characteristics. The power characteristics of the endurance test engine that represent the type design must be established by engine test data collected with (1) no air bleed for aircraft services; and (2) only those accessories installed which are essential for engine functioning, except when the TCDS defines other conditions that are used to determine the engine ratings. The test data is then referenced to the sea level standard day pressure and rating air temperature conditions at which the engine rating is to be defined. Refer to Section 1-2 for the definition of power characteristics.

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

a. The pre- and post-endurance 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)).

c. Applicants should run the calibration tests 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, or non-type design exhaust nozzles. This special test equipment, however, may be necessary to obtain simultaneous redline conditions during the endurance test itself. The power settings must include the highest power or thrust rating capability of the engine during the 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. Applicants should record the calibration test measurements 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 calibration testing could 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, the applicant should record this data 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 compliance with § 33.85.

b. The applicant must determine the engine's power characteristics at the 30-second and 2-minute OEI rating conditions. 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 at 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), and even if the engine still produces rated power at the end of the test, 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. The 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 operating 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 operation. This determination must be based on the inspection and maintenance requirements that are defined in the ICA that will be submitted in compliance with § 33.4. To demonstrate this minimum level of durability and operability, the engine must:

(a) Continue to produce its rated power or thrust at the end of the test without exceeding any of the operating limitations prescribed in the TCDS, §§ 33.4, 33.5, and 33.7.

(b) Demonstrate: (1) acceptable operability from minimum to rated takeoff power or thrust without overtemperature, surge, stall or other detrimental occurrences; and (2) durability while operating up to rated thrust or power or torque, redline and transient rotor speeds and gas temperature, and when applying maximum rated loads on accessory drives and mounting attachments.

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

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

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

(f) Demonstrate starting capability, drainage or expulsion of unwanted fluids or fuel that may accumulate after a false start.

(2) The test engine may also be used for other part 33 engine tests in conjunction with the endurance test runs. In addition, 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 ratings and operating limitations in § 33.7.

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

(c) Suitability and durability of materials in § 33.15.

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

(e) Accessory attachments in § 33.25.

(f) Surge and stall characteristics in § 33.65.

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

(h) Ignition system function in § 33.69.

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

(j) Hydraulic actuating systems, § 33.72.

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

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

(m) Thrust reverser test in § 33.97.

(n) 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 or components may not be adequately substantiated by endurance testing alone in accordance with the requirements of § 33.87. For these systems or components, applicants must complete additional component level tests under the requirements defined in § 33.91 to establish that the systems or components can function reliably in all engine operating and atmospheric conditions that will be certificated.

(a) For example, to properly demonstrate its operability and durability characteristics, the main accessory gearbox must be tested at the maximum rated pad loads and power extraction loads that will be certified. If these extreme gearbox load conditions exceed the capability of the applicant's endurance testing facilities, then the applicant may choose to complete an additional gearbox rig test at these maximum rating 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 the FAA approves a different test sequence. For engines seeking the 30-second OEI and 2-minute OEI ratings, the applicant 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 profiles of the endurance test schedules specified in § 33.87(b), (c), (d), (e), and (f).

(5) The limits of rotor speed, power or thrust, output torque, and gas temperature that are included in the engine TCDS as required by § 33.7 must be less than or equal to those values that were demonstrated during the endurance test for each engine rating condition.

b. Endurance test plan requirements.

(1) The applicant must prepare a test plan for the endurance test defining the manner in which the test will be conducted. This test plan must be submitted early enough to allow the FAA 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(s);

(b) a description of the germane or primary hardware to be tested and certified;

(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. This means that all engine hardware, software, and systems to be certified should have at most only minor deviations from the type design. The applicant must disclose any deviations (referred to as "non-conformances") of the hardware, software, and components from the type design, and must provide acceptable evidence that these non-type design characteristics will not adversely affect the outcome or the integrity of the test. Justification of the acceptability of these non-conformances is frequently referred to as reconciliation. Applicants must submit all such non-type design configuration deviations to the FAA for approval.

(a) The standard type design configuration and operating characteristics of some turbine engines may preclude simultaneous operation at maximum permissible rotor speeds and gas temperatures while maintaining maximum rated thrust, power, or output torque as required by § 33.87(a)(3). Engine operation at the maximum permissible rotor speeds simultaneous with the maximum permissible gas temperature is referred to as the triple redline operating condition. Modification of certain test equipment, engine configurations, and test sequences may be necessary to run the test at these simultaneous triple redline conditions. The applicant must provide a technical substantiation that the test engine with any modifications still properly represents the durability and operating characteristics of a typical type design engine and complies with the § 33.87 requirements.

(b) The applicant may run more than one test on the same set of hardware to be presented for certification if all operating parameters cannot be held simultaneously at 100 percent of the values to be certificated. See Appendix 2 for additional information on an acceptable endurance test cycle for multiple engine tests.

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

(3) The certifying FAA office 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 that FAA 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. The certifying FAA office will determine the extent of any required pre-assembly conformity inspections and calibrations.

(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 the outcome of the endurance test. An example of this type of information is the weight, overhung moment, or power extraction loads imposed on the engine by each accessory. The applicant may install the component or simulating loading device on the test engine when approved by the FAA.

(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) The fuel, lubricating oil, and hydraulic fluid used for the endurance test must conform in all respects to the specifications that will be prescribed in the TCDS and ICA. The test report should contain a statement from the applicant identifying the specifications of all engine fluids used during the test. The verification of fluid properties is the responsibility of the applicant not the fluid suppliers.

(3) Prior to starting the endurance test, applicants should calibrate (1) all test equipment and measuring instrumentation necessary to operate and monitor the engine and the test facility to FAA-approved standards; and (2) all engine components according to their component calibration schedules. Post-test calibrations should also be completed to confirm instrumentation and measurement system accuracy throughout the duration of the test.

e. Pre- and post-endurance testing.

(1) Section 33.63, Vibration, requires that the engine and its components be free from excessive or harmful vibration throughout its operating flight envelope. Changes to the engine's vibration signature over its operating range due to any part deterioration caused by the endurance test can be conveniently measured by comparing vibration surveys conducted before and after the test. These vibration surveys should be conducted during slow accelerations and decelerations of not less than 2-minute durations that cover the range from the minimum to the maximum permissible rotor speeds, including any transient operations. The post-test vibration signatures should not show a significant change from the data recorded during the pre-endurance vibration survey, and must still be at or below the allowable limits that were established in compliance with § 33.63. Significant changes in vibrations must be addressed to determine their causes and, if necessary, make applicable design changes. The test report must document all findings and actions taken. However, the purpose of the surveys conducted during endurance testing is limited to the substantiation of potential vibration signature changes due to engine deterioration. All other requirements for engine vibrations prescribed in § 33.63 and in § 33.83 must be addressed separately.

(2) Oil consumption must be monitored during the test and must be within the allowable limits prescribed in the engine operating documents. We recommend that applicants periodically check oil samples for the presence of metallic particles or other debris that may indicate an impending failure of one or more parts.

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 FAA certification office 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. The applicant must determine and substantiate any corrective actions prior to resuming the test.

g. Endurance test report requirements.

(1) The certification test report(s) should 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 should contain a list 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 takeoff and idling cycle segment [i.e., from § 33.87(b)(1)] and one acceleration and deceleration segment [i.e., from § 33.87(b)(5)] to show engine stabilization at or above the required operating parameter values, such as rotor speed and gas temperature, to be certificated. These traces are necessary to substantiate that a parameter may not stabilize at its 100 percent value within a § 33.87(b)(1) or § 33.87(b)(5) test segment. Applicants must document and substantiate the acceptability of any deviations or exceptions to the test requirements. This requirement also applies to the corresponding test runs of § 33.87(c), (d), (e), (f) or (g).

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

3-2. Specific Requirements in § 33.87(a)(1) through (a)(9).

Note: Unless otherwise specified, guidance provided in the following paragraphs regarding § 33.87(b) requirements also applies to the corresponding test run requirements of § 33.87(c), (d), (e), (f) or (g).

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 as prescribed, we 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 segment sequences do not lessen the severity of the endurance test cycle. The applicant must also substantiate that all test cycle requirements, including the required number of accelerations to rated power and decelerations back to idle power, were properly completed.

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. Software used for engine control should be representative of the final production version.

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

(1) During the endurance test, the engine thrust or power, torque, gas temperature, and rotor shaft rotational speed(s) must be maintained simultaneously at least at 100 percent of the values associated with the particular engine operation being tested**,** with exceptions as provided in §§ 33.87(a)(5), (a)(6), and (a)(7). This means that applicants must run the endurance test to the maximum permissible (or redline) rotor speeds, gas temperature, and rated power, torque, or thrust values be certificated and that will be prescribed in the engine TCDS. These parameters must achieve steady-state operating values with minimal fluctuations or cyclic type variations, and with any minimum variations remaining at or above the 100 percent values to be certificated.

(2) At each rating condition during the endurance test, the test engine must maintain rated power, thrust, or torque, which are the minimum physical power, thrust, or torque values meeting the definition in § 1.1 and the requirements of § 33.7(a) and (c) and § 33.8(b). The rated power, thrust, or torque value that is prescribed in the TCDS is normally referenced to sea level, static, standard day pressure (14.696 psia or 101.3254 kilopascals) and the rated air temperature, with no customer bleed or horsepower extraction allowed, an ideal inlet (100 percent ram pressure recovery), and engine inlet and exhaust test hardware as specified in the TCDS.

(3) 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 rated thrust is inconsequential to a demonstration of the durability of those engine parts that are subject to thrust loads.

(4) 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 conduct more than one test, if necessary, so that all of the required testing at redline conditions is completed. However, all endurance testing must be conducted on the same set of engine hardware to be presented for certification.

(5) When 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. For turbopropeller and turboshaft engines, we will base the approval of torque and output shaft speed limits on those limits that are demonstrated simultaneously during the endurance test.

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

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 installation instructions.

(2) To verify that the lubrication system functions within design intent, the applicant must monitor oil consumption during the endurance test and summarize the results in the certification report. To verify oil type and quality, the applicant must take oil samples before and after the test, and analyze these samples to evaluate any oil property changes. The post-test sample should also be analyzed for the presence of any metallic particles or other contamination that may indicate the deterioration of one or more engine parts. The applicant must disclose any evidence of oil property degradation or particle contamination in the test report. We encourage additional oil sampling during the test since it can help to indicate the beginning of significant part deterioration by monitoring the accumulation of particle contamination of the oil. The oil consumption rate and the system pressure and temperature operating limits that were demonstrated during the endurance test should be consistent with any limits prescribed in the engine installation or operating instructions.

(3) The applicant should take a fuel sample from the fuel supply line to the engine prior to the initial power or thrust calibration check. We may require additional sampling during the endurance test if fuel is used from sources other than the one from which the initial sample was taken. The fuel characteristics must be consistent throughout the test, and conform in all respects to the specifications that will be prescribed in the TCDS. Any fluid property differences from these specifications, including the use of any additives, must be disclosed and justified.

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. The maximum permissible total air bleed from the engine must be extracted during at least 20 percent of the endurance test runs (e.g., 5 of the 25 prescribed 6-hour test sequences). But during these 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.

(a) We recommend that only 5 of the 25 prescribed 6-hour test sequences be run with maximum permissible bleed flow to comply with the intent of § 33.87(a)(5). Running more than five of the endurance test runs with maximum permissible bleed flow may not allow the engine to demonstrate compliance to the intent of § 33.87(a)(3) and therefore should be avoided.

(2) The applicant 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) 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. The combined extraction must equal the total bleed flow limit consistent with 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. The intent of this paragraph is to simulate the power extractions from accessories and the weight and overhung moment characteristics of the type design hardware at all operating power or thrust levels throughout the duration of the endurance test. However, the load imposed by each accessory used only for aircraft service must be the limit load consistent with rated power or thrust levels to be certified. The required loadings for all other power or thrust levels are the normal operating loads.

(a) The accessory drives referred to in this subparagraph are typically for aircraft supplied equipment, such as starter, generator, and engine components supplied by an airframer, and the gearbox spare drive. The mounting attachment points, including the mounting pads for accessory drive and for static structures, must also be loaded. The engine accessories, which are part of the engine type design, must be loaded for the conditions being tested.

(2) For any accessory drive and mounting attachments that cannot be adequately loaded or substantiated by the endurance test, the applicant 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 conditions. For example, the main accessory gearbox may require both endurance rig testing and 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, maximum power extraction loading, and at the extreme operating and environmental conditions to be approved. These extreme conditions may be outside of the engine endurance test set-up capability. In this example, during the engine

endurance test, the gearbox drive position may have actual or non-functioning slave hardware mounted that represents its 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 these parameters to stabilize.

(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 that 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 first 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) For most engines, the gas temperature generally does not require a 5-minute run period to stabilize at the redline value. Therefore, the exception to 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.

1. For rotorcraft engines, the exception also does not normally apply to the rated continuous OEI, rated 30-minute OEI, 2.5-minute OEI, 2-minute OEI or even 30 second OEI runs.

(f) Before the applicant can use the gas temperature stabilization exception 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 we accept the gas temperature stabilization exception, the applicant must still run the test in its entirety at rated thrust or power with rotor speeds (i.e., N1 and N2) at or above redline values. The applicant should maintain the same test configuration and acceleration rate of the engine as in the § 33.87(b)(1) and (b)(2)(ii) periods.

(g) If the applicant demonstrates that the gas temperature stabilization exception 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 the applicant may claim at the takeoff 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). We will, however, still accept this reduced takeoff power redline run time to meet the redline gas temperature run time requirements of § 33.87(a)(3) and (a)(8).

(h) The engine must be qualified with the same exhaust gas temperature stabilization characteristics that it will display in service.

(i) The engine must be controlled using the same exhaust gas temperature measurement and control system that it will use in service.

h. Transient overspeed, overtemperature, 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 (f), as applicable.

(2) A transient condition referred to in § 33.87(a)(8) is 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, 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) Transient limits may not be used as supplementary limitations, regardless of their duration, for engine power setting purposes. The transient limits of shaft overspeed and gas overtemperature prescribed in § 33.7(c)(14) and (c)(15), respectively, are intended for a transitory overshoot before reaching steady state limit values following an engine acceleration in normal operation.

(a) If the number of occurrences of transient conditions up to 30 seconds 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.

(b) If the number of occurrences of the transient conditions is not limited in normal engine operation, then at least 50 percent of the required endurance test 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 (150, 10, and 150, respectively) to takeoff power or thrust. Therefore, a minimum of 155 (50 percent of 310) accelerations must be made to the limiting takeoff power transient conditions during the endurance test.

(c) Section 33.87(a)(7) defines the basis for a possible exception to the § 33.87(a)(3) requirement to maintain gas temperature at the 100 percent or redline value to be certificated during all takeoff test segments. Although an applicant may present data substantiating that an engine cannot achieve a stabilized takeoff redline gas temperature during the § 33.87(b)(5) 30-second takeoff power segments, these accelerations to takeoff power still count toward the total of 310 required accelerations during the endurance test.

(5) We recommend conducting the transient condition test runs during the 150 accelerations to the 5-minute takeoff test segments of § 33.87(b)(1) and during the 10 accelerations to the 30-minute takeoff test segments of § 33.87(b) (2)(ii). Some turbine engines, particularly large turbofan models, may not reach a stabilized gas temperature during the 30-second takeoff power segments of the § 33.87(b)(5) test sequence. Therefore, we do not recommend attempting to run the transient tests during these segments, unless the transient duration to be certified is short enough to allow gas temperature stabilization at the required transient condition.

(6) The transient shaft over-torque limit is not specified in either § 33.7(c) or § 33.87(a)(8). However, as stated in AC 33-2B, we require that the transient over-torque limit approval, as with rotor speed and gas temperature limit approvals, 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 overspeed limits must be based on the limits demonstrated simultaneously during the endurance test.

(7) See Appendix 3 for guidance for 2-minute transient overtemperature 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. Special topics.

a. Endurance test cycles for amended Type Certificate (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 Parts Manufacturer Approvals (PMA).

(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 the applicant may conduct more than one test, if necessary, so that all of the required testing at redline conditions is completed. However, all endurance testing must be conducted on the same set of 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. Endurance Test Schedule, § 33.87(b), for Engines Other Than Certain Rotorcraft Engines.

a. Explanation.

(1) The applicant must perform this 6-hour endurance cycle 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, Figures 1 and 2.

(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, meet 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 atmospheric pressure (14.696 psia or 101.3254 kilopascals) and rated air temperature; with customer bleed or horsepower extraction amounts (if any), 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 physically 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, for example, a fan inlet or exit guide vanes, an adjustable fan exhaust nozzle, or an altitude test cell, may be required to achieve simultaneous rotor shaft rotational speed and gas temperature redline conditions. However, the engine may not be able to produce physical rated power or thrust under these operating conditions. The shortfall in the physical power or thrust may result in insufficient loadings on load-carrying members of the engine, such as thrust bearings, struts, mounts and cases, to comply with the requirements of § 33.87(a)(3). When the minimum physical power or thrust target cannot be achieved, the applicant must provide substantiating data to justify that any thrust shortfall is inconsequential to a demonstration of the durability of those engine parts that are subject to the thrust loads necessary to transmit the engine power to the airframe.

(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 applicant must comply with the applicable requirements in §§ 33.87(a)(1) through (a)(8) in running the test according to this schedule.

b. Guidance. Unless we approve an alternate sequence, the test must include the following runs defined in §§ 33.87(b)(1) through (b)(6). All accelerations to rated power or thrust must start from minimum idle power condition and all decelerations must return to minimum idle power condition.

(1) Section 33.87(b)(1), Takeoff and idling. The intent of this paragraph 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 or power or rated torque for rotorcraft and turbo-propeller engines, maximum permissible speeds and gas temperature, must stabilize at the

takeoff power condition redline values for 5 minutes. Similarly, power or thrust must be maintained at the minimum idle condition for 5 minutes following stabilization.

(a) Applicants must conduct 1 hour of alternate 5-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 stabilized 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 stabilize 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. 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 rated 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 necessitate 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 2 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 for 1.5 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.

(d) The cycle profile shown in Figure 1 in Appendix 13 depicts an apparent acceleration from idle to the maximum continuous power or thrust to begin the 30-minute § 33.87(b)(1)(i) segments that are required for 15 of the 25 cycles. However, that depiction is used only to simplify the presentation of the cycle profile. These 30-minute segments may also be started after a deceleration from the last 5-minute takeoff power or thrust segment of § 33.87(b)(1). A rapid acceleration using a one-second throttle movement from ground idle to maximum rated power or thrust is not required to start these 15 cycles, unless the applicant wishes to use those accelerations for additional transient accelerations.

(e) The cycle profile shown in Figure 2 in Appendix 13 depicts an acceleration from idle to takeoff rated power or thrust prior to starting the ten 30-minute segments prescribed in § 33.87(b)(1)(ii). These 10 accelerations are an integral part of the requirement to complete 310 accelerations to takeoff power or thrust in § 33.87(b) test.

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

(a) In complying with this subparagraph, the applicant must run all 25 of these segments 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 the 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 vibration 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 the minimum vibration cycles for endurance limit. The recommended minimum number of dwell cycles at each step is 10 million. 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 engine vibration is considered significant when it occurs near or at a known resonance point, or within a steady state speed operation, and presents any of the

following characteristics within the operating range, which include transients, declared in the engine installation and operation manuals:

(i) Amplitudes that indicate stresses near the endurance limits; and

(ii) Amplitudes or frequencies that may affect the functionality of engine rotors, systems, or components.

3. 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 the 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 within 30 seconds, 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)(c) 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)(3) requires that the oil inlet and gas temperatures be at least at 100 percent of the value to be certificated for each rating condition being tested. Section 33.87(a)(7), however, permits an exception to this requirement for test segments that are not longer than 5 minutes and do not allow these parameters to stabilize within those segments at their 100 percent or redline value. Experience has shown that the gas temperature of many turbine engines do not stabilize during these 30-second takeoff runs of § 33.87(b)(5). The applicant for these engines may elect to use this option. If the applicant does not run this part of the test to redline gas temperature, then the total steady state run time that can be claimed at takeoff redline gas temperature will be reduced from 18.75 hours to 17.5 hours.

1. Even if the oil or gas temperature stabilization exception allowed by § 33.87(b)(5) can be substantiated, the acceleration and deceleration runs in § 33.87(b)(5) must still be completed in their 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 should 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) The applicant must conduct 100 engine starts 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. These starts are required to demonstrate the engine's capability to purge unwanted fuel before energizing the ignition system.

3. Ten normal restarts preceded by a maximum 15-minute shutdown period.

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 installation instructions.

(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 lever 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 the engine on the starter or draining the fuel as specified in the engine operating instructions. 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 installation instructions.

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

(f) After each of the starting demonstrations, the applicant must show that the engine can accomplish all subsequent normal starts without any abnormal indications, and without exceeding the maximum starting temperature limit specified in the engine instillation or operating instructions.

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

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 prescribed in § 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 power rating. The test must include the sequential test runs defined in § 33.87(c)(1) through (c)(6), unless we approve an alternative test sequence. The required minimum physical power and general endurance test requirements prescribed in § 33.87(b) described in paragraphs 3-4.a.(2) and (3) of this AC are also 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 or thrust; and (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. Endurance Test Schedule, § 33.87(d), for rotorcraft engines for which a continuous OEI rating is desired.

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 FAA. 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) of this AC 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 rated maximum continuous 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 than 12 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 and 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 to a safe altitude.

(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 rated either 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 FAA approves an alternative test sequence. 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) of this AC 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 paragraphs 3-4.b.(2) through b.(5) of this AC, 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 paragraphs 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) and the 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 the 2½-minute OEI rating power described in the "Explanation" section of § 33.87(e). There are, however, significant differences between these ratings.

(1) The use of 30-second OEI and 2-minute OEI ratings is intended for once per flight in service with a required mandatory inspection after each flight. However, we have defined certification requirements around the worst-case scenario involving the possible use of the rating three times in one flight (takeoff, balked landing, and final landing of a rotorcraft). The ratings are intended to safely use available engine design margins for brief periods of exposure. Note that such usage may result in component or part deterioration beyond serviceable limits, and may make these components unavailable for further use.

(2) 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 requirement to substantiate the 30-second OEI and 2-minute OEI ratings capability is that the engine must maintain 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 powers for rotorcraft.

b. The endurance test for the 30-second and 2-minute ratings must be run following the 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 that are defined as consumable in the ICA.

(1) The applicant may also elect to continue the 2-hour test in compliance with § 33.87(f) without an 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) apply to this test schedule.

d. Unless we approve an alternate test sequence, applicants must conduct the prescribed 2-hour test sequence specified in § 33.87(f)(1) through (f)(8) a total of four times as follows to complete the required test:

(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) 1 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 either 30-minute OEI, continuous OEI, or maximum continuous power, whichever is the 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. <u>Endurance Test Schedule, § 33.87(g), Supersonic aircraft engines</u>. We may address the test requirements of supersonic aircraft engines in a future AC.

CHAPTER 4. TEARDOWN INSPECTION.

4-1. General Requirements for All Endurance Tests (Except for Engines with 30-second OEI and 2-minute OEI Ratings), § 33.93 (a). The applicant must completely disassemble each engine after completing a 150-hour endurance test of § 33.87(b), (c), (d), (e), or (g). For rotorcraft engines intending to obtain 30-second OEI and 2-minute OEI ratings under § 33.87(f), the applicant is allowed the option under § 33.93(c) of completing the endurance testing of § 33.87(b), (c), (d), or (e), and then starting 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 completion of 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) The applicant must inspect all engine components and parts 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 requirement 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 FAA.

(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) The applicant 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. The applicant 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 the combination thereof, can be used to substantiate that the part at the existing condition is:

- still airworthy;
- will continue to perform its design functions; and
- is safe for continued engine operation between maintenance periods (inspection, shop visit, and overhaul) of the engine as scheduled in the ICA.

(c) When the applicant specifies a tighter limit in the ICA than the one required under § 33.93, then the ICA should include instructions 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 when 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, we may waive the post-test teardown inspection after the §33.87 tests 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 independently 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 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 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 is an essential part of all engine type certifications. The test may also be used to substantiate engineering changes, repair, and PMA applications. We discuss acceptable means of compliance with § 33.87 for engine type certification and substantiation of major engineering changes 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 major 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 FAA has determined that a repeat demonstration of the § 33.87(b) through (g) endurance test, as applicable, is needed to substantiate the design change. Applicants must comply with all subparagraphs of § 33.87(a). We 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 (i.e., paragraphs 1a(2)(a) and (b)) are based on the assumption that the applicant has conducted a standard endurance test 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.

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

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 certifying FAA office 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 all of 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 engine operating parameters associated with a particular engine operating condition must be maintained during the series of runs specified in § 33.87(b) through (g), as applicable. If a parameter limit (such as rotor speed) for a particular engine rating (such as maximum continuous) is not defined, then the applicant should run the test segments associated with that rating condition to 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)(i), (b)(2)(ii), (b)(3), and (b)(5). This second demonstration would accumulate an additional 87.5 hours of testing at redline fan speed and gas temperature, resulting in a total time of 237.5 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 engine 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 rated thrust, simultaneously.

(1) During the takeoff parts of the test.

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

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

APPENDIX 2. ENDURANCE TEST CYCLE FOR MULTIPLE ENGINE TESTS (Continued)

(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 rated maximum continuous speed*;

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

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

(d) The thrust must be maintained at or above the rated maximum continuous 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)(i), (b)(2)(ii), (b)(3), and (b)(5) at fan rotor speed, gas temperature limits, and rated thrust simultaneously. The Part Two 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 of the test:

(a) The core rotor speed must be maintained at least at the rated takeoff 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 the rated takeoff thrust level.

APPENDIX 2. ENDURANCE TEST CYCLE FOR MULTIPLE ENGINE TESTS (Continued)

(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 rated maximum continuous 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 One and Part Two is: 237.5 hours (i.e., 150 hours and 87.5 hours).

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

**If the maximum permissible rotor speeds and gas temperature are not defined for the maximum continuous rating, then the maximum continuous test segments must be run to the maximum engine rotor speed and gas temperature redline conditions that are normally associated with the takeoff rating.

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

1. Explanation.

a. Two-minute transient over temperature approval for engine acceleration (see § 33.87(a)(3)). We previously approved a 2-minute transient gas overtemperature 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 occurs most often 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, we would not expect such overshoot excursions 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 when 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), we 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

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

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 exception allowance 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, if an applicant proposes 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. We may waive the demonstration required by § 33.87(b)(5) for 30-second periods at takeoff thrust or power 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:

- Maximum permissible gas temperature limit for takeoff (5 minutes).
- Maximum permissible gas temperature limit for takeoff (2-minute overshoot out of a total of 5 minutes).
- 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, or it must be removed from service for maintenance

Note 1. The proposal of a 2-minute gas temperature overshoot limit requires 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 MODIFICATIONS IN 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 used to match 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 stator vane mis-scheduling.

c. Use of customer 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 § 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. The applicant may propose minor modifications to the engine to mitigate these unintended consequences. For example, the applicant may propose a minor modification

APPENDIX 4. ENGINE CONFIGURATION MODIFICATION IN ENDURANCE TEST
(Continued)

to the compressor internal cooling flow circuit, such as increased flow regulating orifice diameters, that might increase the cooling effectiveness of the cooling circuit 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 preceding example, 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 INSPECTIONS 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(s) must substantially conform to the final type design configuration, except for non-type design hardware approved by the FAA. Each applicant must make 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 inspectors or an FAA designee will conduct pre- and post-test conformity inspections. The applicant must disclose any deviations (referred to as "non-conformances") of the hardware, software, and components from the type design, and must provide acceptable evidence that these non-type design characteristics will not adversely affect the outcome or the integrity of the test.

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 prior to 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 certifying FAA office 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, we 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, statement of conformity, Type Inspection Report (TIR) and related instructions, see Chapter 5 of FAA Order 8110.4C, Type Certification.

4. The following example shows 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 the:

APPENDIX 5. ENDURANCE TEST CONFORMITY INSPECTIONS AND TYPE INSPECTION AUTHORIZATION (Continued)

a. Diffuser case, and

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 OEI RATINGS AND ENDURANCE TEST

1. <u>Endurance test for 30-second OEI and 2-minute OEI ratings</u>.

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 complete 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 a lower power level, but still higher than takeoff power (referred to as 2-minute OEI power), is required to complete the climb out to a safe altitude and obtain the 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 run 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 completion of a 150-hour endurance test in accordance with § 33.87(b), (c), (d), or (e).

2. <u>Endurance test for 2½-minute OEI rating</u>.

a. The 2½-minute OEI rating power is intended for the engine to perform similar functions

APPENDIX 6. ROTORCRAFT OPERATION WITH OEI RATINGS AND ENDURANCE TEST (Continued)

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 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 perform very similar functions as 2½-minute OEI ratings in rotorcraft operation. 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 differ as follows:

b. The requirement for teardown inspection for a 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 requirements for teardown inspection for 30-second and 2-minute OEI ratings in § 33.93(b) 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 should be 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:

Time (in 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. Submit the test plan early enough to allow the FAA 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 included in a test plan for the calibration test, endurance test, and teardown inspection. The information is intended as a guide to preparing the plan and is not all-inclusive or mandatory.

a. Description of the Test Objective. List the 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 FAA. For example, it may be necessary to modify certain test equipment, engine configurations, and test sequences 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 or the integrity 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 easy identification. Applicants should also provide a list of components that require pre- and post-endurance test bench calibration and the results of hardware conformity inspections. 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. These may include:

- discussions of pre-and post-endurance calibration tests;
- test cycles/hours;
- test sequences if they differ 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.

APPENDIX 8. ENDURANCE TEST PLAN REQUIREMENTS (Continued)

f. Post test. Following completion of the endurance test, applicants must completely disassemble the engine 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 FAA 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. Conduct the dirty inspection at part level, partial assembly, subassembly, or assembly without prior cleaning. The degree of disassembly largely depends on the findings of the engine and components before, during, or after disassembly.

2. Tear down inspection requirements.

a. Dirty inspection. The applicant should 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 has carefully noted the appearance of subassemblies during the teardown.

b. Clean inspection**.**

(1) Visual inspection. Thoroughly clean and visually inspect all engines for indications of galling, metallic pickup, corrosion, distortion, interference between moving parts, and cracks. Check these parts 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. Carefully inspect hot section parts for indications of cracking, overheating, or burning.

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

(3) Dimensionally inspect all critical engine parts that are subject to wear, growth, rubbing or distortion to determine the extent of any changes that occurred during the test. Dimensional changes may be determined 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 FAA project engineer as an attachment to the Conformity Inspection

APPENDIX 9. TEARDOWN INSPECTION REQUIREMENTS - DIRTY INSPECTION AND CLEAN INSPECTION (Continued)

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 ensure that questionable parts are identified and retained by the applicant in safe storage for review, as needed, by FAA certification engineers.

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 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 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 would not result in an unsafe condition to the aircraft.

2. As part of the engine type certification process, the applicant for an aircraft engine TC prepares ICA, which provide information on the proper maintenance of the engine. 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 remains 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. The reports, however, should be selective and not used as a data dump.

2. The following paragraphs describe types of data, analysis and other information that applicants should include in reports for the calibration test, endurance test, and teardown inspection. The information categories are for use as a guide in preparing the reports and are not all-inclusive or mandatory.

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

b. Success Criteria. Describe 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. Include 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**.** Include redline target value changes and hardware changes that are different from the bill of materials contained in the TIA. 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. Include results from these areas of the test:.

(1) Pre-endurance testing. Include discussions of 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) Descriptions of any deviations from the prescribed cycle requirements. The applicant must substantiate that these modified cycles are still in compliance with the regulation.

APPENDIX 11. ENDURANCE TEST REPORT REQUIREMENTS (Continued)

(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 allowance 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) 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. Include the results of the post-endurance calibration and vibration survey. The vibration survey must show that vibration levels did not significantly change over the duration of the endurance test and are still at or below the allowable limits established in compliance with § 33.63. The performance calibration test must show that the engine is still capable of producing its rated power or thrust without exceeding any of the operating limits prescribed in the TCDS.

f. Post test. Following the completion of the endurance test, the applicant 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. The applicant should tabulate any significant inspection findings of engine parts 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

APPENDIX 11. ENDURANCE TEST REPORT REQUIREMENTS (Continued)

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 tabular or graphic formats in sufficient detail to show compliance with applicable requirements of § 33.87(a) and § 33.87(b) through (f). For example, these tables or plots may include typical gas temperature, rotor speed or thrust/power versus time or power setting parameter, oil temperature versus rotor speed, or vibration versus rotor speed.

(2) Include photographs showing significant hardware findings from the pre-test and post-test inspections in the test report.

h. Analysis.

(1) Performance data. The applicant 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. The applicant 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. The applicant 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.

APPENDIX 11. ENDURANCE TEST REPORT REQUIREMENTS (Continued)

(6) Fluid properties verification. The test report should contain a statement from the applicant that all fluids used during the endurance testing conformed in all respects to the fluid specifications that will be prescribed in the TCDS. Any fluid property differences from the specifications that will be prescribed in the TCDS, including the use of any additives, must be disclosed and justified. Test results that verify fluid properties should be disclosed in the report.

(7) Vibration signature analysis. The applicant must analyze the vibrations induced by unbalances in both the high and low speed rotor systems and assure that the vibration level associated with a deteriorated engine is acceptable. The post endurance test vibration level should remain at or below the allowable limits that were established in compliance with § 33.63.

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. Civil Air Regulation (CAR) 14 CFR Part 13—Aircraft Engine Airworthiness.

a. Part 13, effective March 5, 1952. The Civil Aeronautics Board adopted a revised Civil Air Regulations, Part 13, on January 28, 1952. The previously effective part 13 was promulgated in 1941 and remained substantially unchanged until 1952. This version of part 13 represented the first time the certification of turbine-type engine rules were included in the regulations. 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 part 13 rule. The technical content of the calibration test was similar to § 33.85(a), except that part 13 did not address compressor air bleed for the test. The part 13 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), but uses 91 percent takeoff, and 90 and 75 percent maximum continuous power/thrust test runs instead of § 33.87(b)(2) through § 33.87(b)(4), which specifies testing at maximum continuous, takeoff, and incremental cruise power or thrust. The part 13 teardown inspection paragraph (§ 13.256) required a complete engine disassembly and detailed inspection of the tested engine to check for fatigue and wear.

b. Part 13, Amendment 13-1, effective August 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 made these two essentially the same as § 33.87(b)(2) and § 33.87(b)(4).

(2) Other revisions were: (a) the addition of a requirement that during the endurance test, the engine power/thrust and rotational speeds 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. Part 13, Amendment 13-2, effective May 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 values” to “at not less than 100 percent of the specified values.”

d. Part 13, Amendment 13-5, effective February 12, 1963. This amendment revised part 13 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 rated power for turbine engine used in rotorcraft. The technical content of this new schedule is essentially the same as § 33.87(c), “Rotorcraft engines for which a 30-minute OEI power rating is desired.”

APPENDIX 12. CHRONOLOGICAL REVISIONS OF ENDURANCE TEST REGULATIONS
(Continued)

e. Part 13, Amendment 13-6, effective April 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. This 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-minute power” and a “30-minute power” to substantiate these rated powers. The test requirements for these ratings are essentially same as § 33.87(e) except:

(1) Section 33.87(e)(2) allows three OEI rating combinations for rotorcraft performance needs. These are: (a) 2½-minute OEI/maximum continuous; (b) 2½-minute OEI/30-minute OEI; and (c) 2½-minute OEI/continuous OEI ratings; while § 13.254(c) allowed only option “(b)”.

(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 be run to 2½ OEI power while § 13.254(c) does not.

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

2. <u>14 CFR, Part 33 – Airworthiness Standards: Aircraft Engines</u>.

a. Part 33, effective February 1, 1965.

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

(2) Section 33.85, Calibration tests, is the same as its equivalent paragraph in part 13 except for an additional requirement that the engine power control 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 part 13, except for minor editorial differences.

(4) Section 33.99, General conduct of block tests, was completely revised from its equivalent paragraph in part 13.

APPENDIX 12. CHRONOLOGICAL REVISIONS OF ENDURANCE TEST REGULATIONS
(Continued)

b. Part 33, Amendment 6, effective October 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 is the same in the current (Amendment 20) regulations.

(2) Section 33.85(a) of the calibration test was revised to include only the compressor air bleed essential for engine functioning during the test. Section 33.85(b) was revised to the current regulation. Both paragraphs now agree with the current regulation.

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

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

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 revised to the current requirements.

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

c. Part 33, Amendment 10, effective March 26, 1984.

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

(a) Section 33.87(a)(3) and (a)(5) were revised to allow the applicant to reduce power or thrust or rotor speeds below the 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.

APPENDIX 12. CHRONOLOGICAL REVISIONS OF ENDURANCE TEST REGULATIONS
(Continued)

(c) A new requirement was added to specify that a rated 2½-minute OEI 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 current requirements.

d. Part 33, Amendment 12, effective October 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 August 19, 1996.

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

(2) 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 to paragraph (f) for the ratings.

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

APPENDIX 13. GRAPHIC PROFILES 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 30-second and 2-minute OEI ratings, § 33.87(f).

Test cycle	1-4	Figure 11

APPENDIX 13. GRAPHIC PROFILES OF ENDURANCE TEST SCHEDULES (Continued)

Page 1 of 2 Pages

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

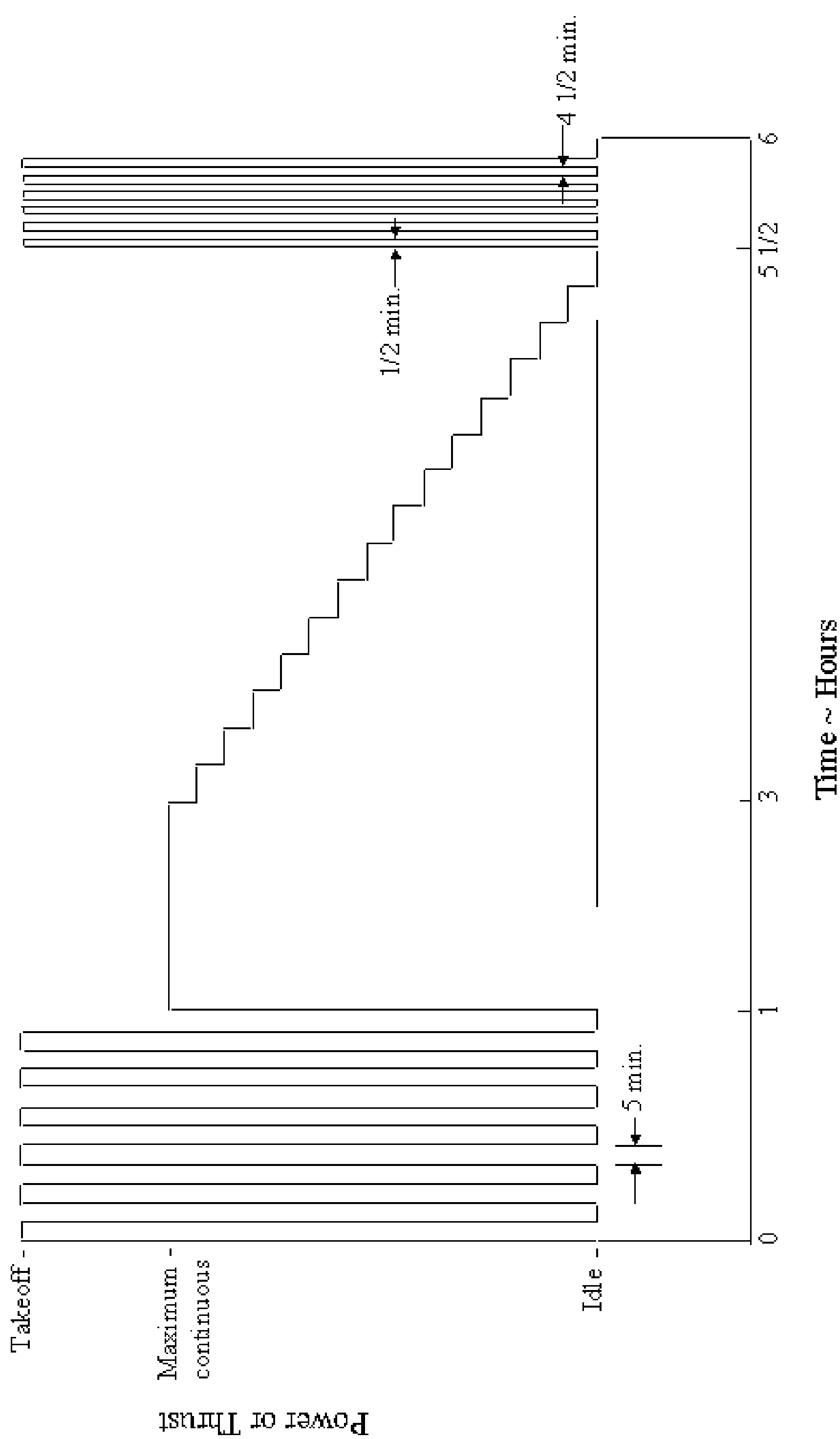

Figure 1

APPENDIX 13. GRAPHIC PROFILES OF ENDURANCE TEST SCHEDULES (Continued)

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

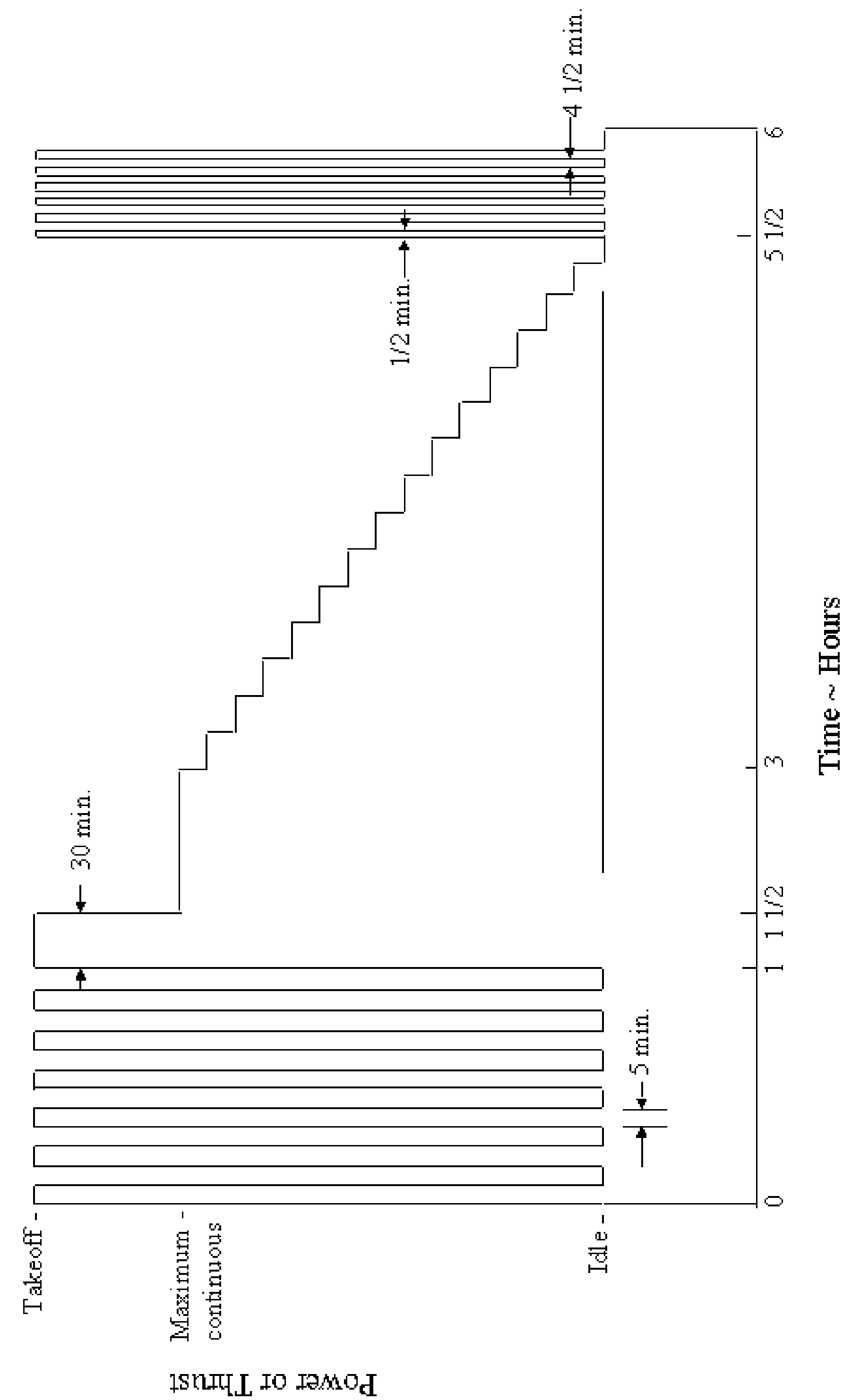

Figure 2

APPENDIX 13. GRAPHIC PROFILES OF ENDURANCE TEST SCHEDULES (Continued)

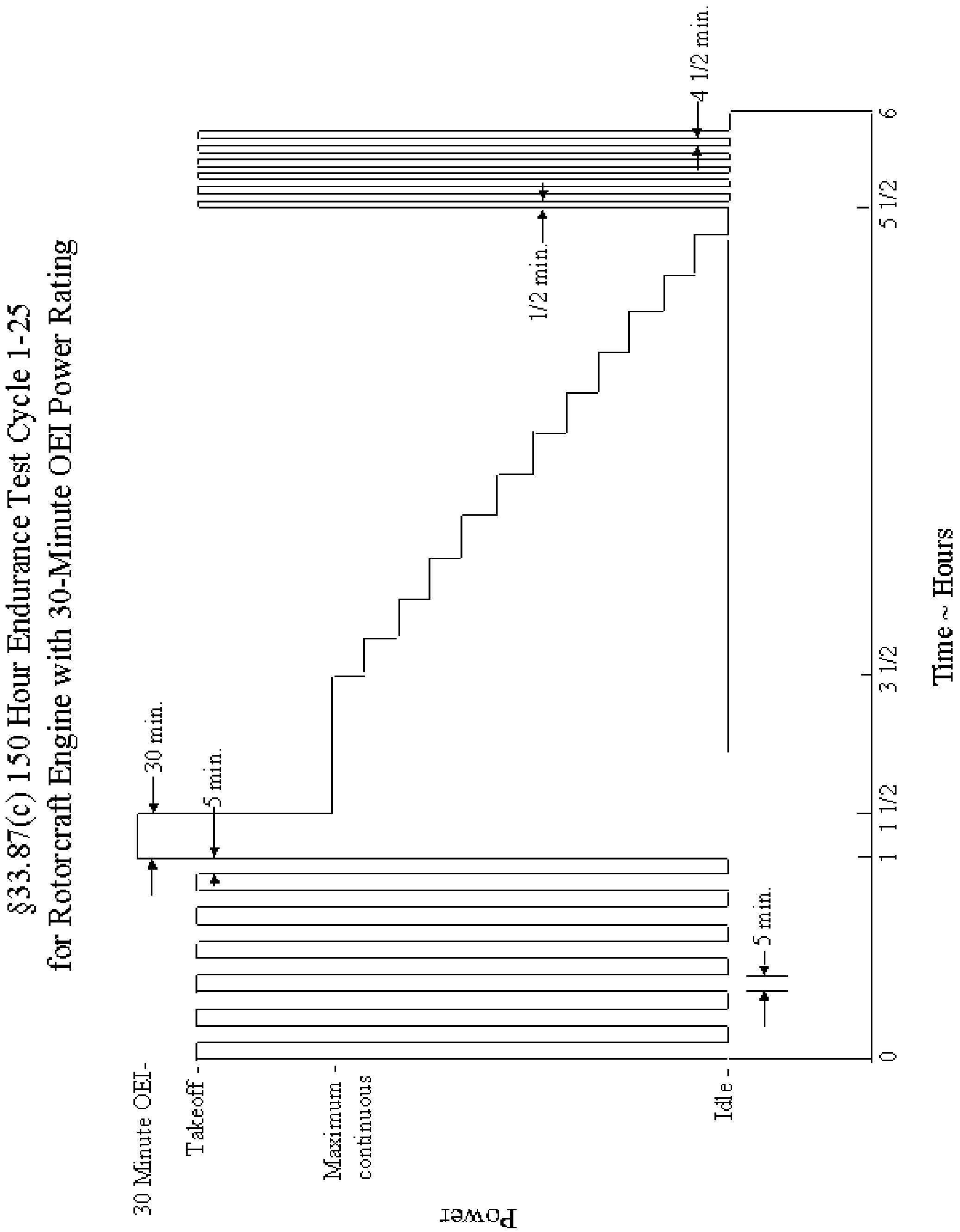

Figure 3

APPENDIX 13. GRAPHIC PROFILES OF ENDURANCE TEST SCHEDULES (Continued)

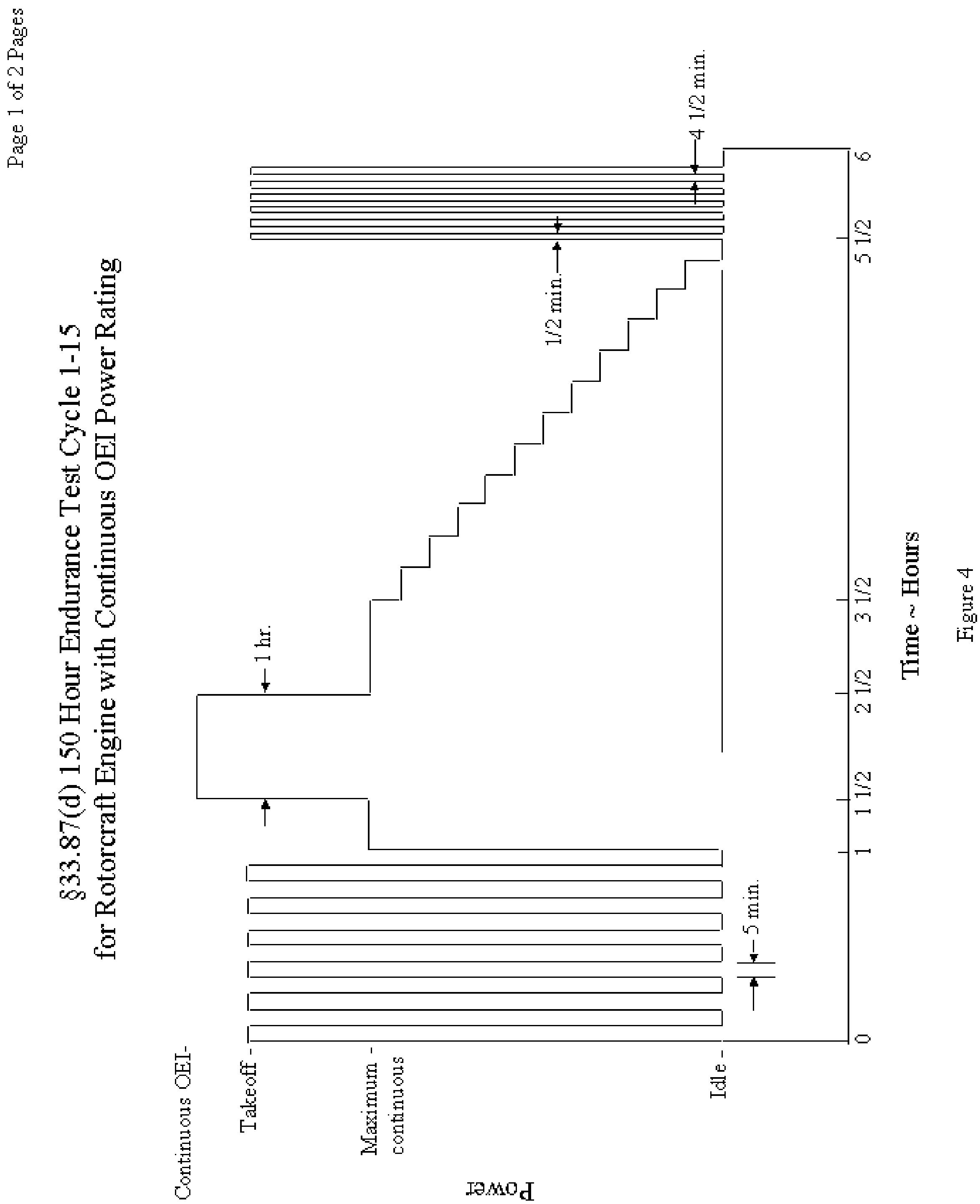

Figure 4

APPENDIX 13. GRAPHIC PROFILES OF ENDURANCE TEST SCHEDULES (Continued)

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

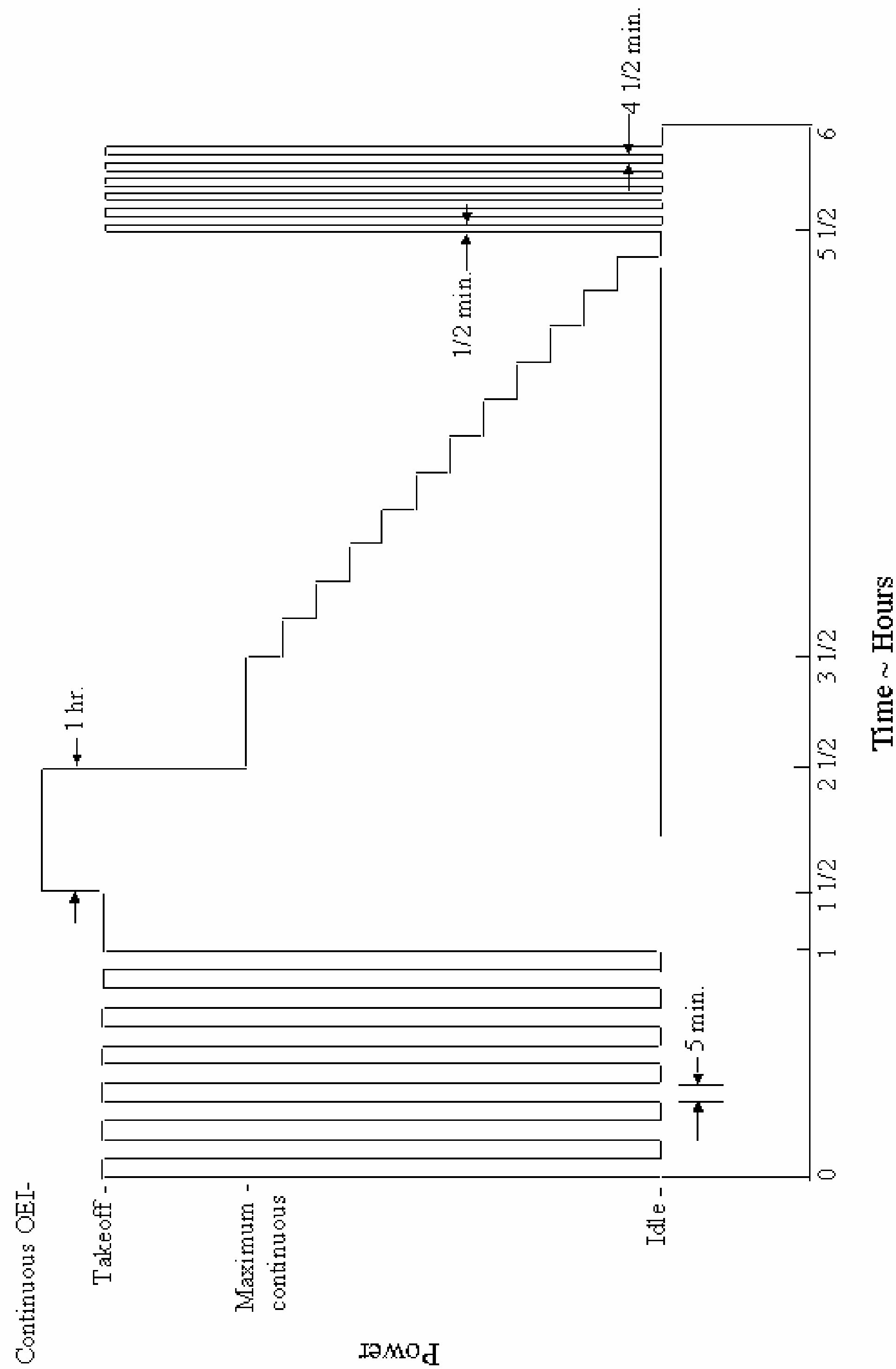

Figure 5

APPENDIX 13. GRAPHIC PROFILES OF ENDURANCE TEST SCHEDULES (Continued)

Page 1 of 2 Pages

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

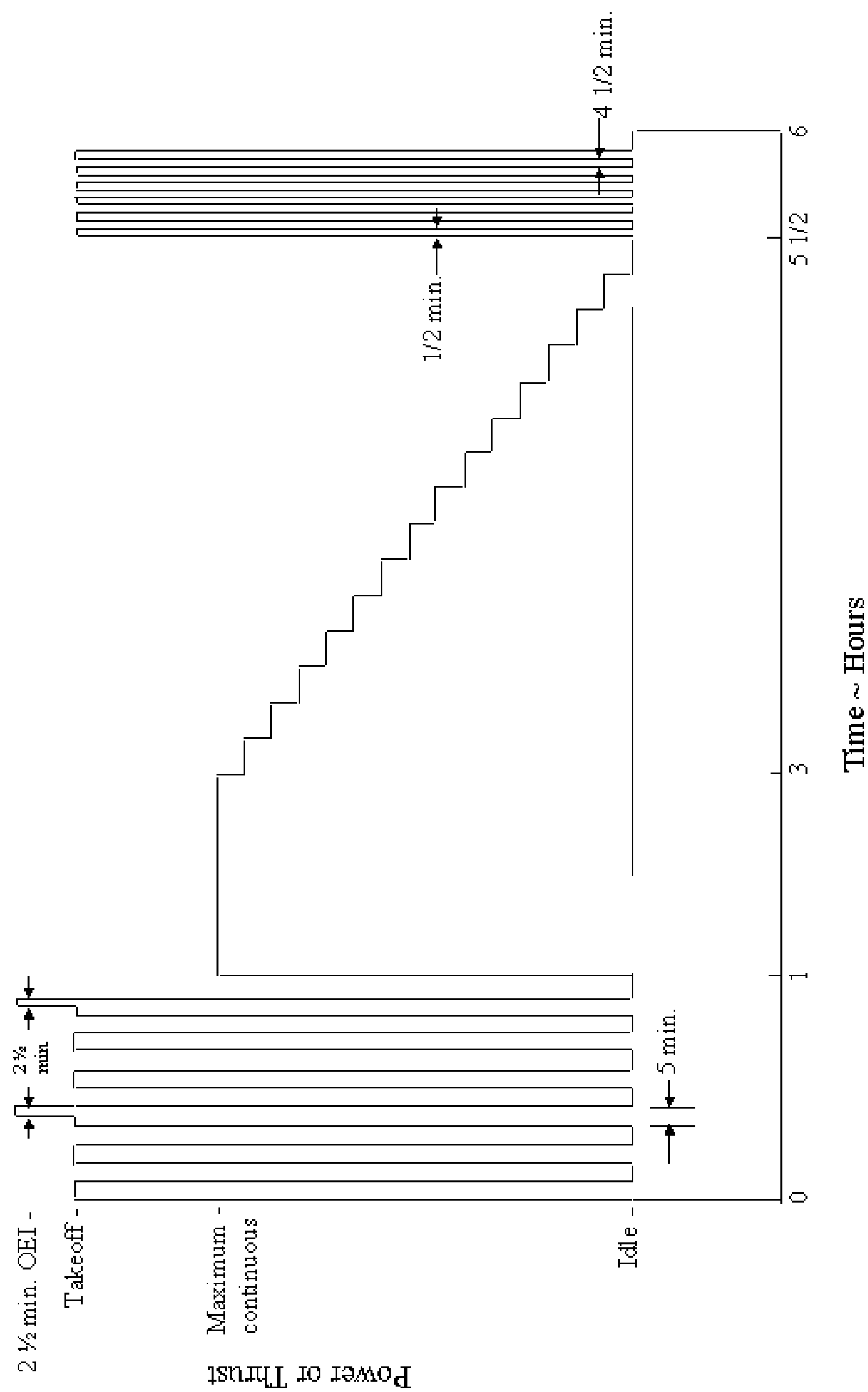

Figure 6

APPENDIX 13. GRAPHIC PROFILES OF ENDURANCE TEST SCHEDULES (Continued)

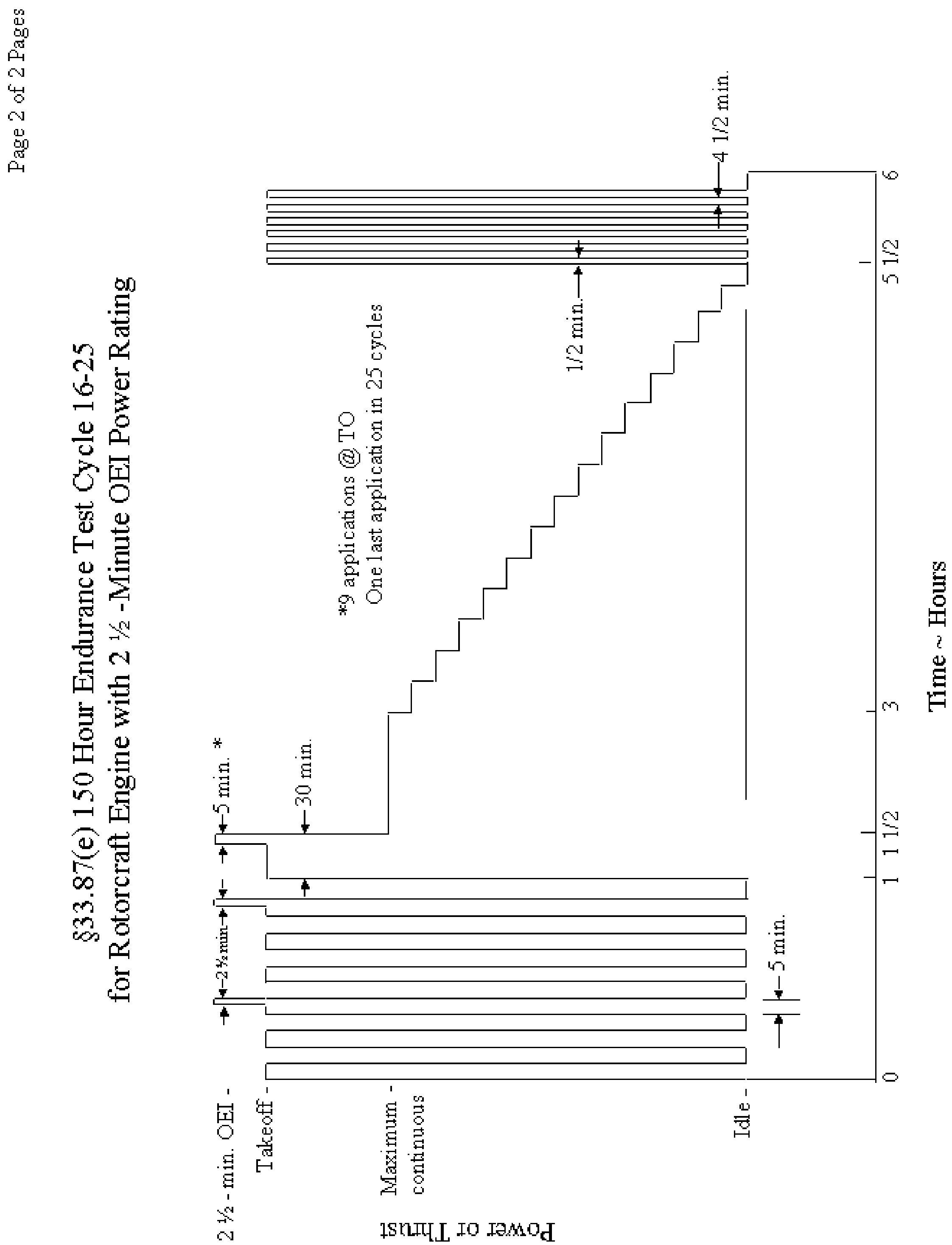

Figure 7

APPENDIX 13. GRAPHIC PROFILES OF ENDURANCE TEST SCHEDULES (Continued)

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

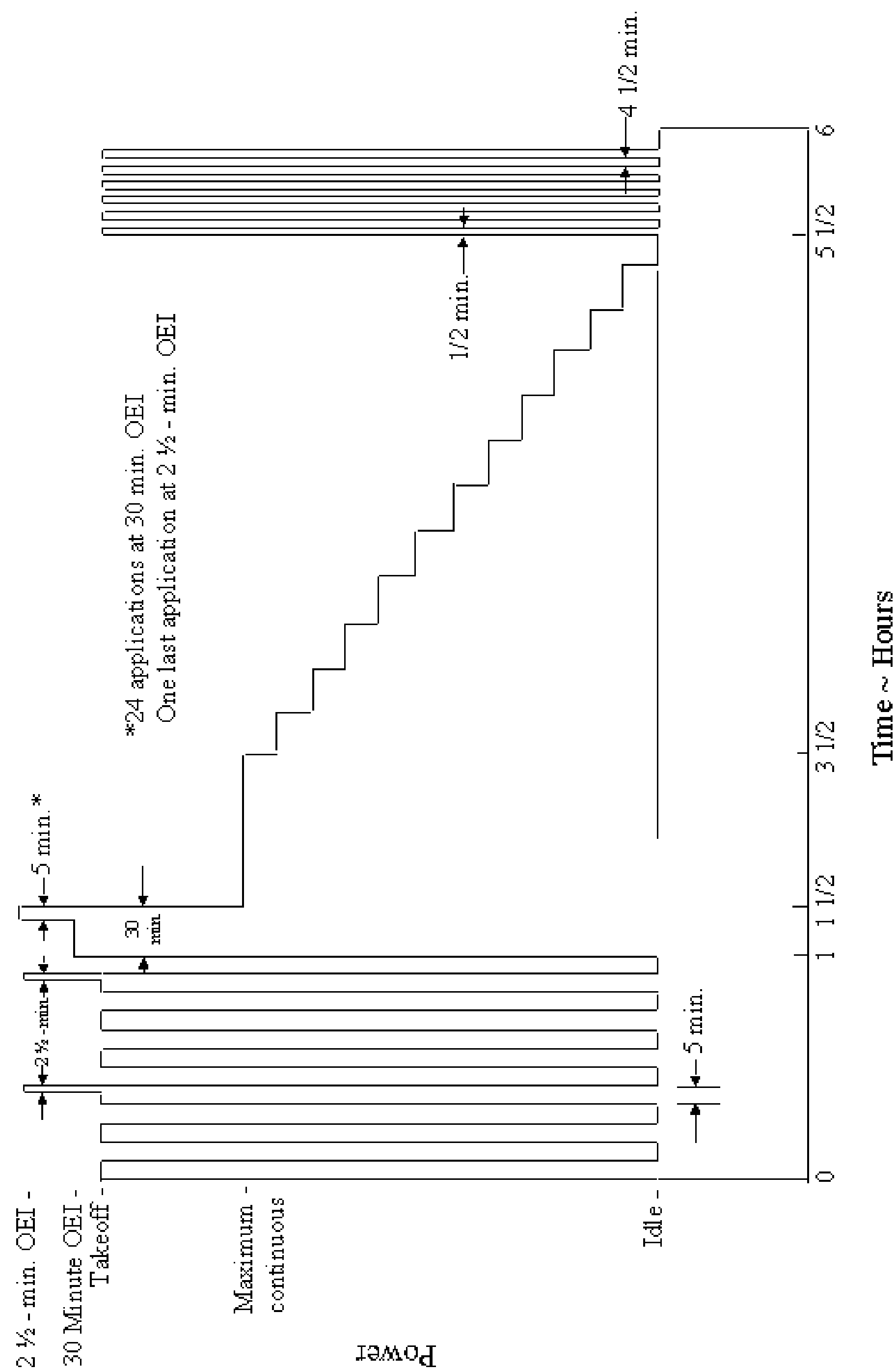

Figure 8

APPENDIX 13. GRAPHIC PROFILES OF ENDURANCE TEST SCHEDULES (Continued)

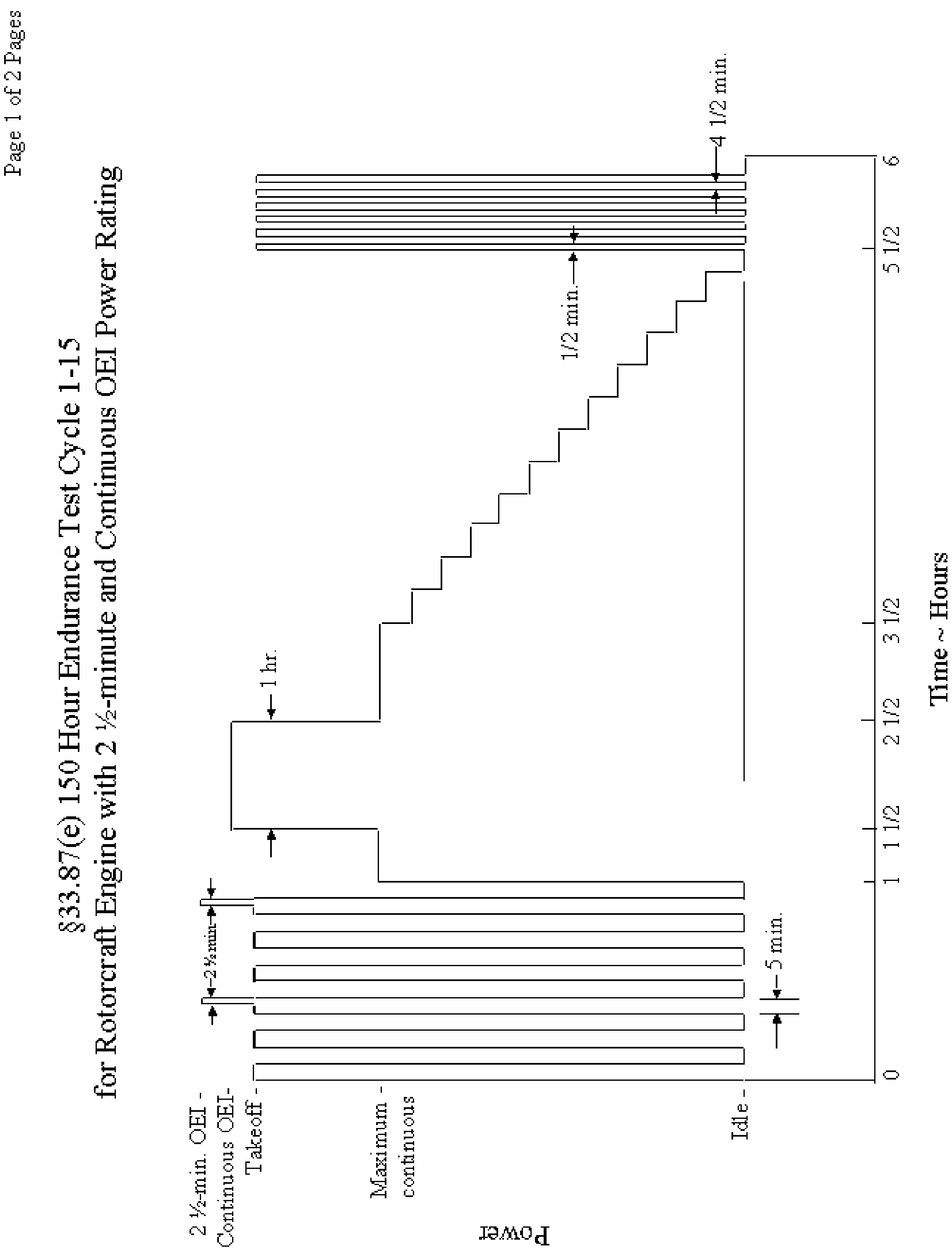

Figure 9

APPENDIX 13. GRAPHIC PROFILES OF ENDURANCE TEST SCHEDULES (Continued)

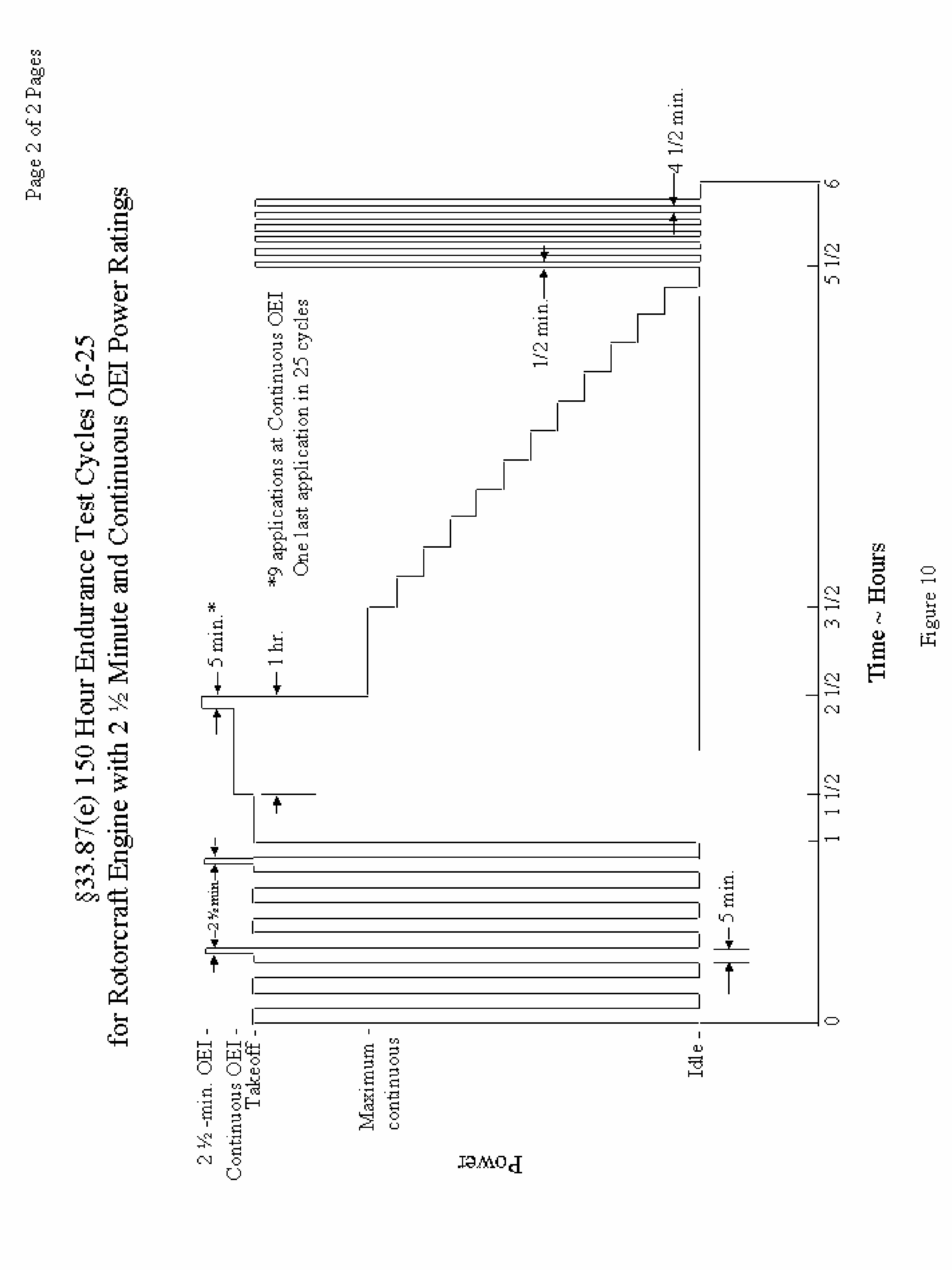

Figure 10

APPENDIX 13. GRAPHIC PROFILES OF ENDURANCE TEST SCHEDULES (Continued)

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

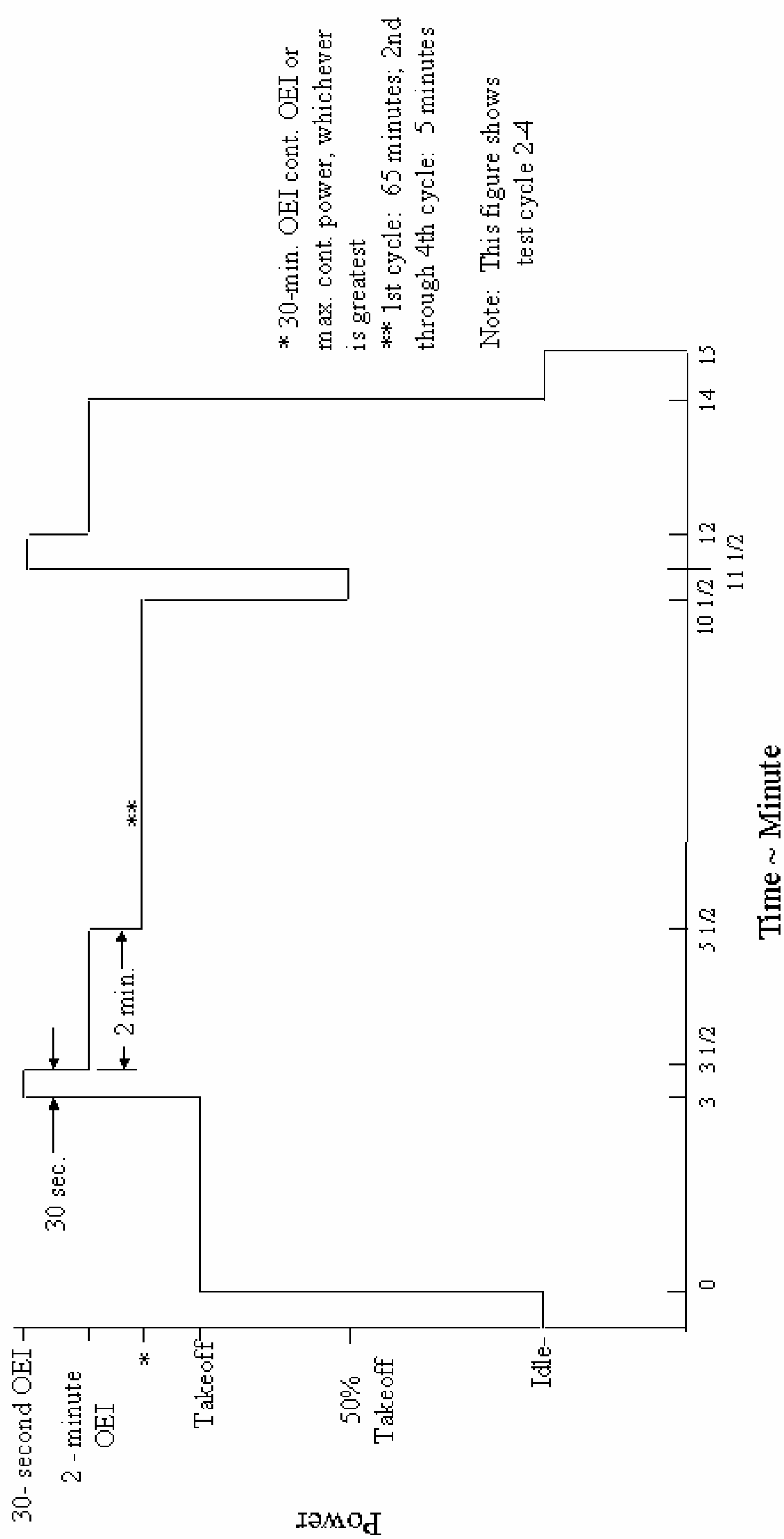

Figure 11