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

Advisory Circular

Subject: Engine Overtorque Test, Calibration Test, Endurance Test, and Teardown Inspection for Turbine Engine Certification (§§ 33.84, 33.85, 33.87, and 33.93)

Date: XX/XX/XX
Initiated By: AIR-625

AC No: AC 33.87-1A
Change: 1

1. Purpose. This advisory circular (AC) change updates the references provided in the original document and aligns the content with current terminology and regulatory language. The AC provides guidance for showing compliance to Title 14, Code of Federal Regulations (14 CFR) 33.87 when an applicant proposes to perform tests out of the normal sequence described in §§ 33.87 (b), (c), (d), (e), (f), or (g), as applicable.

2. Principal Changes.

a. Paragraph 5.b.(4) is added to include FAA Form 8130-9.

b. Chapter 3, paragraph 3-1, item (e), now states that the vibration signature should include both the synchronous and non-synchronous vibration components of the frequency spectrum. This paragraph is also changed to add that accelerometers in other applicable locations may also be used to record vibration data.

c. Chapter 3, paragraph 3-1, item (g)(1), now includes a listing of engine faults in the context discussed in this paragraph.

d. Chapter 3, paragraph 3-2, item (a), is changed to include turbine-entry gas temperature (TET) guidelines for the applicant during the endurance test showing of compliance.

e. Chapter 3, paragraph 3-2, item (e)(4), is changed to clearly state that power or thrust, the rotor speed(s), or both may be less than 100 percent. Power and thrust are grouped together, but they appeared to not be on the previous revision.

f. Chapter 3, paragraph 3-4, item (b)(1)(b), is changed to incorporate regulatory language, specifically to refer to "augmented takeoff power ratings."

g. Chapter 4, paragraph 4-1, is changed to state that an FAA Certificate Management Section (CM section) inspector, instead of an FAA Manufacturing Inspection District

Office inspector, may need to witness the teardown inspection activities. The certificate management sections have replaced the MIDOs.

h. Chapter 4, paragraph 4-1, item (b)(2)(d); Appendix 5, items (1) and (2); and Appendix 11, items (1), (2), and (3), are changed to state “CM section inspector” instead of “manufacturing inspector” to reflect the change made in paragraph 4-1.

i. Appendix 6, item (h)(8), is added to list engine anomalies.

j. Appendix 11, items (2)(a)(9), (2)(a)(10), and (2)(a)(11), are added to account for chafing, fretting, or other degradation of electrical wiring harnesses or grounding straps; degradation of electrical bonding resistance at critical components (e.g. Full Authority Digital Engine Control, fuel metering unit, variable geometry actuators, and speed sensors); and distortion or damage to mounting hardware used to install components to engine structures.

k. New material added in this change has shifted the pagination of certain content. Pages for which the pagination has shifted, but which otherwise contain no content that has changed compared to the original document, are indicated with an asterisk (*) in the Page Control Chart.

l. For the purposes of capturing minor editorial and grammatical changes that do not affect the technical content of this AC, we have included change bars to note where these changes have been made so that they are easily identifiable.

m. The AC change number and the date of the change is shown at the top of each applicable page. The change bar in the right or left margin indicates where the change is located. The changes described may shift the original text.

PAGE CONTROL CHART

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a. http://www.faa.gov/regulations_policies/advisory_circulars

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Aircraft Certification Service

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Advisory Circular

Subject: Engine Overtorque Test, Calibration Test, Endurance Test, and Teardown Inspection for Turbine Engine Certification (§§ 33.84, 33.85, 33.87, 33.93)

Date: 03/09/15
Initiated By: ANE-111

AC No: 33.87-1A

1. Purpose.

a. This advisory circular (AC) provides a method of compliance for the test requirements of Title 14, of the Code of Federal Regulations (14 CFR) 33.84 (engine overtorque test) when the applicant chooses to run that test as part of the endurance test of § 33.87. It also provides information and guidance on the test requirements of §§ 33.85 (calibration test), 33.87 (endurance test), and 33.93 (teardown inspection).

b. 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, applicants for engine type design approval, and FAA designees.

b. This is a guidance document. Its content is not legally binding in its own right and will not be relied upon by the Department as a separate basis for affirmative enforcement action or other administrative penalty. Conformance with this guidance document is voluntary only. Nonconformity will not affect rights and obligations under existing statutes and regulations. 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 (the FAA) will consider other methods of demonstrating compliance that an applicant may present. Terms such as “should,” “may,” and “must” are used only in the sense of ensuring applicability of this particular method of compliance when the method of compliance in this AC is used.

c. If you choose to use this AC, you should conform to all aspects of the AC. However, we acknowledge that no document can provide guidance that will cover all future engine designs, operating characteristics, or unique certification circumstances. Therefore, If the FAA becomes aware of circumstances in which following this AC would not result in compliance with the applicable regulations, the FAA may require additional substantiation or design changes as a basis for finding compliance.

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

3. Cancellation. This AC cancels AC 33.87-1, "Calibration Test, Endurance Test, and Teardown Inspection for Turbine Engine Certification (§§ 33.85, 33.87, 33.93)," April 13, 2006.

4. Explanation of changes. This revision:

a. Adds guidance for the changes made to §§ 33.87 and 33.93 at amendments 25 and 30.

b. Adds guidance for the new § 33.84 regulation introduced by amendment 30.

c. Clarifies and corrects several sections of this AC.

5. Related Regulations and Documents.

a. Related Regulations.

(1) Part 21, §§ 21.31 and 21.33.

(2) Part 33, §§ 33.4, 33.5, 33.7, 33.8, 33.63, 33.82, 33.83, 33.91, and 33.99.

b. Related Documents.

(1) AC 33.7-1, "Ratings and Operating Limitations for Turbine Engines (§§ 33.7 and 33.8)."

(2) AC 33.87-2, "Comparative Endurance Test Method to Show Durability for Parts Manufacturer Approval of Turbine Engine and Auxiliary Power Unit Parts."

(3) FAA Order 8110.4C, "Type Certification."

(4) FAA Form 8130-9, "Statement of Conformity."

6. Discussion.

a. In 1965, we replaced the airworthiness standards of 14 CFR part 13 for the turbine engine calibration test, endurance test, and teardown inspection with those in part 33. Subsequently, we revised those requirements numerous times over the past four decades. The most significant revisions were in amendments 6 and 10, adopted in 1974 and 1977, respectively. These amendments upgraded the engine endurance test and teardown inspection requirements to accommodate the increasing complexity of modern turbine engines, and the interface between engines and airframes. See appendix 12 of this AC for a historical background of the changes to the airworthiness standards for the engine calibration test, endurance test, and teardown inspection.

b. In the past, several engine manufacturers have proposed engine testing that is more representative of expected in-service operations in place of the endurance cycle defined in § 33.87. We accepted some of those proposals; however, we determined that those alternate approaches do not provide an equivalent level of testing. We no longer accept these previously approved methods of compliance to § 33.87. Those previously acceptable alternatives are not acceptable because the test in § 33.87 does not simulate in-service operation. Rather, compliance to § 33.87 is to demonstrate an accelerated durability test of the engine; to demonstrate a minimum level of engine operability and durability throughout the engine's assigned ratings and operating limitations.

c. Engine endurance testing is covered by several regulations, not just § 33.87. The test requirements are specified in § 33.82, the calibration tests in § 33.85, the teardown inspection in § 33.93, and the block tests in § 33.99. For engine components and systems that cannot be adequately verified by endurance testing in accordance with the provisions of § 33.87, the applicant must conduct the testing required by § 33.91 to establish that these components are able to function reliably in all certificated operating conditions.

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

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 supporting data.

If you have any suggestions for improvements or changes, you may use the template provided at the end of this AC.

\\SIGNED\\ by Colleen M. D'Alessandro for
Ann C. Mollica
Acting Manager, Engine and Propeller Directorate
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Table of Contents

Chapter 1. General

1-1. Definitions. The following definitions apply to the terms used in this AC.

a. Engine component. Systems and accessories that are part of the engine type design.

b. Endurance test cycle. The series of runs or sequences prescribed in § 33.87(b) through (g).

c. Germane or primary hardware. The hardware used in the certification test that is affected by, or directly affects the outcome of the certification test and the pass or fail criteria for the given test objectives.

d. Redline conditions. The highest physical rotor speed, gas temperature, or output shaft torque, including transients, which may not be exceeded during operation at any applicable rating. The type certificate data sheet (TCDS) prescribes the limitations for each approved engine rating.

e. Test hardware. The parts and components assembled on the engine and to be tested, or, if not mounted on the engine, are part of the engine type design. The test hardware may deviate from the type design if it remains representative of the type design and the applicant justifies the differences in the test plan. This justification is frequently referred to as "reconciliation."

f. Triple redline test condition. The engine operation at simultaneous redline rotor speeds, redline gas temperature, and full rated thrust or torque, as required by § 33.87(a)(3). For example, for a two-shaft system engine, the engine operation at simultaneous redlines of the two rotor speeds (e.g. low pressure and high pressure rotor systems) and redline gas temperature, in addition to full rated thrust or torque.

Chapter 2. Calibration Tests

2-1. Power Characteristics.

a. The power characteristics should be established based on the endurance test of the engine that represents the type design and is in the following configuration:

(1) No air bleed for aircraft services, and

(2) With only those accessories installed that are essential for engine functioning, except when the TCDS defines other conditions that are used to determine the engine ratings.

b. The test data is then referenced to the standard atmosphere conditions for which the engine rating is defined.

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

a. The pre- and post-endurance calibration tests required by § 33.85, establish the engine's power characteristics in the type design configuration over its entire operating range of speeds, pressures, and temperatures. These tests provide the means for measuring the engine deterioration caused by the endurance test.

b. To identify the changes in engine power characteristics that may occur during the engine endurance test of § 33.87, applicants must compare the engine's power characteristics established before and after the endurance test, except as provided by § 33.85(d) for the 30-second and 2-minute OEI ratings. This exception is further discussed in paragraph 2-3 of this AC.

c. Applicants should run the calibration tests with a clean inlet and exhaust, and without special test equipment, such as inlet screen, pre-swirler, mixer screen, or non-type design exhaust nozzles. In addition, the facility hardware must be similar to a production test cell (e.g., engine cowling, bell mouth, and normal engine control schedules). When special test equipment is necessary to obtain simultaneous redline conditions during the endurance test, applicants must address the engine configuration changes. See paragraph 3-1.c. and appendix 4 of this AC for further guidance. The power settings should include the highest power or thrust rating capability of the engine during the initial and final power calibrations. See paragraphs 3-4.a.(2)(a) and (2)(b) of this AC for power or thrust setting adjustments and permitted power or thrust shortfalls.

d. The calibration test data should 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 limit(s) specified in the TCDS.

e. The applicant should record the calibration test measurements only after 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 need 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). The extended engine operation at the 30-second OEI and 2-minute OEI ratings during calibration testing could increase hardware deterioration beyond what the endurance test would demonstrate for the ratings alone. Therefore, the data recorded during the OEI power segments in § 33.87(f) may be used toward compliance with 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 pretest 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.

a. The applicant should determine the engine's power characteristics at the 30-second and 2-minute OEI rating conditions. These power characteristics should include deterioration determined from the pretest calibration before the endurance test of § 33.87(f), up to and including the third test sequence of the 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.

b. 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 should evaluate the mode of deterioration to ensure that the availability of 30-second rated power in service will not be compromised by deterioration variability.

c. 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 of § 33.87(b), (c), (d), (e), or (g) are to demonstrate that at the end of the test, the engine conforms to its type design and is safe for continued operation. The requirement for § 33.87(f) is to demonstrate that at the end of the supplemental test, at a minimum, the structural integrity of the engine is maintained. This determination should be based on the inspection and maintenance requirements that are defined in the instructions for continued airworthiness (ICA) that will be submitted in compliance with § 33.4. To demonstrate this minimum level of durability and operability, the engine should:

(a) Continue to produce its rated power or thrust at the end of the test in § 33.87(b), (c), (d), (e), or (g) without exceeding any of the operating limitations defined by compliance with §§ 33.4, 33.5, and 33.7 and prescribed in the TCDS.

(b) Demonstrate acceptable operability from minimum to rated takeoff power or thrust without overtemperature, surge, stall, or other detrimental occurrences.

(c) Demonstrate durability while operating up to rated thrust, power, or torque; redline and transient rotor speeds and gas temperatures; and when applying maximum rated loads on accessory drives and mounting attachments.

(d) Demonstrate the maximum compressor bleed air capability for engine and aircraft use. Paragraph 3-2.e. of this AC provides guidance for maximum compressor bleed air.

(e) Demonstrate acceptable operation at minimum and maximum fuel and hydraulic fluid pressure limit conditions. Advisory Circular 33.7-1 provides information and guidance on the fuel pressure limit locations.

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

(g) Demonstrate starting capability and 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:

(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(f).

(e) Durability in § 33.19(a).

(f) Accessory attachments in § 33.25.

(g) Surge and stall characteristics in § 33.65.

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

(i) Ignition system function in § 33.69.

(j) Fuel system in § 33.67(a) and (b).

(k) Lubrication system, § 33.71(a) and (b).

(l) Hydraulic actuating systems, § 33.72.

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

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

(o) Thrust reverser test in § 33.97.

(p) Fuel venting emissions in Subpart B of 14 CFR 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 engine's endurance testing. However, some systems or components may not be adequately substantiated by endurance testing alone under the requirements of § 33.87. For these systems or components, applicants should 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. 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 applicant must conduct the prescribed 6-hour endurance test cycle 25 times to complete the required 150 hours of operation unless we approve 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 1 of this AC 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) Applicants should prepare a test plan for the endurance test defining the manner in which the test will be conducted. Applicants should submit this test plan early enough to allow us the time to review and approve the plan before 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) The pass/fail criteria.

(2) See appendix 2 of this AC for additional information about test plan requirements.

c. Test engine configuration.

(1) The test engine configuration 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 should disclose, in the test plan, any deviations (referred to as "nonconformances") of the hardware, software, and components from the type design. The applicant should provide acceptable evidence that these non-type design parts are representative of the capabilities, durability, and operating characteristics of the type design parts, and they will not adversely affect the outcome or the integrity of the test. Further, the non-type design part should not adversely affect the functioning of any other part or system.

Justification of nonconformance acceptability is frequently referred to as reconciliation. Applicants should submit all such non-type design configuration deviations and associated reconciliations to us for approval.

(a) The standard type design configuration and operating characteristics of some turbine engines may preclude achieving a triple redline test for compliance with § 33.87(a)(3). Modification of certain test equipment, engine configurations, and test sequences may be necessary to run the test at triple redline conditions. The applicant should show through analysis that the test engine, with any modifications, still represents the durability and operating characteristics of a typical type design engine, and that the engine is capable of complying with § 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 3 of this AC for additional information on an acceptable endurance test cycle for multiple engine tests.

(2) Appendix 4 of this AC shows methods that may be used for matching engine speeds and temperatures for the desired test conditions.

(3) Appendix 5 of this AC provides guidance for the endurance test engine conformity inspections.

(4) The applicant should provide information on aircraft 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 us.

(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 power extraction from the engine core could stall the engine at flight idle or below, or during transient operations. To determine the level of horsepower extraction appropriate for the various segments of the endurance test, the applicant should consider:

(a) The effects of high levels of horsepower extraction on engine stability, operating characteristics, and durability of the power extraction hardware, and

(b) The effects of electrical load transients at critical engine operating conditions, including idle.

d. <u>Engine component and test equipment calibrations</u>.

(1) Before and after the endurance test, the applicant should establish and record the adjustment setting and functioning characteristic of each engine component that can be adjusted

independently of installation on the engine, 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 should 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 to the specifications prescribed in the TCDS and ICA. The applicant should provide a statement in the test report identifying the specifications of all engine fluids used during the test. Verification of fluid properties is the responsibility of the applicant, not the fluid suppliers.

(3) Prior to starting the endurance test, applicants should calibrate:

(a) All test equipment and measuring instrumentation necessary to operate and monitor the engine and the test facility to FAA-approved standards,

(b) All engine components according to their component calibration schedules.

(4) Applicants should maintain instrumentation calibration and measurement system accuracy throughout the test. This may be accomplished by verifying the post-test calibrations or using recognized and documented applicant procedures available to the FAA if requested.

e. Engine vibration signature. Applicants should establish the engine vibration signature during both pre-endurance and post-endurance tests by recording the vibration amplitudes as a function of engine rotor speed. The vibration signature should include both the synchronous and non-synchronous vibration components of the frequency spectrum. Engine accelerometers mounted on the engine cases and other applicable locations (including gearboxes, inlets, etc.) may be used to record the vibration data. 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. Applicants should conduct these vibration surveys by applying slow accelerations and decelerations of not less than 2-minute durations that cover the range from minimum to maximum permissible rotor speeds, including any transient operations. Post-endurance test vibration signatures should not show a significant change from the data recorded during the pre-endurance vibration survey, and should still be at or below the allowable limits established for compliance with part 33 requirements. The only purpose of the surveys conducted during endurance testing is to determine potential vibration signature changes due to engine deterioration. Applicants should address significant changes in vibrations to determine their causes and, if necessary, make applicable design changes; the test report should document all findings and actions taken.

f. Servicing and repairs during the endurance test.

(1) Applicants should monitor oil consumption during the test and ensure it remains within the allowable limits prescribed in the engine operating documents. If the oil consumption exceeds the allowable limits, the applicant should determine the cause and take corrective action during the test, or otherwise revise the engine manuals to reflect the consumption observed during the test. We also recommend that applicants periodically check oil samples for the

presence of metallic particles or other debris that may indicate impending failure of one or more parts.

(2) During the endurance tests, only servicing and minor repairs may be permitted by the ICA service and maintenance instructions, refer to § 33.99(b). 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.

(3) Section 33.99(b) requires that the applicant must subject the engine or its parts to additional test(s) or penalty test run(s) that we find necessary if during the endurance test, 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; or because of findings from the teardown inspection.

(4) If an engine part fails during the test, the applicant should determine the cause of failure and assess the effect on the durability and operability of the engine. The applicant should determine and justify any corrective actions before 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 showing 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 data analyses, 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. Engine faults in this context include, but are not limited to:

(a) Anomalies reported by the engine control system or engine monitoring instrumentation systems, including sensor faults, actuation system faults, electronic system built-in-test faults, and control system communication faults;

(b) Engine power and speed oscillations/overshoots exceeding certification limits;

(c) Pressures and temperatures in the fuel system, oil system, rotors, casings, other structures, and accessory compartments exceeding transient certification limits;

(d) Unusual or high-vibration signatures at synchronous and non-synchronous frequencies;

(e) Debris in the oil or fuel systems exceeding field limits;

(f) Mechanical or structural failures; and

(g) Wear or damage outside ICA limits.

(2) The report should also provide comparative tabulations (test results as related to § 33.87 requirements) of:

(a) The total time spent at each sequence of the endurance test cycle and associated power condition, and

(b) The minimum certificated parameter values obtained during each of those test cycle sequences.

(3) To show engine stabilization at or above the required operating parameter values, such as the rotor speed and gas temperature to be certificated, applicants should include a trace of one typical takeoff and idling cycle segment performed without any air bleed required by § 33.87(b)(1), and another for one acceleration and deceleration segment required by § 33.87(b)(5). These traces are necessary to prove that a parameter may not stabilize at its 100 percent value within § 33.87(b)(1) or (b)(5) test segment. Applicants should provide supporting data showing that any deviations or exceptions to the test requirements are acceptable. This requirement also applies to the corresponding test runs of § 33.87(c), (d), (e), (f), or (g).

(4) Appendix 6 of this AC provides additional information on test report requirements.

3-2. Specific Requirements in §§ 33.87(a)(1) through (a)(9). Unless otherwise specified, the guidance 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 endurance test cycle sequence prescribed in §§ 33.87(b) through (e) and the 2-hour test sequence in § 33.87(f) when applicable. We may allow test segments to be run out of their normal sequence when applicants have difficulty with readjusting the engine and test facility configuration to run all test segments sequentially, as prescribed. Applicants intending to run the tests with sequence changes should show that changes to the published endurance test cycle sequence(s) do not lessen the severity of the endurance test cycle. The applicant must also show that all test cycle requirements, including the required number of accelerations to rated power and decelerations back to idle power, were properly completed. In addition, if proposing to run the test out of the prescribed sequence, the applicant should show that the turbine-entry gas temperature (TET) the engine experiences in service does not exceed the TET demonstrated during this endurance test. Specifically, the applicant should consider how the relationship between the measured exhaust gas temperature (EGT) in the test and the TET will vary due to engine-to-engine scatter in a typical fleet, deterioration in service, instrumentation accuracy limits, and flight envelope effects when proposing their EGT redlines. The applicant should also consider the most adverse stack-up of these effects. When direct TET measurement is technically difficult without major modification of the engine outside the type design, it may be predicted using validated thermodynamic or thermomechanical analysis.

b. Automatic control of the engine, § 33.87(a)(2). Any automatic engine control that is part of the engine type design 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 type design version. See paragraph 3-1.c of this AC for additional guidance related to test engine configuration.

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 under § 33.87(a)(5), (a)(6), and (a)(7). These values mean that applicants must run the endurance test to the maximum permissible (or redline) rotor speeds, gas temperature, and rated power, torque, or thrust values proposed for certification and prescribed in the engine TCDS. These parameters should 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 14 CFR 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 air 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. See paragraphs 3-4.a.(2)(a) and (2)(b) of this AC for power or thrust setting adjustments and permitted power or thrust shortfalls.

(3) If the engine cannot achieve the rated minimum physical thrust or power requirement, then the applicant should present data or analysis that shows that any difference is inconsequential to the durability of those engine parts that are subject to thrust or power loads. We will determine whether the showing is adequate or whether it requires an equivalent level of safety in accordance with § 21.21(b)(1).

(4) The ambient test conditions or the test engine configuration may not allow the engine to reach the triple redline test condition. 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 should be conducted on a single set of engine hardware.

(a) 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 demonstrated simultaneously during the endurance test.

(b) Appendix 3 of this AC presents an example of an acceptable two-part test.

(5) 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.

(6) For a transient overtemperature having the time limit greater than 30 seconds and less than or equal to 2 minutes, the applicant should apply the 100 percent gas temperature limit required by § 33.87(a)(3) to the value of the transient overtemperature for the duration proposed. The applicant should apply this transient overtemperature for each test period at takeoff power or thrust conditions, and for the entire time of all the 30-second periods at takeoff power or thrust unless § 33.87(a)(7) applies. See appendix 7 of this AC for guidance on two-minute transient overtemperature limit approval.

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

(1) The fuel, lubricating oil, and hydraulic fluid used for the endurance test must conform to the fuel, lubricating oil, and hydraulic fluid requirements listed in the TCDS and installation instructions.

(2) To verify that the lubrication system functions within design intent, the applicant should monitor oil consumption during the endurance test and summarize the results in the certification report. To verify oil type and quality, the applicant should take oil samples before and after the test, and analyze these samples to evaluate any oil property changes. The applicant should analyze the post-test sample for the presence of any metallic particles or other contamination that may indicate the deterioration of one or more engine parts. The applicant should disclose any evidence of oil property degradation or particle contamination in the test report. Additional oil sampling should be done during the test. The additional sampling will assist oil monitoring for particle contamination, which in turn will help to identify the beginning of significant part deterioration. The oil consumption rate, 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 fuel characteristics should be consistent throughout the test and conform in all respects to the specifications prescribed in the TCDS. Applicants should disclose and justify any fluid property differences from these specifications, including the use of any additives. To establish a baseline, the applicant should take a fuel sample from the engine fuel supply line before 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.

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

(1) The applicant should ensure that the maximum permissible total air bleed be extracted from the engine during at least five of the 25 endurance test cycles, except for the 30-second and 2-minute OEI test run under § 33.87(f) (see paragraph e.(6) below). For these five test runs with the maximum air bleed, the regulation permits the power, thrust, or rotor speeds to be less than their 100 percent redline values; however, the gas temperature must be maintained to at least the 100 percent redline value. Any power, thrust, or rotor shaft rotational speed reduction

should not exceed the reductions due to bleed extraction if the engine were in the type design configuration.

> **Note:** We recommend that only five of the 25 endurance test cycles be run with maximum permissible air bleed flow to comply with the intent of § 33.87(a)(5). Running more than five of the endurance test cycles with maximum permissible air bleed flow may not allow the engine to demonstrate compliance to the intent of § 33.87(a)(3) and, therefore, should be avoided.

(2) In the test plan, the applicant should specify the total compressor air bleed flow rate limit and the proportional split from each compressor air bleed port on engines having multiple bleed ports. Examples of aircraft service air bleed uses are wing and cowling anti-ice, aircraft environmental control systems (for example, air conditioning), and engine cross-bleed starting. During the endurance test, the applicant must demonstrate the maximum allowable air bleed flow rate and the individual air bleed port flow limits specified in the TCDS and in the § 33.5 manual.

(3) On engines with multiple air bleed ports, the air bled from each port should be extracted simultaneously at rates consistent with normal engine operation and design intent. The combined extraction should equal the total air bleed flow limit consistent with the rating condition being tested.

(4) During the test runs with maximum air bleed, the power or thrust or the rotor speed(s), or both 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 should not exceed reductions that would be due to air 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 rating to be certified.

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

(6) For the test in § 33.87(f), an exception is permitted by the regulation to reduce test complexity and improve the flexibility necessary to attain key parameters, such as speed, temperature, and torque. For this test, applicants do not need to use maximum air bleed for engine and aircraft services if they show by test, or analysis based on test, that the engine's ability to meet the teardown inspection requirements under § 33.93 is not enhanced. See paragraph 3-8.f. of this AC for guidance regarding what the analysis should include.

f. <u>Accessory drive and mounting attachment loads, § 33.87(a)(6)</u>.

(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 facility units of a similar type. An exception is permitted by § 33.87(a)(6)(iii) for the 30-second and 2-minute OEI test run under § 33.87(f) (see paragraph f.(5) below). The intent of this requirement is to simulate power extractions, weights, and overhung moments of the type design hardware for all operating power or thrust levels throughout the endurance test. However, the load imposed by each accessory used for aircraft service only should be the limit load consistent with rated power or thrust levels to be certified. The required loads for all other power or thrust levels are the normal operating loads.

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

(3) For any accessory drive and mounting attachment that cannot be adequately loaded or substantiated by the endurance test, the applicant should conduct additional component tests 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.

(4) When a gearbox rig test is necessary, the rig test is generally run at maximum drive-pad loading, maximum power extraction loading, and at 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 and during the engine endurance test, the gearbox drive position may have facility hardware, either actual or nonfunctioning, mounted to represent its weight and overhung moment.

(5) The applicant does not need to load the accessory drives and mounting attachments when running the test required for the 30-second and 2-minute OEI ratings under § 33.87(f). In this case, the applicant should show that there is no effect on the durability of any accessory drive or engine component. If the accessory drives and mounting attachments are not loaded, the equivalent power should be added to the required power at the output drive. This will ensure that the power turbine rotor assembly is operated at or above the same levels it would be if the accessory drives and mounting attachments were loaded.

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

(1) The regulation allows for an exception from testing at the 100 percent oil or EGT "where test periods are not longer than 5 minutes and do not allow stabilization." This exception applies if at the end of any test period of 5 minutes or less, the type design characteristics of the engine are such that either the oil or EGT is still increasing and have not yet achieved their

limiting value. To satisfy the requirements of this exception, the applicant should provide supporting data showing that these are the engine's normal engine operating characteristics.

(2) The term "stabilization" of this requirement 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 any minimum variations remain at or above the 100 percent value to be certificated.

(3) To establish the time duration it takes for parameters to stabilize, the applicant should start measuring time from when the throttle is first moved from the minimum idle position toward the takeoff power position. Move the throttle from the minimum idle position to the takeoff power position within 1 second.

(4) The exception to the § 33.87(a)(7) requirement to maintain the gas temperature at the 100 percent or redline value does not apply to the 5-minute or longer runs at takeoff power or thrust during the 5-minute test periods in §§ 33.87(b)(1), (c)(1), (d)(1), and (e)(1). Nor does it apply to the 30-minute test periods in §§ 33.87(b)(2)(ii), (c)(2)(ii), (d)(2)(ii), and (e)(2). This means that the gas temperature must be stabilized at or above the 100 percent redline value before those 5-minute and 30-minute test periods, respectively, can begin. For most engines, the gas temperature does not generally require a 5-minute run period to stabilize at the redline value.

(5) For rotorcraft engines, the exception to the § 33.87(a)(7) requirement to maintain the gas temperature at the 100 percent or redline value to be certificated does not normally apply to the test periods rated continuous OEI, rated 30-minute OEI, 2 ½-minute OEI, 2-minute OEI, or even 30 second OEI runs.

(6) To request the exception to the gas temperature stabilization for the 30-second test run segments in § 33.87(b)(5), the applicant should follow the conditions specified in paragraph 3-4.b.(4)(b) of this AC. Similarly, for exceptions to § 33.87(c)(6), (d)(6), and (e)(2), follow the guidance as provided in the corresponding paragraphs 3-5.f, 3-6.e, and 3-7 of this AC.

(7) If the applicant demonstrates that the gas temperature stabilization exception is permitted during the 30-second test run segments in § 33.87(b)(5), (c)(6), (d)(6), and (e)(2), then the total run time that can be claimed at takeoff redline gas temperature should be reduced by the 1.25-hour duration of these segments. For example, the total run time that may be claimed at the takeoff redline gas temperature for compliance with § 33.87(b)(5) is reduced from 18.75 hours (accounting for the §§ 33.87(b)(1) and (2)(ii) segments and § 33.87(b)(5) segments) to 17.5 hours (which accounts for the §§ 33.87(b)(1) and (2)(ii) segments only). 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).

(8) During the test segments run at a gas temperature below the 100 percent redline, because the gas temperature stabilization exception is permitted, the applicant should maintain the rated thrust or power with rotor speeds (i.e., N1 and N2) at or above redline values.

(9) The applicant should qualify the engine with the same EGT stabilization characteristics that it will display in service.

(10) The applicant should control the engine using the same EGT measurement and control system that it will use in service.

(11) At least one endurance test cycle must be run with fuel, oil, and hydraulic fluid at the minimum pressure limit, and at least one endurance 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 applicant may artificially adjust the fluid temperature with a test facility heat exchanger to achieve the desired value, or may use other means if it is shown not to affect the test outcome.

h. Transient overspeed, overtemperature, and overtorque 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, gas temperature, or shaft torque 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. Applicants should limit rotor speed, gas temperature, or shaft torque transients associated with the 2 ½-minute, 2-minute, and 30-second OEI ratings to very brief periods of 10 seconds maximum.

> **Note:** The FAA has approved transient overtemperatures that exceeded 30 seconds and up to 2 minutes. However, § 33.87(a)(8) is intended and remains suitable to evaluate rotor speed and gas temperature transient overtemperature for periods of 30 seconds or less. See appendix 7 of this AC for guidance on 2-minute transient overtemperature limit approval.

(3) Applicants may not use transient limits as supplementary limitations, regardless of their duration, for engine power setting purposes. The transient limits of shaft overspeed, gas overtemperature, and shaft overtorque prescribed in §§ 33.7(c)(14), (c)(15), and (c)(16), 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 requirement under § 33.87(a)(3) 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 showing that an engine cannot achieve a stabilized takeoff redline gas temperature during the 30-second takeoff power segments under § 33.87(b)(5), these accelerations to takeoff power still count toward the total 310 accelerations required during the endurance test.

(4) We recommend conducting the transient condition test runs during the 150 accelerations to the 5-minute takeoff test segments of §§ 33.87(b)(1), (c)(1), (d)(1), and (e)(1) and during the 10 accelerations to the 30-minute takeoff test segments of §§ 33.87(b)(2)(ii), (c)(2)(ii), (d)(2)(ii), and (e)(2). Some turbine engines, particularly large turbofan models, may not reach a stabilized gas temperature during the 30-second takeoff power segments of the test sequence under § 33.87(b)(5). 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.

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 major design changes, parts manufacturer approvals (PMAs), repairs, and alterations.

(1) Applicants should consider the endurance test as an essential part of all major design change approvals, i.e., amended type certificates (TCs), supplemental type certificates (STCs), and amended STCs. See appendix 8 of this AC for guidance on compliance with § 33.87 for engine TCs and major design changes, i.e., amended TCs, STCs, and amended STCs.

(2) Parts manufacturer approvals and major repairs and alterations may require running certain endurance testing for compliance with § 33.87. Advisory Circular 33.87-2, provides guidance on showing compliance with § 33.87 for PMAs by means of comparative test methods.

b. Endurance test 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, so that all required testing is completed at redline conditions.

However, applicants should conduct all endurance testing on the same set of engine hardware to be presented for certification.

(2) Appendix 3 of this AC presents additional information on an acceptable endurance test cycle for multiple engine tests.

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

a. Explanation.

(1) The applicant must perform this endurance test cycle 25 times, for a total of 150 hours of testing on all turbojet, turbofan, and turbopropeller engines. The endurance test 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 endurance test cycle for § 33.87(b) is presented graphically in appendix 1, figures 1 and 2 of this AC.

(2) The test engine must maintain the rated power or thrust. Advisory Circular 33.7-1 provides information and guidance on the engine ratings and associated limitations. Specifically, the methods, ambient conditions, and engine configuration the applicant should use to establish and demonstrate the ratings that are then applied during the endurance test.

(a) The minimum physical power or thrust value required for testing under § 33.87(b) may be adjusted from the actual testing conditions to the conditions specified in the TCDS under which the rated power or thrust is determined. Applicants are not allowed to adjust 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. Special test hardware, such as 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 physical power or thrust may result in insufficient loading on load-carrying members of the engine, such as thrust bearings, struts, mounts, and cases to comply with the requirements under § 33.87(a)(3).

(b) The applicant may propose data to justify the power or thrust shortfall when the minimum physical power or thrust target cannot be achieved. The data should address the engine parts that are affected by the power or thrust magnitude and should show that their durability is not affected. We will review the proposal to see if it needs to be evaluated as an equivalent level of safety under § 21.21(b)(1).

(c) For all test conditions, the applicant should identify in the test plan the parameters relevant to the purpose of the test together with the appropriate times for their recording during the test. Except during transient conditions, the applicant should allow the engine to stabilize before recording the data.

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 requirement 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 (minimum idle) and the maximum operating power or thrust condition (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, should stabilize for 5 minutes at the takeoff power condition redline values. Similarly, power or thrust should be maintained for 5 minutes at the minimum idle condition following stabilization.

(a) Applicants should conduct one hour of alternate 5-minute periods at rated takeoff power or thrust and at minimum idle power or thrust with the following requirements:

1 Before beginning any of the 5-minute takeoff segments, the physical rotor speeds, indicated gas temperature, and physical thrust or power should 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 3 of this AC for multiple endurance test requirements.

2 Before beginning any of the 5-minute minimum idle segments of the test run, the physical rotor speeds and physical power or thrust should 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 should 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 power 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 power ratings that do not materially increase operating severity:

1 If use of the rating is not limited, all takeoff runs must be made at the augmented rating, and

2 If use 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 1 second or less. If the applicant incorporates different regimes of control operation requiring control scheduling, then a longer period of time is acceptable, but for not more than 2 seconds. Examples of different modes of control operations requiring control scheduling are separate stops or detents in the power-control level lever for another rating, which is incorporated between idle and takeoff thrust or power, and which requires scheduling of the power-control lever motion in going from one extreme position to the other.

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

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

(a) In compliance with these two requirements, the engine must run 15 of the 25 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 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 endurance test cycle.

(b) Before 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 1 of this AC depicts an apparent acceleration from idle to the maximum continuous power or thrust to begin the 30-minute segments that are required for 15 of the 25 cycles under § 33.87(b)(2)(i); however, that depiction is only used 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 under § 33.87(b)(1). A rapid acceleration using a 1-second throttle movement from idle to maximum rated power or thrust is not required to start these 15 cycles unless the applicant requested to use those accelerations for additional transient accelerations.

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

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

(a) In compliance with this requirement, the applicant must run all 25 of these segments for 2 hours and 30 minutes at equal speed and time increments by moving the power lever. Specifically, the successive power lever positions must correspond 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 should increase the number of increments to increase the amount of running time made while subject to the peak vibrations, up to no more than 50 percent of the total time spent in incremental running. Applicants may vary thrust and power in place of rotor speed for engines operating at constant 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 tests conducted under § 33.83. The running time allocated for any peak vibration should be sufficient to accumulate at least the minimum vibration cycles for endurance limit. Based on industry practices, 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 applicant may calculate the test time by dividing the number of cycles by the frequency.

2 Any engine vibration that occurs within the declared operating speed ranges, including transients, is considered significant when it occurs at or near a known resonance point, or within a steady-state speed operation and presents any of the following characteristics:

(aa) Amplitudes that indicate stresses near the endurance limits, or

(bb) 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. For example, consider blades, stators, turbine or compressor assemblies, pumps, and the oil tank.

(4) Section 33.87(b)(5), 30 minutes of accelerations and deceleration runs.

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

1 All accelerations should start from minimum idle thrust or power and all decelerations should return to minimum idle thrust or power. During runs at rated thrust or power, 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 under § 33.87(a)(3). If the redline gas temperature does not stabilize within 30 seconds, then only the rated takeoff thrust or power and rotor speeds need to 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 should 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 should 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 should be stabilized at the nominal idle power operating temperature prior to beginning the next acceleration to the takeoff thrust or power level.

(b) Sections 33.87(a)(3) and 33.87(a)(7) require that the gas temperature and oil inlet temperature be at least at 100 percent of the value for each rating condition being tested to be certificated. Section 33.87(a)(7), however, permits an exception to this requirement for test segments that are not longer than five 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 temperatures of many turbine engines do not stabilize during these 30-second takeoff runs under § 33.87(b)(5). For these engines, the applicant 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. Before the applicant can use the gas temperature stabilization exception, the following conditions apply:

1 The applicant should supply data in the test plan 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, e.g., 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.

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 exclusion under § 33.87(a)(7) will be sought for the 30-second test run segments under § 33.87(b)(5). The actual acceleration vs. time plots should then be included in the test report.

3 Even if the oil or gas temperature stabilization exception is justified, the acceleration and deceleration runs under § 33.87(b)(5) should 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 periods under §§ 33.87(b)(1) and (b)(2)(ii).

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

(a) The purpose of an engine start demonstration is to show that normal starts can be accomplished without exceeding the maximum starting temperature limit or causing engine hardware distress following:

1 A short period of engine shutdown,

2 An extended period of engine shutdown,

3 Minimum fuel drainage time or engine motoring time to purge accumulated fuel in the engine, or

4 A false start.

(b) The applicant must conduct 100 engine starts to satisfy the requirements under § 33.87(b)(6). The 100 starts consist of:

1 Twenty-five normal starts preceded by a minimum 2-hour shutdown.

2 At least 10 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 At least 10 normal restarts preceded by a maximum 15-minute shutdown period.

4 Fifty-five additional normal starts if 10 false starts and 10 normal restarts are run. However, if more than 10 false starts and/or more than 10 normal restarts are run, there will be a lesser number of remaining 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 should 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 should adhere to the values specified in the installation instructions.

(e) The remaining starts in paragraph 3-4.b(5)(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 during and after the endurance test.

(f) After each of the starting demonstrations, the applicant should 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 installation or operating instructions.

(g) Any limitations associated with the normal start, such as the starting time or other engine operating parameters, should be specified in the TCDS and in the operating instructions manual as required by § 33.5(b)(3)(i).

3-5. Endurance Test Schedule, § 33.87(c), for Rotorcraft Engines for which a 30-minute OEI Power Rating is Desired.

a. Guidance.

(1) 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 1 hour and 30 minutes of test time in § 33.87(b)(3) at rated maximum continuous power is now split between 1 hour at maximum continuous power in § 33.87(c)(3) and 30 minutes at 30-minute OEI in § 33.87(c)(4). The test must include the sequential test runs defined in §§ 33.87(c)(1) through (c)(7) unless we approve an alternative test sequence. Also, applicable to this test schedule is the guidance described in paragraph 3-4.a.(2) of this AC for required minimum physical power and the general endurance test requirements prescribed in § 33.87(a).

(2) 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.

(3) See figures 3 and 4 in appendix 1 of this AC for a graph representation of the § 33.87(c) 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 maximum continuous and takeoff power.

(1) In compliance with this paragraph, the applicant should run the first 15 of 25 cycles for 30 minutes each at the rated maximum continuous power, and run the remaining 10 cycles for 30 minutes each at the rated takeoff power.

(2) The applicant should maintain all limit parameters (rated power and associated maximum permissible torque, rotor speed, and gas temperature) for 30 minutes at the limit levels (redlines) associated with the rated maximum continuous or rated takeoff.

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

(1) In compliance with this paragraph, the applicant should run 25 endurance test cycles at rated maximum continuous power for 1 hour each after completing the test sequence at rated maximum continuous and takeoff power of § 33.87(c)(2).

(2) The applicant should maintain all limit parameters (rated power and associated maximum permissible torque, rotor speed, and gas temperature) at maximum continuous rating power values for 1 hour.

e. Section 33.87(c)(4), Rated 30-minute OEI power.

(1) In compliance with this paragraph, the applicant should run 25 endurance test cycles at rated 30-minute OEI power for 30 minutes each after completing the test sequence at rated maximum continuous power of § 33.87(c)(3).

(2) The acceleration should start from maximum continuous power and the deceleration should return to minimum idle power after this test sequence. The applicant should maintain all limit parameters (rated power and associated maximum permissible torque, rotor speed, and gas temperature) at 30-minute OEI rating redline values for 30 minutes at the rating.

f. Sections 33.87(c)(5), Incremental cruise power or thrust, § 33.87(c)(6) Acceleration and deceleration runs, and § 33.87(c)(7), Starts. The guidance for these three sections is identical to that described in paragraphs 3-4.b.(3), (4), and (5) for the requirements in §§ 33.87(b)(4), (b)(5), and (b)(6) respectively.

3-6. Endurance Test Schedule, § 33.87(d), for Rotorcraft Engines for which a Continuous OEI Rating is Desired.

a. Guidance.

(1) This test schedule is required for rotorcraft engines for which the applicant desires a continuous OEI power rating. The schedule is the same as § 33.87(b), except that a 1-hour test run at continuous OEI rating power replaces the 1 hour of maximum continuous time in each of the test runs under § 33.87(b)(3). The test must include the sequential runs in §§ 33.87(d)(1) through (d)(6) sequence unless we approve a different test sequence. Also, applicable to this test schedule is the guidance described in paragraph 3-4.a.(2) of this AC for the required minimum physical power and the general endurance test requirements prescribed in § 33.87(a).

(2) The 150 hours of testing time will consist 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.

(3) See figures 5 and 6 in appendix 1 of this AC for a graph representation of the § 33.87(d) 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 the same as that described under "Guidance" in paragraph 3-4.b.(1) of this AC for § 33.87(b)(1) and paragraph 3-4.b.(2) of this AC for § 33.87(b)(2).

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

(1) In complying with this paragraph, the applicant must run 15 of the 25 endurance test cycles at rated continuous OEI power for one hour each after completing the test sequence under § 33.87(d)(2)(i) at rated maximum continuous power. The applicant must run 10 of the 25 endurance test cycles at rated continuous OEI power for one hour each after completing the test sequence under § 33.87(d)(2)(ii) at rated takeoff power.

(2) The applicant must maintain all limit parameters (rated power and associated maximum permissible torque, rotor speed, and gas temperature) 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, the applicant must run 25 endurance test cycles 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) The applicant must maintain all limit parameters (rated power and associated maximum permissible torque, rotor speed, and gas temperature) 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 sections is identical to that described in paragraphs 3-4.b.(3), (4), and (5) of this AC for the requirements 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 under § 33.87(b)(4).

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 multiengine rotorcraft is limited by the power available from the remaining operating engine(s) when one engine fails or is shutdown during flight. Flight performance analysis has shown that in the event of engine failure at the critical point during take-off or landing, a period of higher power, referred to 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 fight until able to reach a suitable landing site. This power level will be rated maximum continuous, 30-minute OEI, or continuous OEI power depending on the rating structure of the engine. For these reasons, the endurance test schedules for the 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, 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.

(3) See appendix 9 of this AC for more information on rotorcraft operation at the 2½-minute OEI condition.

(4) The schedules prescribed in §§ 33.87(e)(1) and (e)(2) are required for rotorcraft engines for which the applicant desires a 2½-minute OEI power rating. The applicant should select one of the three combinations of ratings in paragraphs 3-7.a.(2)(a), (2)(b) and (2)(c) above for the engine model being certified and apply the associated test schedules for compliance with endurance test requirements.

(5) See figures 7 through 11 in appendix 1 of this AC for a graph representation 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 we approve an alternate test sequence. The guidance described in paragraphs 3-4.a.(2) of this AC for the required minimum physical power and the general endurance test requirements prescribed in § 33.87(a), apply to this test schedule.

(1) Section 33.87(e)(1), Takeoff, 2½-minute OEI and idling. This 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 to be conducted at rated takeoff power. The applicant should conduct the remaining 2.5 minutes at rated 2½-minute OEI power.

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

(a) For engines with rated takeoff, maximum continuous, and 2½-minute 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 in the last one of the 25 endurance test cycles under § 33.87(b)(2)(ii), the last 5 minutes must be run at 2½-minute OEI power rating.

(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)(7) in paragraphs 3-5.c through 3-5.f of this AC, except that, during the last of the 25 endurance test cycles, the last 5 minutes of § 33.87(c)(4) 30 minutes run at the 30-minute OEI power must be run at the 2½-minute OEI power.

(c) For engines with rated takeoff, maximum continuous, 2½-minute OEI, and continuous OEI ratings, the guidance is the same as that given for § 33.87(d)(2) through (d)(7) described in paragraphs 3-6.b through 3-6.e of this AC, except that during the last of the 25 endurance test cycles, the last 5 minutes of § 33.87(d)(4) 1-hour run at continuous OEI must be run at 2½-minute OEI power rating.

(d) See appendix 10 of this AC 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 for which 30-second OEI and 2-minute OEI Ratings are Desired.

a. The 30-second OEI and 2-minute OEI power ratings. When used in combination, the 30-second OEI and 2-minute OEI power ratings enable rotorcraft to perform a mission very similar to that of the 2½-minute OEI power rating described in section 3-7.a, "Explanation," of this AC. There are, however, significant differences between these ratings.

(1) The use of the 2½-minute OEI rating is not limited to a certain number of occurrences, while the use of the 30-second OEI and 2-minute OEI ratings is limited to three occurrences during a single flight. In service, use of the 30-second OEI and 2-minute OEI ratings is likely once per flight with a required mandatory inspection after that 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 intent of the 30-second OEI and 2-minute OEI ratings is to safely use available engine design margins for brief periods of exposure.

(2) Inspection and maintenance actions are not required after a flight when the 2½-minute OEI rating is used. Inspection and maintenance actions, however, are required after a flight when either the 30-second OEI or the 2-minute OEI rating is used. This difference is supported by the pass or fail criteria of the teardown inspection requirements in § 33.93. Following the endurance test for the engine's 2½-minute OEI rating, the teardown inspection must show that all engine parts are in a condition for safe operation in compliance with § 33.93(a)(2). Following the endurance test for the engine's 30-second OEI and 2-minute OEI ratings, the teardown inspection must show that the engine maintains its structural integrity in compliance with § 33.93(b)(2). Note that use of the 30-second OEI and 2-minute OEI ratings may result in component or part deterioration beyond serviceable limits, making these components unavailable for further use. See appendix 9 of this AC for more information on use of 30-second OEI and 2-minute OEI ratings for rotorcraft.

b. Endurance test for 30-second and 2-minute OEI ratings. The endurance test comprises of the 150-hour test run under § 33.87(b), (c), (d), or (e), as applicable to the engine OEI ratings structure, followed by a supplementary 2-hour test under § 33.87(f). See figures 12 and 13 in appendix 1 of this AC for graph representations of the § 33.87(f) test schedules.

(1) Following the tests in § 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 under § 33.87(b), (c), (d), or (e), except for those parts that are

defined as consumable in the ICA. The level of component cleaning to facilitate the inspection before rebuilding for the test under § 33.87(f) should be acceptable to us. The applicant should show that any cleaning during the teardown inspection, or replacement of consumable parts, will not enhance the engine's ability to meet the requirements under § 33.93(b).

(2) The applicant may elect to continue the 2-hour test under § 33.87(f) without an intervening disassembly and inspection. In this case, the applicant must show that, after the test, the condition of engine parts and components comply with § 33.93(a) instead of § 33.93(b).

c. Test conduct. All requirements under § 33.87(a) apply to the conduct of the 2-hour test, except as permitted by § 33.87(f) and as discussed further in this section. The required minimum physical power and general endurance test requirements described in section 3-4.a, "Explanation," of this AC for § 33.87(b) apply to this test schedule. In changing the power setting at the beginning and the end of each test sequence, the applicant should move the power control lever from one position to the other in no more than one second.

d. Test sequences.

(1) The applicant must conduct the prescribed 2-hour test sequence specified in §§ 33.87(f)(1) through (f)(8) a total of four times as follows:

(a) Three minutes at rated takeoff power;

(b) Thirty seconds at rated 30-second OEI power;

(c) Two minutes at rated 2-minute OEI power;

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

(e) One minute at 50 percent takeoff power;

(f) Thirty seconds at rated 30-second OEI power;

(g) Two minutes at rated 2-minute OEI power; and

(h) One minute at minimum flight idle condition.

(2) The applicant must run the test sequences in §§ 33.87(f)(1) through (f)(8) four times, continuously and without stopping. In the event of a stoppage, the applicant should repeat the interrupted sequence in full, or the sequence may be restarted from the interruption point if there are technical justifications acceptable to us. If we determine that the sequence does not need to be repeated in its entirety, the applicant should restart the test from a point where the

engine's thermal condition would be the same as at the time of interruption. If we determine that the number of interruptions is excessive, the applicant should repeat the entire test under § 33.87(f).

e. Test time. The accumulated time of two hours of testing is split among four test sequences. The total duration of the first sequence is 75 minutes, while the duration for sequences 2, 3, and 4 is 15 minutes each. The time difference between these sequences is a result of the requirements under § 33.87(f)(4). These requirements also dictate different test schedules for the first sequence depending on the other ratings of the engine undergoing certification. The intent of the power level of test condition under § 33.87(f)(4) is to demonstrate the highest en route OEI or non-OEI power. The following are test time breakdowns among the four sequences accounting for different engine rating scenarios (see tables 1 and 2 below).

(1) Test time breakdown when (a) the engine does not have a 30-minute OEI rating, or (b) the 30-minute OEI rating is less than either the continuous OEI, or the maximum continuous ratings, or both (see table 1).

Table 1.

Sequence 1						
33.87 section	Takeoff (minutes)	30-sec OEI (minutes)	2-min OEI (minutes)	Flight idle (minutes)	Greatest of continuous OEI or maximum continuous (minutes)	50% takeoff (minutes)
f(1)	3					
f(2)		0.5				
f(3)			2			
f(4)					65	
f(5)						1
f(6)		0.5				
f(7)			2			
f(8)				1		
Sequences 2, 3, and 4						
f(1)	3					
f(2)		0.5				
f(3)			2			
f(4)					5	
f(5)						1
f(6)		0.5				
f(7)			2			
f(8)				1		
Total test time (min)	**12**	**4**	**16**	**4**	**80**	**4**

(2) Test time breakdown when the 30-minute OEI rating is greater than both the continuous OEI and the maximum continuous ratings (see table 2).

Table 2.

Sequence 1							
33.87 section	Takeoff (minutes)	30-sec OEI (minutes)	2-min OEI (minutes)	Flight idle (minutes)	30-min OEI (minutes)	Greatest of Continuous OEI or maximum continuous (minutes)	50% takeoff (minutes)
f(1)	3						
f(2)		0.5					
f(3)			2				
f(4)					30	35	
f(5)							1
f(6)		0.5					
f(7)			2				
f(8)				1			
Sequences 2, 3, and 4							
f(1)	3						
f(2)		0.5					
f(3)			2				
f(4)						5	
f(5)							1
f(6)		0.5					
f(7)			2				
f(8)				1			
Total test time (min)	**12**	**4**	**16**	**4**	**30**	**50**	**4**

f. Air bleed during test. During the test in § 33.87(f), maximum air bleed for engine and aircraft services under § 33.87(a)(5) do not need to be used if the applicant can show by test, or analysis based on testing, that the engine's ability to meet the teardown inspection requirements of § 33.93 is not enhanced. We permit this exception to reduce test complexity and improve the flexibility needed to attain key parameters during the test (rotational speed, temperature and torque). The analysis should include:

(1) The effect of the bleed air extraction on the engine secondary air system which provides cooling air to various engine components, and

(2) The thermodynamic cycle effects of bleed (for example, core speed to output shaft speed changes).

g. Accessory drives and mounting attachments. If, during testing, the accessory drives and mounting attachments are not loaded, the applicant must add the equivalent power extraction to the engine shaft output drive, as required under § 33.87(a)(6)(iii). This is so that the power turbine rotor assembly is operated at or above the same levels as if the accessory drives and mounting attachments were loaded.

h. Engine operating limitations. The engine operating limitations of the 30-second and 2-minute OEI ratings should be based on the minimum values obtained during the application of the 2-hour test under § 33.87(f). Further, the applicant should identify the limitations in the TCDS. The applicant should also account for stabilization time, instrumentation range of accuracy, and automatic controls features declared under §§ 33.29(c) and 33.28(k).

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

3-10. Endurance Test Schedule, § 33.84, Engine Overtorque Test.

a. Maximum engine overtorque test, § 33.84. These requirements apply to turbopropeller and turboshaft engines that incorporate a free power turbine. The test requirements may be addressed as part of the endurance test of § 33.87(b), (c), (d), or (e). This guidance only applies when maximum engine overtorque testing is incorporated in the endurance test schedule of § 33.87. This guidance does not address the alternative tests available under § 33.84(a)(1).

b. Maximum engine overtorque. The maximum engine overtorque is permitted for all engine ratings, except for the 30-second and 2-minute OEI ratings, as stated by § 1.1, General definitions.

(1) The maximum engine overtorque is an "over the limit" condition that could last up to 20 seconds, and which occurs inadvertently. After this condition occurs, the engine must remain operational without any maintenance action other than to correct the cause. The applicant should identify the failure modes that could produce engine overtorque conditions. For example, sudden changes in the rotorcraft or aircraft blade pitch or power demand, such as an engine failure on a twin-engine rotorcraft, can cause a significant decrease in the rotor or propeller speed.

(2) When overtorque conditions may occur in association with more than a single rating, the applicant should declare the highest torque value as the maximum engine overtorque. The applicant should apply this value during the maximum overtorque test.

c. Test conditions. The required test conditions specified in § 33.84(b) apply to the declared maximum engine overtorque. The applicant should incorporate the test into the endurance sequence for the rated power where the overtorque occurs. For example, when the maximum overtorque is associated with the 30-minute OEI rating, the 15 minute test time required in § 33.84(b)(1) may be incorporated into § 33.87(c)(4), either by running the entire 15 minutes during one of the 25 endurance cycles, or splitting the 15 minutes among the 25 endurance cycles into periods of not less than 2½ minutes each. The following test parameters apply:

(1) The power turbine rotational speed must be equal to the highest speed at which the maximum overtorque can occur in service. It should not exceed the limit speed associated with the rating for which the maximum overtorque is considered.

(2) The turbine-entry gas temperature must be equal to the maximum steady-state temperature approved for use during periods longer than 20 seconds when operating at conditions not associated with 30-second or 2-minute OEI ratings. We may waive the requirement to run the test at the maximum approved steady-state temperature if the applicant shows that other testing provides the desired temperature effects when considered in combination with the other parameters identified in §§ 33.84(b)(1), (b)(2), and (b)(3).

(3) The engine oil temperature should be within the normal operating range. For engines incorporating a reduction gearbox, the gearbox oil temperature must be equal to the maximum temperature when the maximum engine overtorque could occur in service.

d Post-test engine inspection. The engine subjected to the maximum overtorque during the endurance test under § 33.87 must meet the teardown inspection requirements, §§ 33.93(a)(1) and (a)(2), which we discuss further in chapter 4 of this 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 the 150-hour endurance test under § 33.87(b), (c), (d), (e), or (g). For rotorcraft engines with 30-second OEI and 2-minute OEI ratings, the applicant may complete the endurance testing under § 33.87(b), (c), (d), or (e), and then start the testing under § 33.87(f) without intervening disassembly and inspection. For this option, the applicable teardown inspection requirements are those of § 33.93(a) instead of § 33.93(b). An FAA Certificate Management Section (CM section) inspector may need to witness the teardown inspection activities.

a. Section 33.93(a)(1). The applicant must verify that the adjustment setting and functioning characteristics of each engine component are within the limits established and recorded in compliance with § 33.82 before the endurance test. These components include, at the minimum, engine control system components, pumps, actuators, heat exchanger, and valves.

b. Section 33.93(a)(2).

(1) Explanation.

(a) The engine and engine parts or components must conform to their type design consisting of the data and information prescribed under § 21.31. In addition, allowances are permitted for used part conditions provided by the information submitted in compliance with § 33.4 or the TCDS, which includes the engine manual or overhaul manual limits, as applicable.

(b) The phrase, "eligible for incorporation into an engine for continued operation," means that the installation of the part will continue to keep the engine in an airworthy condition. An aircraft engine is "airworthy" when it conforms to its approved design and is in a condition for safe operation, see 14 CFR part 21.1(b)(1).

(2) Guidance.

(a) The applicant should inspect all engine parts and components in both "dirty" and "cleaned" conditions using the ICA inspection instructions. The applicant should record the findings in the certification report. The engine parts and components must conform to their type design after accounting for allowances for used parts condition. Appendix 11 of this AC provides more detailed guidance for teardown inspections.

(b) The dirty inspection after the endurance test is necessary to preserve evidence that may be lost after cleaning, such as oil-coked parts, temperature affected parts, metal particles, and soot deposits. The applicant may conduct the dirty inspection at the individual part level, partial assembly, or complete assembly level. The degree of disassembly and dirty layout largely depends on observations made before and during disassembly of the engine or components. The applicant shouldn't clean any engine part or fully disassemble the test engine without completing the dirty inspection at each step, or otherwise the applicant may request a deviation from this guidance.

(c) The clean inspection should include the following:

1 A visual inspection for unacceptable wear, e.g., galling, distortion, or cracks.

2 A nondestructive inspection for cracks or incipient failures.

3 A dimensional inspection for wear, growth, rub, or distortion.

4 A visual, bench, or teardown inspection, or all, of controls, component, and accessory hardware.

(d) 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 in the engine for continued safe operation. The CM section inspector or designee should validate the applicant's conformity inspection. The applicant should use the inspection limits in the engine manual or the overhaul manual (overhaul, heavy maintenance, shop manual, off-wing manual), as applicable. The applicant should document any part that no longer conforms to its type design in the test report.

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

1 Change the manual inspection limit to agree with the results of the endurance test. In this case, the applicant should show that the part conforming to the new manual inspection limits remains in airworthy condition between maintenance periods (e.g., inspections, shop visits, and overhaul) of the engine; or

2 Redesign the part to meet the manual inspection limit; or

3 Maintain the manual inspection limit, and

(aa) Modify the frequency and procedures of the engine inspection program in the ICA to ensure that the part is inspected and removed from service before reaching the prescribed limit condition, and

(bb) Identify in the test report any part condition that exceeds manual return-to-service limits and justifies part acceptability. The justification may be based on engineering analysis and service experience from a part of similar type design and must show that the part in the existing condition is:

1) Still airworthy;

2) Capable of performing its design functions; and

3) Safe for continued engine operation between engine maintenance periods (inspection, shop visit, and overhaul) as scheduled in the ICA.

(f) In the ICA, the applicant may specify inspection and maintenance limits or criteria that are more conservative than those established for compliance with § 33.93.

(g) All engine components must pass post-test inspection and functional tests, such as a calibration test or a component acceptance test, when applicable, to ensure 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 test under § 33.87 as its sole endurance test, should be torn down for inspection. Newly designed components, components with major modifications, or components existing on other engine models with significantly different operating conditions would generally require a separate component test under § 33.91(a). For the component requiring a separate component test, we may waive the post-test teardown inspection after the tests under § 33.87 if the applicant shows that the component test condition is more severe than the endurance test, and if the teardown inspection will be performed after completing the component test.

(h) 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 test under § 33.87(f), the applicant should record the components' adjustment settings and functional characteristics that can be established independent of installation on the engine. The applicant must show that these adjustment settings and functional characteristics remain within the limits that were established and recorded at the beginning of the test.

b. The test under § 33.87(f) for 30-second OEI and 2-minute OEI ratings is run following a 150-hour endurance test under § 33.87(b), (c), (d), or (e). Before starting the endurance test of § 33.87(f), the applicant may completely disassemble the test engine to show compliance to § 33.93(a).

c. Following completion of the test under § 33.87(f), the applicant must perform a teardown inspection based on the pass or fail criteria prescribed in § 33.93(b). The applicant must show that no failure of any significant engine component has occurred during the test or during the subsequent teardown inspection. For the purpose of this paragraph, engine components considered significant are those that can affect structural integrity, including, but not limited to, engine mounts, cases, bearing supports, shafts, and rotors. If any failure is seen, 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.

d. The applicant may choose not to disassemble and inspect the engine after completion of the 150-hour endurance test and before starting the supplemental test under § 33.87(f). In this case, the applicant must perform the teardown inspection under § 33.93(a) at the end of the 2-hour supplemental test.

e. The applicant should document in the test report the component and engine part deterioration during the test under § 33.87(f). Such deterioration should not indicate a potentially hazardous condition for the engine. In addition to the damage that is readily visible, the applicant should detect and assess damage that is not visible. Such non-visible damage may include 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 to properly identify these component conditions, and should define appropriate maintenance actions for maintaining the continued airworthiness of the engine.

Appendix 1. Graphic Profiles of Endurance Test Schedules

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

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

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

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

a. <u>§ 33.87(b) and § 33.87(e)</u>

b. <u>§ 33.87(c) and § 33.87(e)</u>

c. <u>§ 33.87(d) and § 33.87(e)</u>

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

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

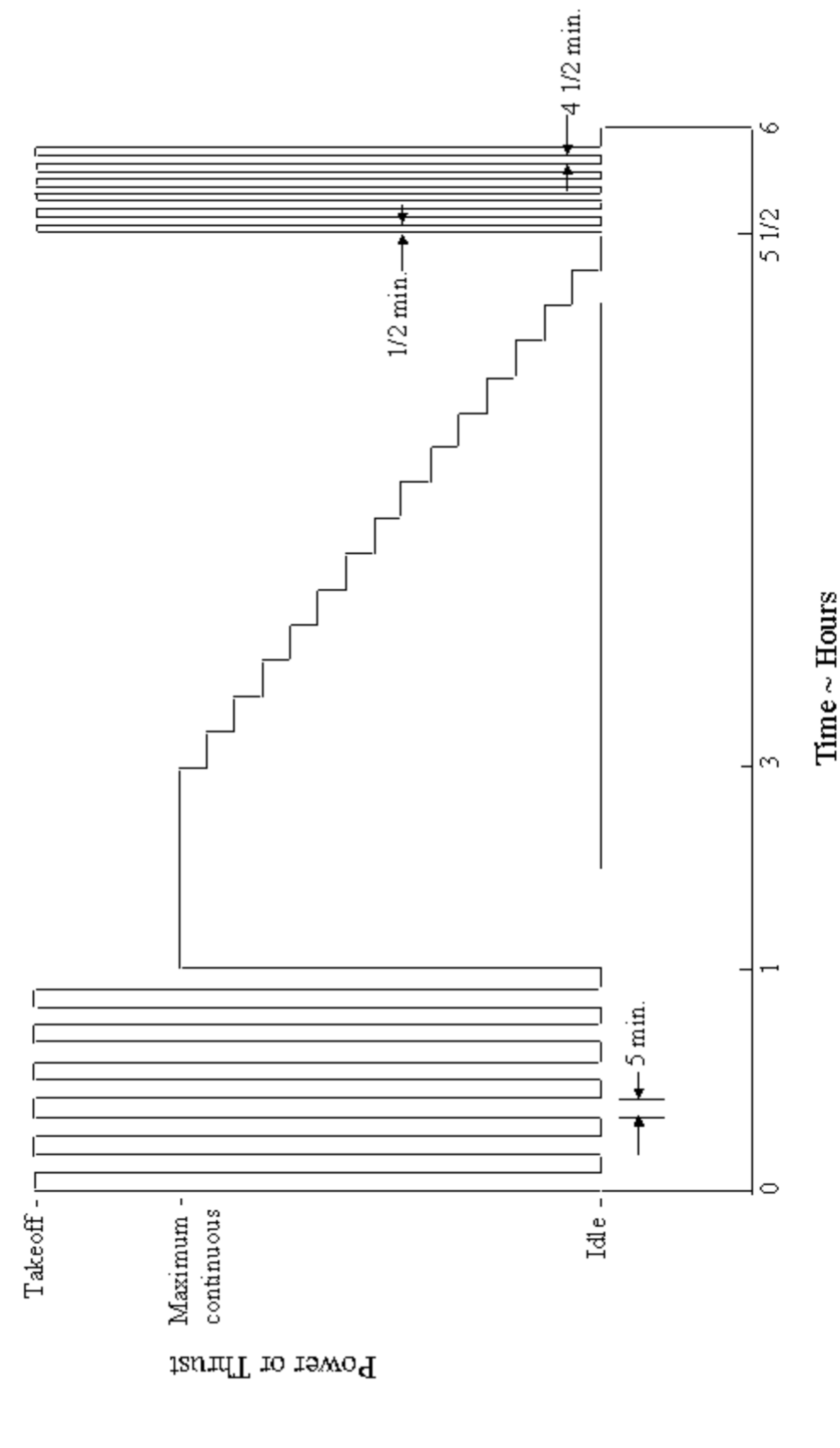


Figure 2. § 33.87(b), 150-Hour Endurance Test Cycles 16-25

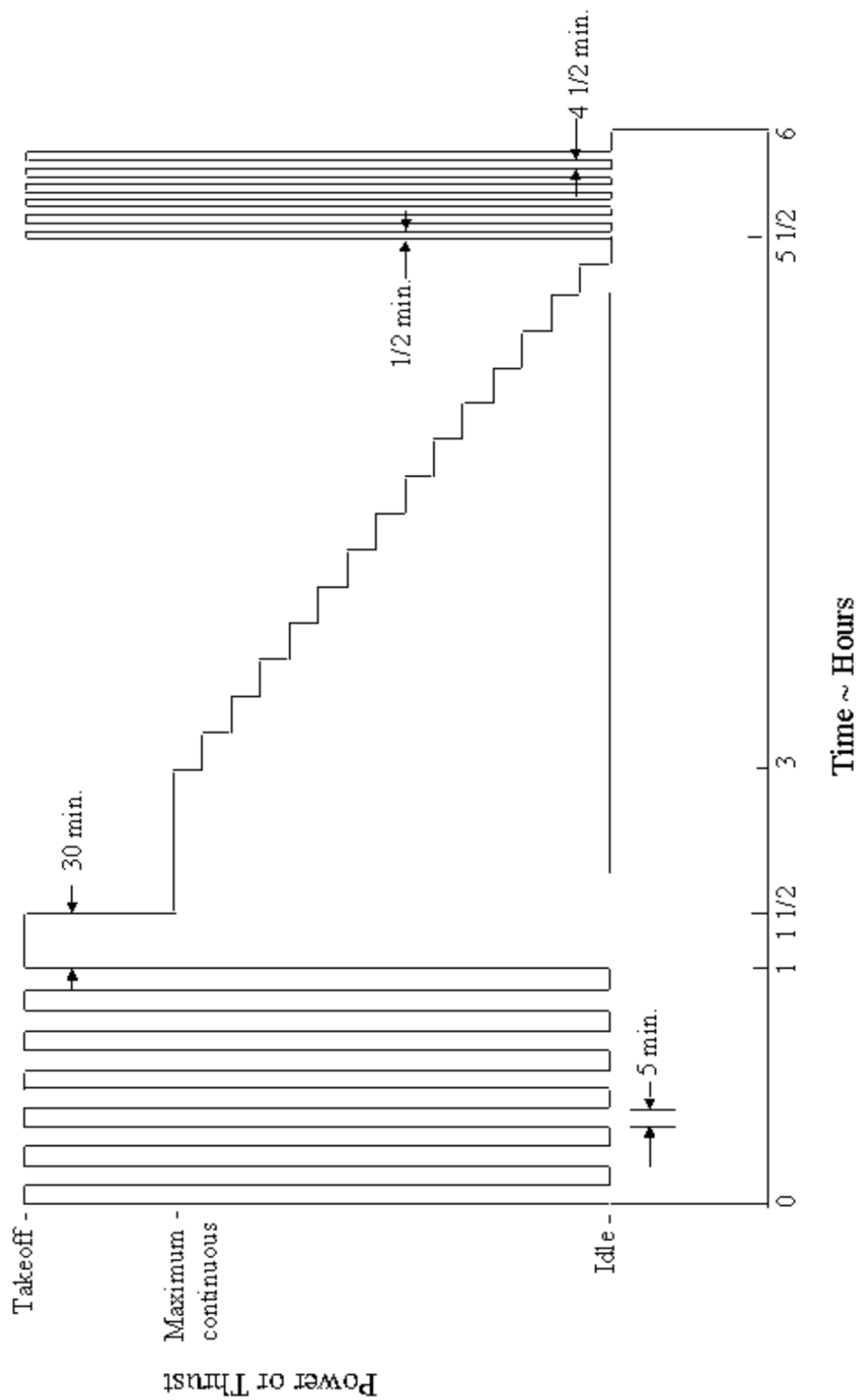


Figure 3. § 33.87(c), 150-Hour Endurance Test Cycles 1-15 for Rotorcraft Engine with 30-Minute OEI Power Rating

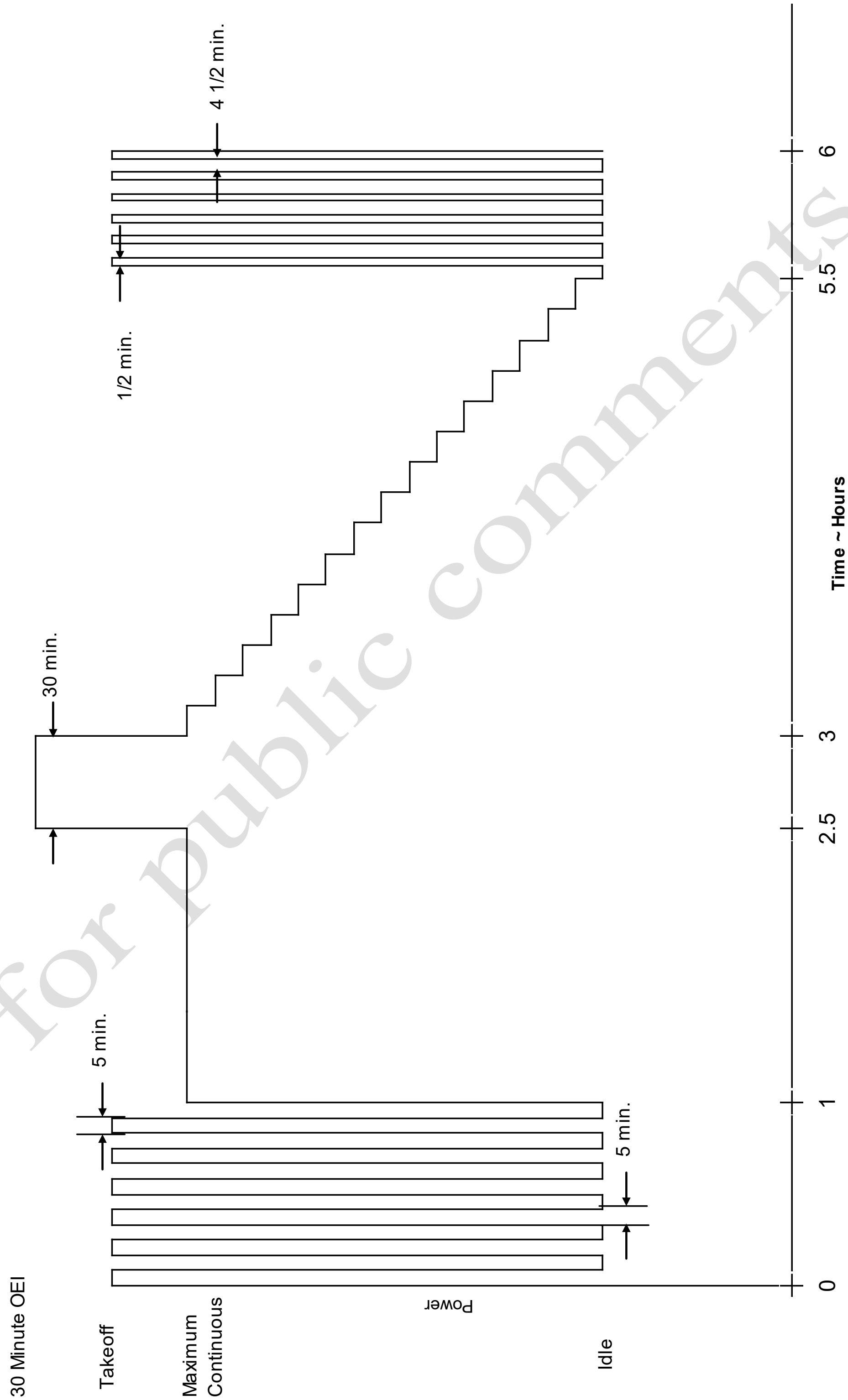


Figure 4. § 33.87(c), 150-Hour Endurance Test Cycles 16-25 for Rotorcraft Engine with 30-Minute OEI Power Rating

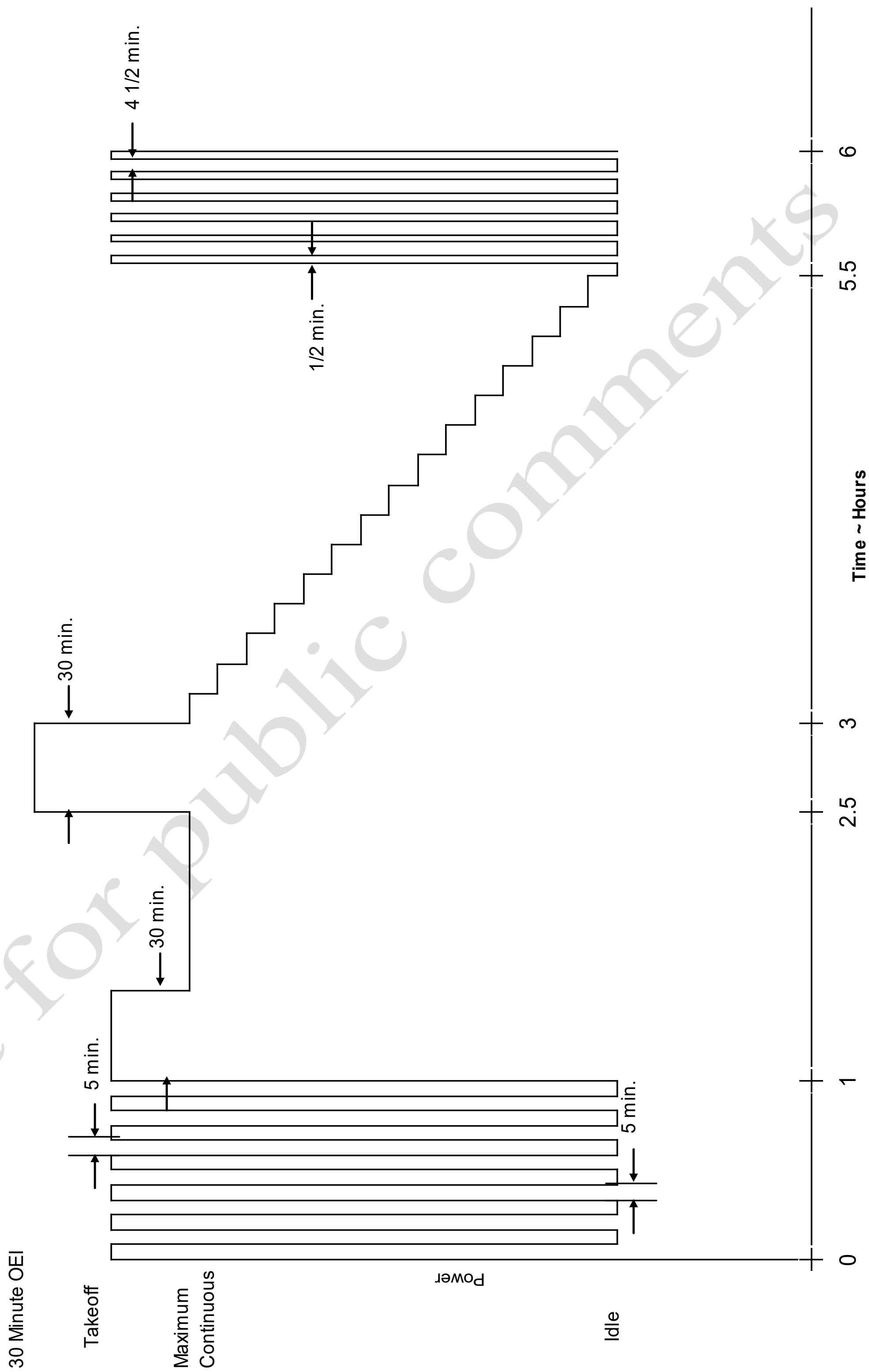


Figure 5. § 33.87(d), 150-Hour Endurance Test Cycles 1-15 for Rotorcraft Engine with Continuous OEI Power Rating

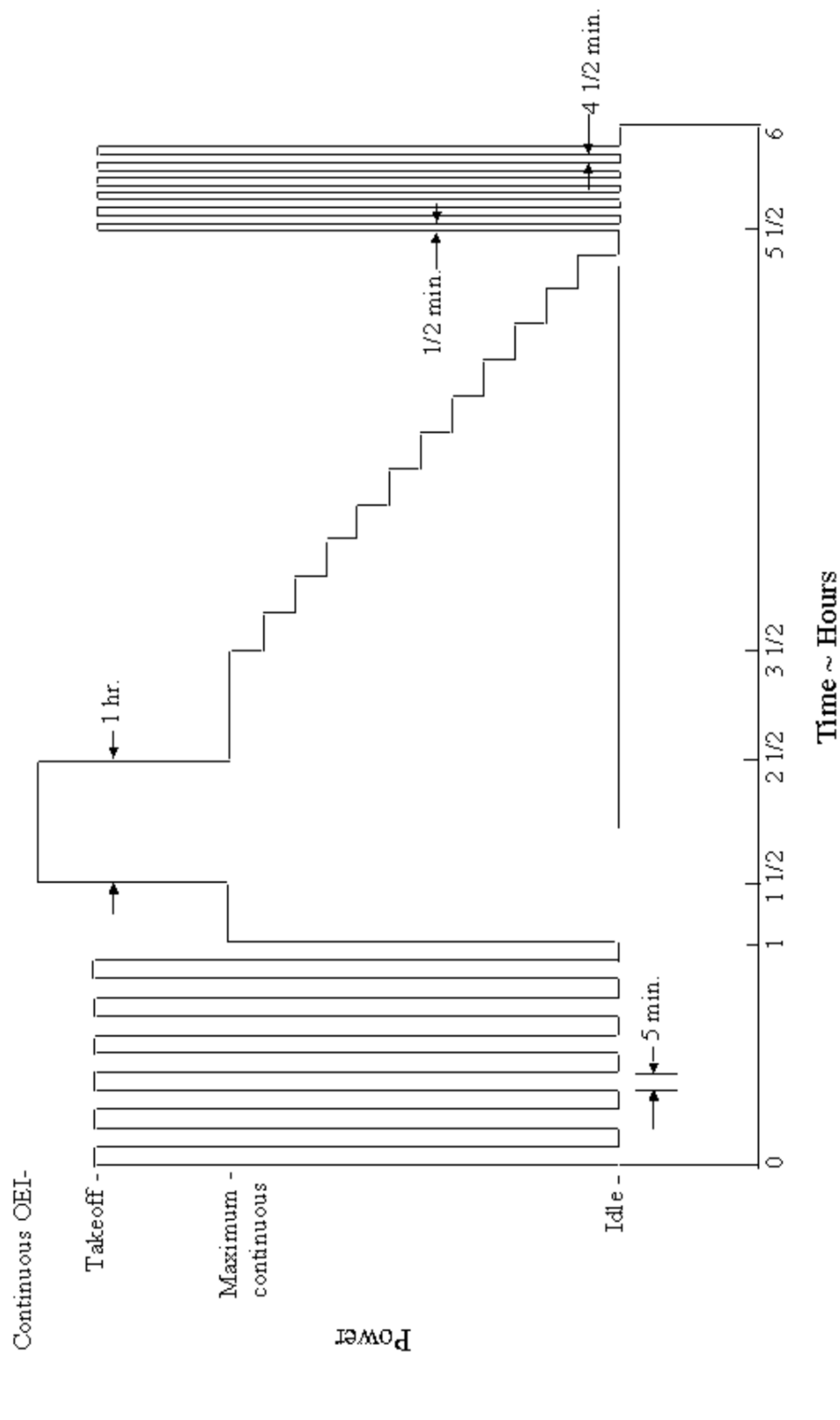


Figure 6. § 33.87(d), 150-Hour Endurance Test Cycles 16-25 for Rotorcraft Engine with Continuous OEI Power Rating

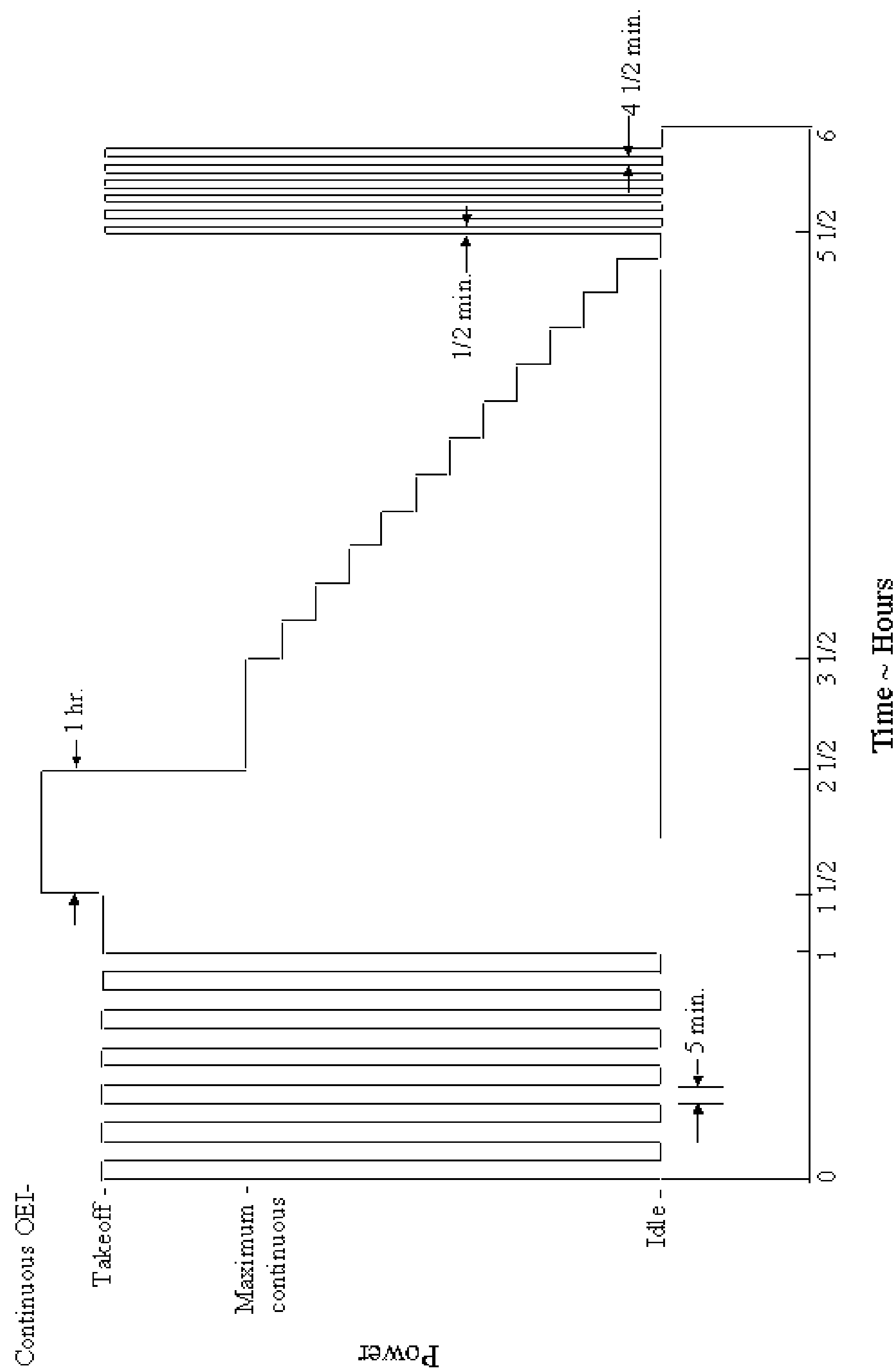


Figure 7. § 33.87(e), 150-Hour Endurance Test Cycles 1-15 for Rotorcraft Engine with Rated 2 ½ Minute OEI Power Rating

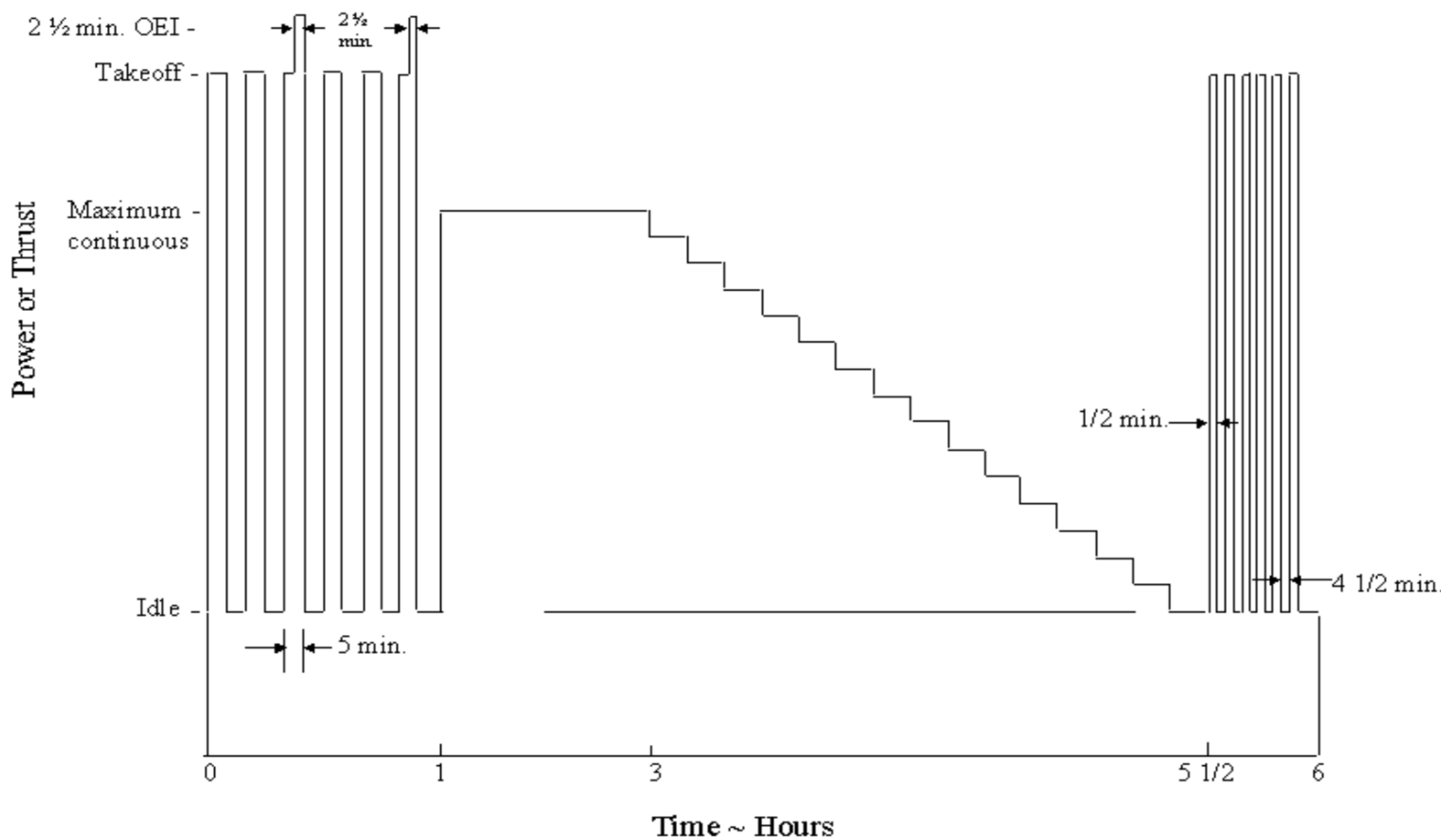


Figure 8. § 33.87(e), 150-Hour Endurance Test Cycles 16-25 for Rotorcraft Engine with Rated 2 ½ Minute OEI Power Rating

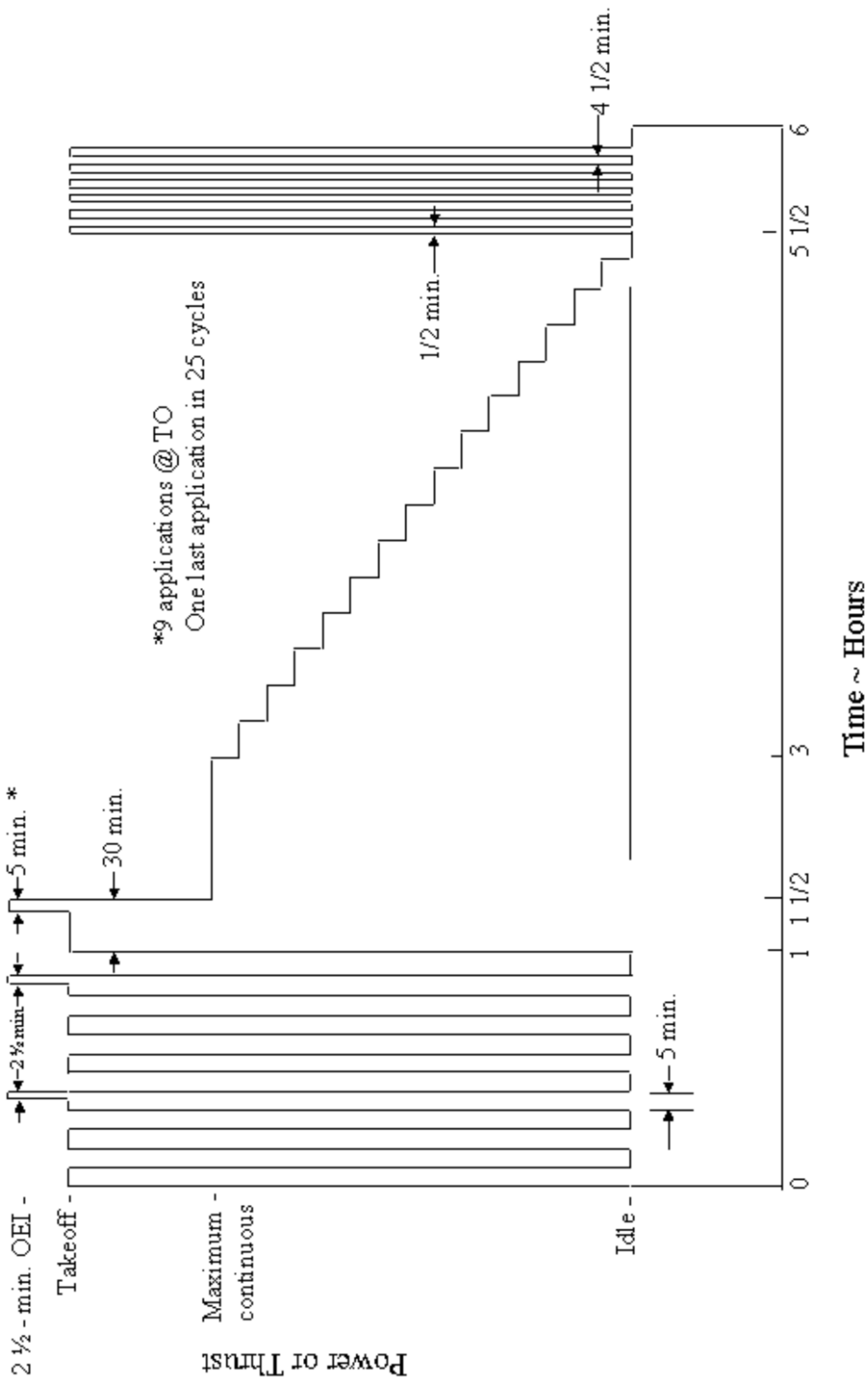


Figure 9. § 33.87(e), 150-Hour Endurance Test Cycles 1-25 for Rotorcraft Engine with Rated 2 ½ Minute and 30-Minute OEI Power Rating

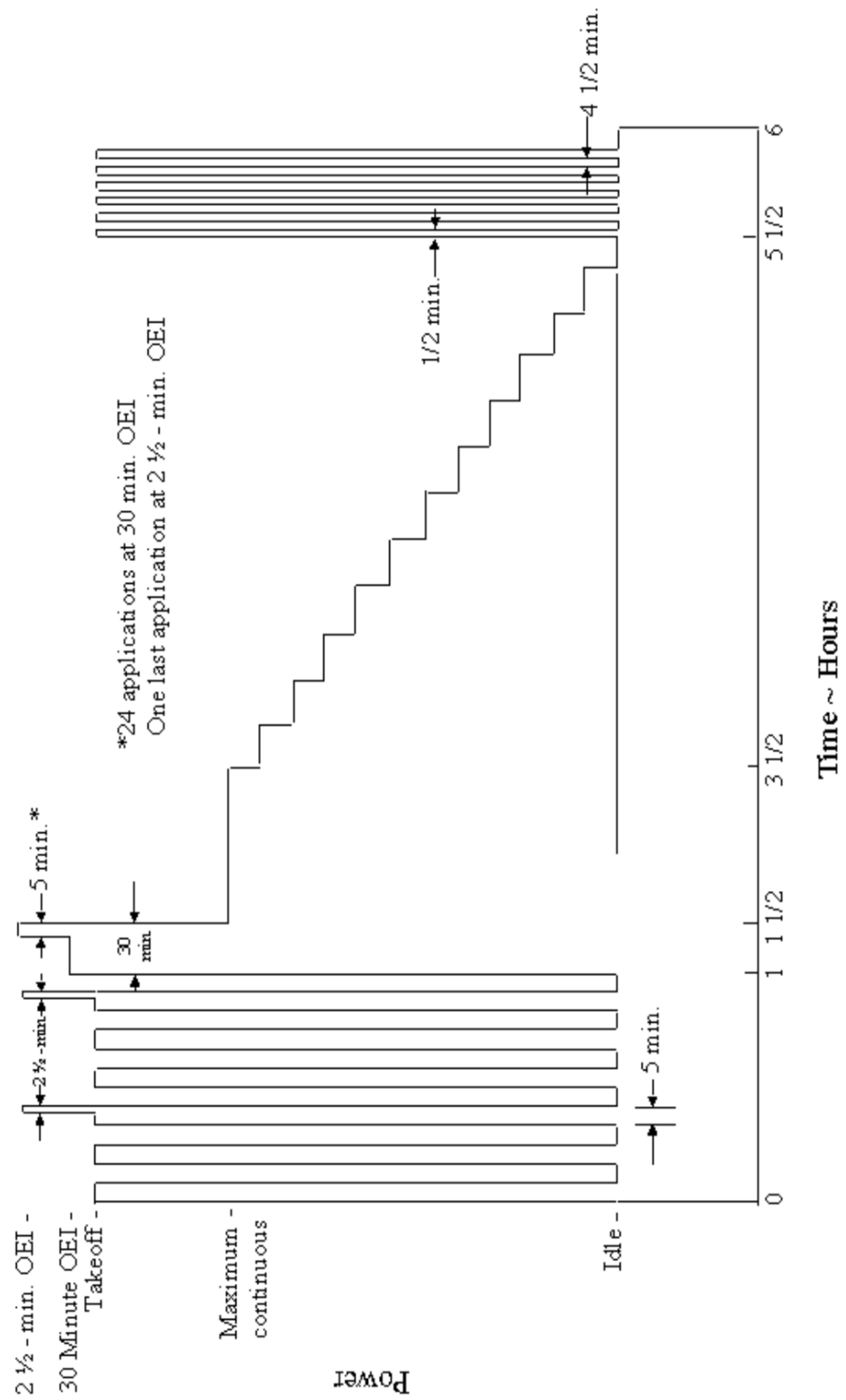


Figure 10. § 33.87(e), 150-Hour Endurance Test Cycles 1-15 for Rotorcraft Engine with Rated 2 ½ Minute and Continuous OEI Power Rating

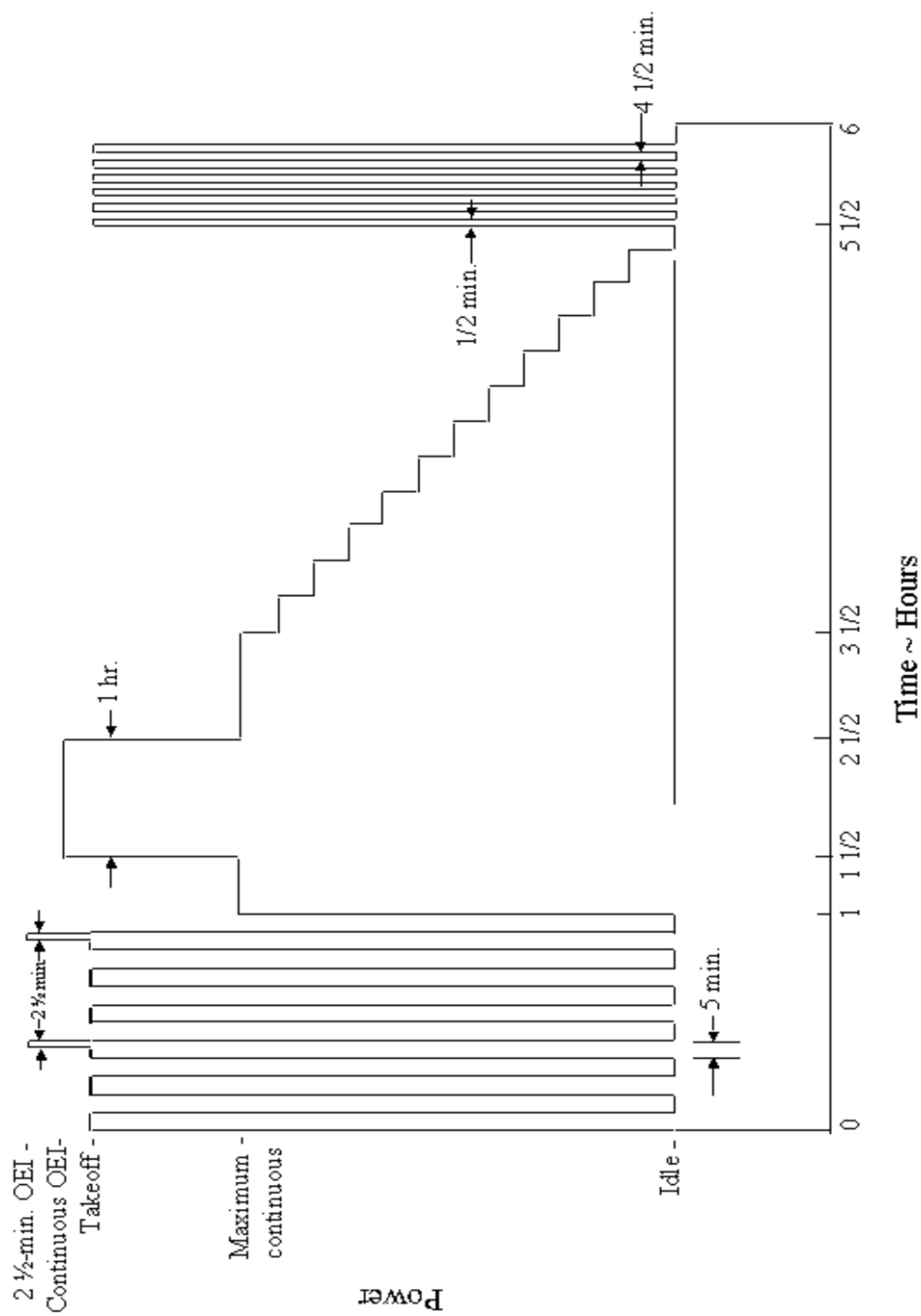


Figure 11. § 33.87(e), 150-Hour Endurance Test Cycles 16-25 for Rotorcraft Engine with Rated 2 ½ Minute and Continuous OEI Power Rating

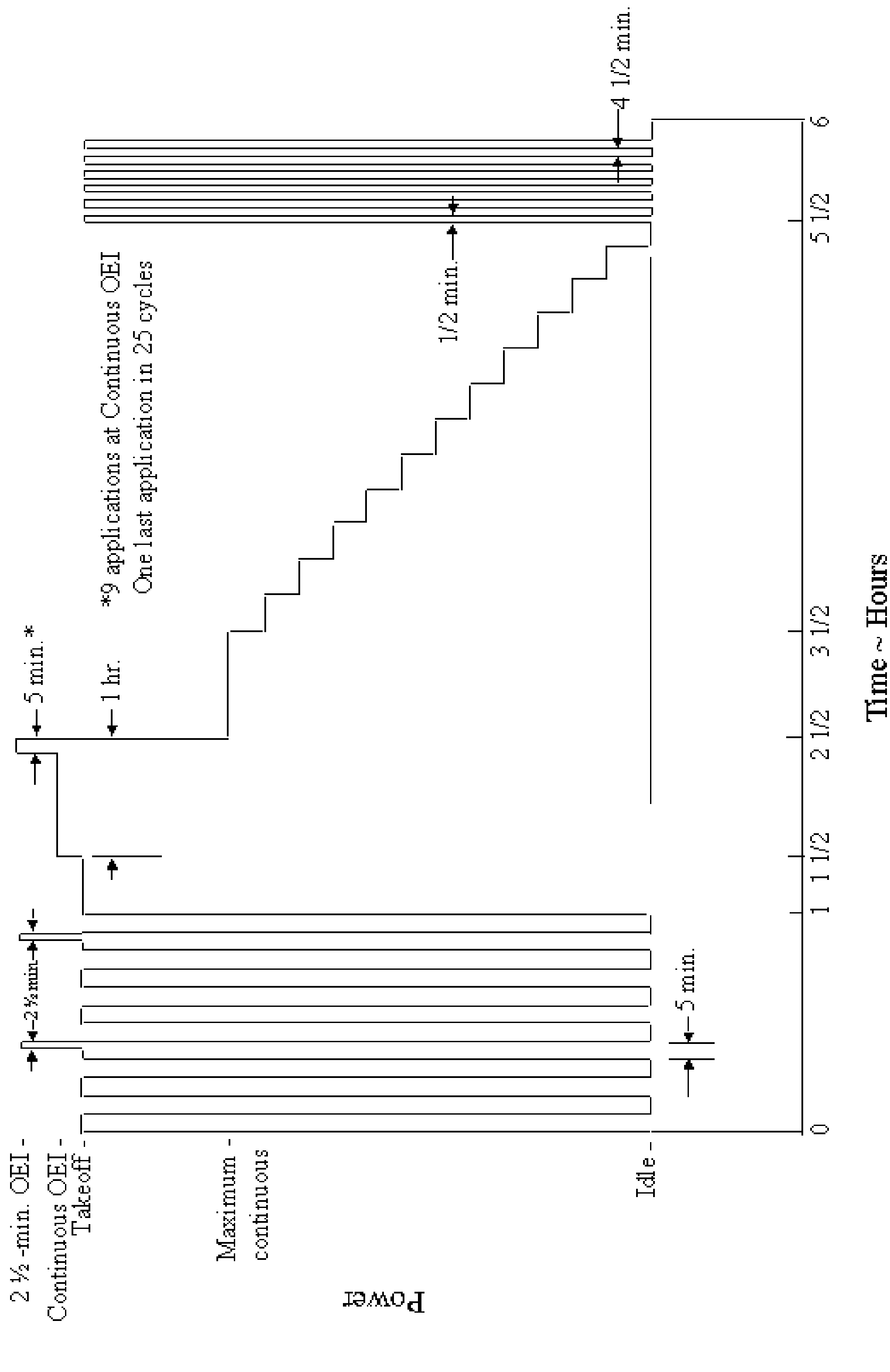


Figure 12. § 33.87(f), 2-Hour Supplemental Endurance Test, Cycle 1 of 4 for Rotorcraft Engine with 30-Second and 2-Minute OEI Power Ratings

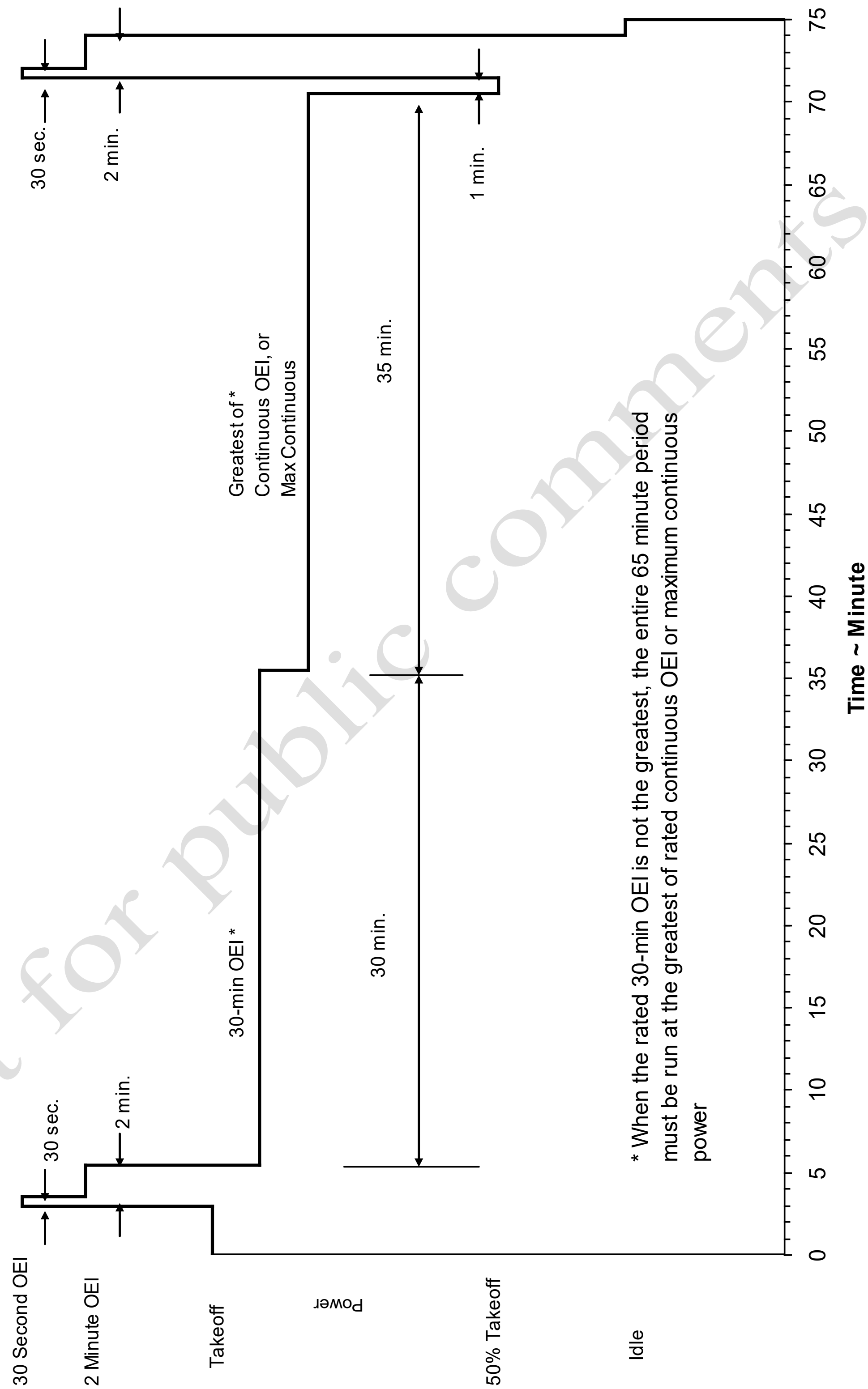
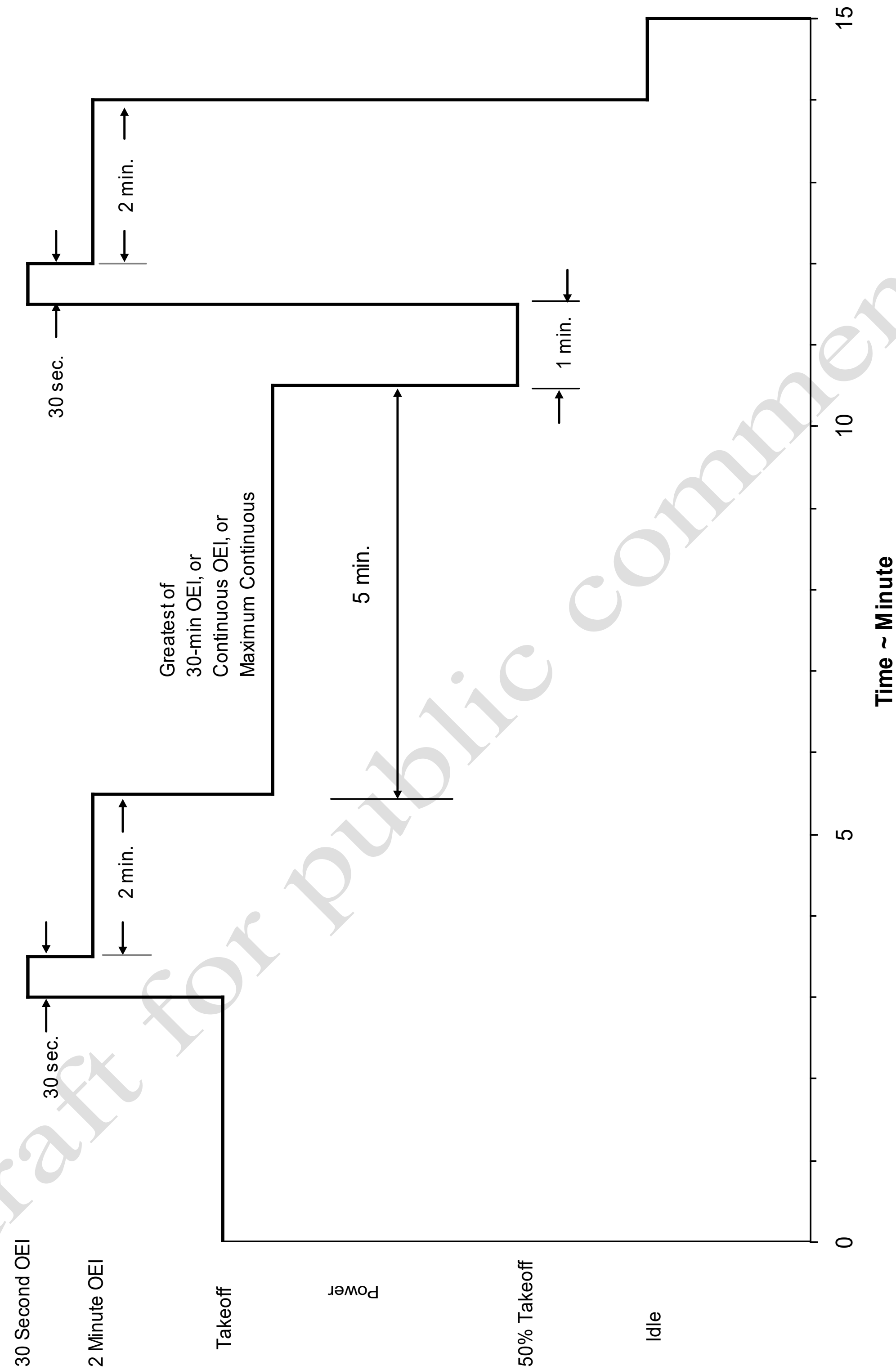


Figure 13. § 33.87(f), 2-Hour Supplemental Endurance Test, Cycles 2-4 for Rotorcraft Engine with 30-Second and 2-Minute OEI Power Ratings



Appendix 2. 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 or fail criteria. Submit the test plan early enough to allow us sufficient amount of time to review and approve the plan before the start of the test.

2. The following paragraphs describe the types of information included in a test plan for the calibration test, endurance test, and teardown inspection. We intend this information as a guide to preparing the plan and is not all-inclusive or mandatory.

a. Description of the Test Objective. The applicant should 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 applicant should identify the test engine configuration. The configuration of the test engine must substantially conform to the final type design; however, non-type design hardware, components, and software may be used in the test engine to achieve certain test conditions when approved by us. For example, the applicant may need to modify test equipment, engine configurations, and test sequences in order to run the test at simultaneous triple redline conditions. In this case, the applicant should identify, in the test plan, the parts and components in the test engine that are non-type design. The applicant should also validate that the non-type design parts and components will not adversely affect the test outcome or the test integrity.

c. Facility test equipment. The applicant should list all facility test equipment necessary to conduct the test, the configuration of slave hardware, the bleed configuration, and the oil system modification(s) to achieve maximum oil temperature, etc. The applicant should also identify the calibration means for the test equipment.

d. Conformity. The applicant should identify the germane hardware of the test engine in a user-friendly format for easy identification. The applicant should also list the components that require pre- and post-endurance test bench calibration, and the required conformities of the test engine. Appendix 5 of this AC provides additional information on conformity inspections.

e. Test procedure. The test procedure should provide sufficient details to describe the method of compliance. These may include:

(1) discussions of pre- and post-endurance calibration tests,

(2) test cycles or hours,

(3) test sequences if they differ from those prescribed in § 33.87(b) through (g),

(4) fuel, oil, and hydraulic fluid to be used and sampling intervals,

(5) oil consumption, and

(6) other component testing requirements, as applicable.

f. Post-test. Applicants should detail the inspection requirements for the engine "dirty" and "clean" inspections done at the end of the endurance test and following the complete engine disassembly.

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

Appendix 3. Endurance Test Cycle for Multiple Engine Tests

1. Regulatory basis for multiple engine tests.

a. Section 33.87(a)(3) allows for 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 under §§ 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 the applicant presents for certification.

b. For rotorcraft engines for which the applicant desires 30-second OEI and 2-minute OEI ratings, the applicant must repeat the test sequence defined in § 33.87(f) for 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 should not be less than 240 minutes.

c. Section 33.87(a)(3) also requires 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 under §§ 33.87(b) through (g), as applicable. If a parameter limit for a particular engine rating (for example, rotor speed for maximum continuous rating) is not defined, then 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 during the first test, the applicant demonstrates simultaneous core rotor speed limit and the gas temperature limit, the applicant should demonstrate 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 provided in paragraphs a. and b. below:

a. Part One. Run a standard 150-hour 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, the applicant must maintain:

(a) The fan rotor speed at the level associated with producing the test parameters in 2.a.(1)(b), (c), and (d) of this paragraph,

(b) The core rotor speed at or above the takeoff redline limit,

(c) The gas temperature at or above the takeoff redline limits, and

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

(2) During the maximum continuous parts of the test, the applicant must maintain:

(a) The fan rotor speed at the level associated with producing the test parameters in 2.a.(2)(b), (c), and (d) of this paragraph,

(b) The core rotor speed at the maximum permissible speed associated with the maximum continuous rating. If a maximum permissible rotor speed is not defined for the maximum continuous rating, then the maximum continuous test segments must be run to the rotor speed redline limit usually associated with the takeoff rating,

(c) The gas temperature at or above the rated maximum continuous limit. If a gas temperature limit is not defined for the maximum continuous rating, then the maximum continuous test segments must be run to the maximum gas temperature redline limit usually associated with the takeoff rating, and

(d) The thrust at or above the rated maximum continuous value.

b. Part Two. Re-run only the takeoff and maximum continuous parts of the cycle under 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 run time for Part Two is 87.5 hours, which consists of 18.75 hours at takeoff power, 45 hours at maximum continuous, and 23.75 hours at minimum idle.

(1) During the takeoff parts of the test, the applicant must maintain:

(a) The core rotor speed at the level associated with producing the test parameters in 2.b.(1)(b), (c), and (d) of this paragraph,

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

(c) The gas temperature at the takeoff redline limit, and

(d) The thrust at the rated takeoff thrust level.

(2) During the maximum continuous parts of the test, the applicant must maintain:

(a) The core rotor speed at the level associated with producing the test parameters in 2.b.(2)(b), (c), and (d) of this paragraph,

(b) The fan rotor speed at the maximum permissible speed associated with the maximum continuous rating. If a maximum permissible rotor speed is not defined for the maximum continuous rating, then the maximum continuous test segments must be run to the rotor speed redline limit usually associated with the takeoff rating,

(c) The gas temperature at the maximum continuous redline limit. If a gas temperature limit is not defined for the maximum continuous rating, then the maximum continuous test segments must be run to the maximum gas temperature redline limit usually associated with the takeoff rating, and

(d) The thrust 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.

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 applicant should include the modifications to the engine configurations and additional facility test equipment in the test plan. See appendix 2, paragraphs 2.b. and 2.c. 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 the high-pressure compressor or low-pressure compressor, or both.

d. Use of a variable area hot section nozzle.

e. Use of a variable area exhaust nozzle.

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

3. Operating the engine at triple redline conditions requires some nonstandard adjustments to the engine's 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. Section 33.87 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 restoring the type design cooling by modifying the compressor internal cooling flow circuit and increase the flow regulating orifice diameters.

c. For each proposed modification, the applicant should show in the test plan that the modification doesn't enhance the capability to withstand the rigors of the intended test conditions for that modified part or any other part affected by the modified part. For example, for the modification discussed in paragraph b. of this appendix, the applicant should show that:

(1) The 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 to withstand the rigors of the test for the hot section parts that are pressurized or cooled by this flow. The reconciliation for any such modified parts (i.e., non-type design) should be included in the reconciliation section of the test plan.

d. The modifications to the test engine configuration should still allow the engine to substantially conform to the final type design. In addition, the test engine, as modified, should 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 calibration and endurance test engine(s) must substantially conform to the final type design configuration, except for non-type design hardware approved by us. The applicant should make all inspections necessary to determine that the parts and components of the engine adequately conform to the drawings and specifications of the type design, and the engine is built to the assembly procedures specified in the type design. Our CM section inspectors or an FAA designee will conduct pre- and post-test conformity inspections. The applicant should also disclose any deviations (referred to as "nonconformances") of hardware, software, and components from the type design, and should provide acceptable evidence that these non-type design characteristics will not adversely affect the outcome or the integrity of the test. Finally, the applicant should report the data generated in pretest conformity inspections to us for our review. For reporting, the applicant should use the applicable reporting format. Refer to FAA Order 8110.4C for the type certification procedures related to conformity inspections.

2. Certain test hardware should be subject to preassembly conformity inspections by either our CM section inspector or the FAA-designated inspector. The inspectors should give particular attention to critical characteristics of critical and major parts that are subject to significant temperatures, distortion, cracking, fatigue, creep, and wear. This conformity inspection may vary, depending upon circumstances, and is based on a conformity inspection plan. Our pretest review of applicant's quality control procedures, inspection personnel experience, and inspection facilities capability will help to determine the extent of the required conformity inspections prior to the endurance test. Refer to FAA Order 8110.4C for conformity inspection requirements.

3. The type inspection authorization (TIA) is normally prepared by an FAA certification branch upon the applicant's request and is used to authorize conformity inspections to ensure that the test engine hardware conforms to the approved type design for certification. The TIA should identify the test engine configuration, including germane hardware for the test, the FAA-approved non-type design hardware, and the parts that are subject to preassembly inspection. We may also issue a TIA requiring special inspections on either the test engine or the test facilities when we find it necessary. For more information on the request for conformity inspection, TIA, statement of conformity, type inspection report, and related instructions, see chapter 5 of FAA Order 8110.4C.

4. The following example shows hardware that is germane to a demonstration under § 33.87 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:

a. Diffuser case,

b. Combustor section, which includes:

(1) Fuel nozzles;

(2) Inner and outer liners, inner and outer cowls, and domes;

(3) Inner and outer support rings; and

(4) Combustion case.

c. High-pressure turbine (HPT) section, which includes:

(1) Disks, vanes, blades, and side plates;

(2) Air seals and shrouds;

(3) Inner and outer supports, and outer case; and

(4) Cooling air manifold.

d. HPT to low-pressure turbine (LPT) transition duct,

e. LPT section, which includes:

(1) Disks, blades, and vanes;

(2) Air seals and shrouds; and

(3) Inner and outer supports and outer case.

f. Exhaust section, which includes:

(1) Turbine exhaust case,

(2) Tailpipe, and

(3) Gas temperature probe assembly.

Appendix 6. Test Reports Requirements

1. The certification test reports should contain sufficient data (for example, plots, tabulations, figures, and photographs) and discussions to show that the engine successfully completed all requirements of the calibration test, endurance test, and teardown inspection. In addition to test results and data analyses, the applicant should include analyses of engine faults, significant hardware deterioration, and corrective actions.

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, facility hardware, and special test facility hardware required, e.g., 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 show 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 test areas:

(1) Pre-endurance testing. Include discussions of the results of the pre-endurance engine and component test calibrations that were used to establish the baseline operating characteristics of the engine.

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

(a) Descriptions of any deviations from the prescribed cycle requirements. The applicant must show that these modified cycles are still in compliance with the regulation.

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

(c) Comparative tabulations (versus 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 under § 33.87(a)(7).

2 The minimum certificated parameter values obtained during each of the cycle segments showing 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 segment under § 33.87(b)(1) and one segment (first 5 minutes only) under § 33.87(b)(5), showing stabilization at or above the required values to be certificated prior to starting the timer for each part. This trace will also show the stabilization time for the gas temperature if the stabilization exception provided under § 33.87(a)(7) is used.

(d) Validation that any shortfall between a reduced thrust level that can be achieved and the required minimum physical thrust is inconsequential to the demonstration of 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 should show that vibration levels did not significantly change throughout the endurance test and are still at or below the allowable limits established for compliance with part 33 requirements. 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 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 applicant should disassemble, clean, and inspect the hardware. 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. If any component fails the acceptance test procedure (ATP), the applicant should describe any cause and corrective action and include a summary of the ATP results in the test report. Also, in the test report, identify any engine manual or return-to-service limits affected by the post-test hardware condition, and justify any changes made to these manual limits.

g. Data reporting.

(1) The applicant should present test data in either tabular or graphic formats, and in sufficient detail to show compliance with the test requirements. For example, tables or plots may include typical gas temperature, rotor speed, thrust or 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 pretest and post-test inspections in the test report.

h. Analysis.

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

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

(3) Fault and maintenance messages. The applicant should analyze any component that has an indicated maintenance message recorded during the endurance test. The applicant should also include the messages, cause, comments, and corrective action(s) in the report.

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

(5) Oil pressure and 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 should also show that satisfactory engine operation with the oil temperature at or exceeding both steady-state and transient maximum temperature limits has been successfully demonstrated.

(6) Fluid properties verification. The endurance 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. Disclose these test results that verify fluid properties in the report.

(7) Vibration signature analysis. The applicant should 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 for compliance with part 33 requirements.

(8) Engine anomalies. The applicant should analyze and explain:

(a) Engine power/speed oscillations/overshoots exceeding certification limits;

(b) Pressures/temperatures in the fuel system, oil system, rotors, casings, other structures, and accessory compartments exceeding transient certification limits;

(c) Unusual or high vibration signatures at synchronous and non-synchronous frequencies;

(d) Debris in oil or fuel systems exceeding field limits;

(e) Mechanical failures; and

(f) Wear or damage observed outside ICA limits.

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

Appendix 7. Endurance Testing for a Two-Minute Transient Overtemperature Limit Approval

1. Explanation.

a. Two-minute gas transient overtemperature approval for engine acceleration (see § 33.87(a)(3)). We previously approved a 2-minute gas transient overtemperature limit 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 subsequent to a large temperature excursion that causes a difference in the thermal growth rate of the engine cases and rotors and a decrease in engine cycle efficiency. This condition occurs most often when an engine is accelerated to takeoff from a cold state.

(1) For turbine engines installed on rotorcraft, the 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 temperature 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. The following are examples of flight conditions when the temperature overshoot may occur and the gas transient overtemperature limit could be used:

(a) Engine acceleration during first takeoff of the day.

(b) Engine acceleration from a cold soak low power condition.

(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 transient overtemperature 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 transient overtemperature. However, since the transient overtemperature 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 transient overtemperature or the 5-minute steady-state temperature limits, or both.

2. Guidance.

a. For approval of gas transient overtemperature limits greater than 30 seconds and less than or equal to 2 minutes under § 33.87(a)(3), the applicant must demonstrate the proposed limit value and duration for all test periods at takeoff thrust or power condition in § 33.87. This should include the running time of all 30-second periods at takeoff power or thrust in § 33.87, unless the exception allowance for gas temperature and oil inlet temperature under § 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 transient overtemperature limit as part of the 5-minute rated takeoff maximum permissible temperature limit, the following apply:

(1) For the test run under § 33.87(b), the applicant should 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 transient overtemperature limit. We might 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 TCDS would then specify a 2-minute transient overtemperature out of a 5-minute maximum permissible gas temperature limit for the takeoff rating as follows:

(a) Maximum permissible gas temperature limit for takeoff (5 minutes).

(b) Maximum permissible gas temperature limit for takeoff (2-minute transient overtemperature out of a total of 5 minutes).

(c) A note that indicates that the engine must produce rated takeoff thrust or power within both, the 2-minute transient overtemperature and the 5-minute steady-state redline temperature limits, or it should be removed from service for maintenance.

(3) For the approval of the 2-minute gas transient overtemperature limit, the applicant must also comply with the test requirements of §§ 33.27 and 33.88 using the 2-minute gas transient overtemperature value as the maximum steady-state operating temperature limit.

(4) For the approval of a gas transient overtemperature limit that exceeds 2 minutes, the applicant must demonstrate the transient overtemperature value for the entire 18.75 hours of running time at takeoff thrust or power.

Appendix 8. Endurance Test for Engine Certification and Showing of Compliance for Engineering Changes

1. The endurance test is an essential part of all engine type certifications. The test may also be used to show compliance for engineering changes introduced by repairs and PMA applications. We discuss acceptable means of compliance with § 33.87 for engine type certification and major design changes in the following paragraphs.

a. New type certificate. Run the endurance test as prescribed in §§ 33.87(a) through (g), as applicable, i.e., standard 150-hour endurance test, with no deviations.

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

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

(2) The engine is a derivative model with major design changes, and the same or lower ratings and 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 show compliance for the proposed hardware changes.

(3) The engine is a derivative model with major design changes, and the same or lower ratings and operating limitations, and for which we have determined that a repeat demonstration of the endurance test under §§ 33.87(b) through (g), as applicable, is needed to show compliance for 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 test under § 33.87.

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

c. Supplemental type certificate (STC) and amended STC. The applicant should identify the effects of the major design change on the validity of the endurance test run during the engine type certification. Compliance with all subparagraphs of § 33.87(a) is required. Our certifying office will determine which subparagraphs of § 33.87(a) are affected by the proposed design changes and require reevaluation by test. The certifying office will also determine which subparagraphs have existing data from a test completed under § 33.87 for which compliance findings by similarity can be made. When the major design change requires a repeat demonstration of § 33.87, the applicant should run the applicable endurance test cycle prescribed in §§ 33.87(b) through (g), with no deviations.

Appendix 9. Rotorcraft Operation with OEI Ratings and Endurance Test

1. Endurance Test for 30-second OEI and 2-minute OEI Ratings.

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

b. In the event of an engine failure at the critical decision point (CDP) of an aircraft during takeoff or landing, a short burst of very high power, referred to 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 of 2 minutes and at 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 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 2-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 under § 33.87(b), (c), (d), or (e).

2. Endurance Test for 2½-minute OEI Rating.

a. The 2½-minute OEI rating power is intended for the engine to perform similar functions as 30-second OEI and 2-minute OEI ratings in an OEI flight condition for a rotorcraft, but at a generally lower power level relative to these two ratings. Similarly, the engine rating structure for a rotorcraft having 2½-minute OEI is typically selected from one of the following 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 endurance test prescribed in § 33.87(e) applies to the above rating structures.

3. The Difference Between the OEI Ratings.

a. In rotorcraft operation, 30-second OEI and 2-minute OEI ratings perform very similar functions as 2½-minute OEI ratings. The significant difference between them is the limited use in service with mandatory inspection and maintenance actions for 30-second OEI and 2-minute OEI power ratings use. 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 be unavailable for further use.

b. 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:

(1) The requirement for teardown inspection for a 2½-minute OEI rating after an endurance test under § 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.

(2) The requirements for teardown inspection for 30-second and 2-minute OEI ratings under § 33.93(b) are that each engine part may exhibit deterioration in excess of that permitted under § 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 10. Accumulated Endurance Testing Times for § 33.87(e)

1. The endurance tests under § 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 "Guidance" section of § 33.87(e).

(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 the three schedules are found in table 3, which represents the rating combinations in paragraph 1 above.

Table 3. Accumulated Test Times for Each Rating Combination Under 33.87(e)

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

* 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 11. Teardown Inspection Requirements—Dirty Inspection and Clean Inspection

1. The FAA's CM section inspector, project engineer, or authorized designees should witness the teardown inspection. Refer to Order 8110.4C paragraph 5-14 for the teardown inspection requirements. The teardown inspection consists of two parts—a dirty and a clean inspection. Applicants should 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. At a minimum, the applicant should note the items listed below, and our CM section inspector should verify that the appearance of subassemblies and parts during the teardown is carefully noted.

(1) Component's adjustment setting and functioning characteristics not within the limits established and recorded at the beginning of the endurance test;

(2) Any abnormal indication of leaks in valves, seals, or fittings;

(3) Indications of excessive or lack of lubrication;

(4) Excessive coking;

(5) Metal or foreign particles in the oil screens or passages;

(6) Sticking or broken parts;

(7) Lack of freedom of moving parts;

(8) Excessive breakaway torques;

(9) Chafing, fretting, or other degradation of electrical wiring harnesses or grounding straps;

(10) Degradation of electrical bonding resistance at critical components (e.g., Full Authority Digital Engine Control, fuel metering unit, variable geometry actuators, and speed sensors);

(11) Distortion or damage to mounting hardware used to install components to engine structures; and

(12) Any other condition that may not be noticeable after complete disassembly and cleaning.

b. Clean inspection

(1) Visual inspection. Thoroughly clean all engine parts and subassemblies.

(a) Visually inspect all engine parts for indications of galling, metallic pickup, corrosion, distortion, interference between moving parts, and cracks;

(b) Check parts for discoloration that may be due to excessive heat or lack of lubrication;

(c) Give special attention to bearings, gears, seals, or other rotating parts; and

(d) Inspect hot section parts for indications of cracking, overheating, or burning.

(2) Nondestructive inspection. Inspect highly stressed engine parts for cracks or incipient failures using 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.

3. The applicant should submit the inspection report, as verified by our CM section inspector, as an attachment to the Conformity Inspection Record, FAA Form 8100-1. The applicant should include the inspection results in this report, giving a comprehensive description of all defects, failures, wear, or other unsatisfactory conditions, including photographs, as required. The CM section inspector should ensure that the applicant identified and retained all questionable parts in safe storage for review, if requested.

Appendix 12. Historical Background for the Calibration Tests, Endurance Tests, and Teardown Inspection Requirements

1. General.

a. The basic requirements under § 33.87 regarding test cycles and testing at maximum thrust, power, torque, redline rotor speeds, and engine turbine gas temperatures have remained substantially the same since their introduction in 1958 and through amendment 2 of part 13 of the Civil Air Regulation (CAR), despite several regulatory reviews. 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.

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

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

a. CAR part 13, effective March 5, 1952. The Civil Aeronautics Board adopted a revised CAR part 13, on January 28, 1952. The Board promulgated the previously effective CAR part 13 in 1941. Part 13 remained substantially unchanged until 1952, and represented the first time turbine-type engine certification rules were included in the regulations. The Board designated general block tests, calibration tests, and a 150-hour endurance test for turbine engines as §§ 13.250, 252 and 254, respectively, in part 13. The technical content of the calibration test was similar to Federal Aviation Regulation (FAR) 14 CFR part 33.85(a), except that the CAR part 13 did not address compressor air bleed for the test. The CAR part 13 endurance test consisted of 30 run periods of 5 hours each, as specified by the test schedule. This endurance test resembled today's FAR part 33.87(b)(1), but it used 91 percent takeoff, and 90 and 75 percent maximum continuous power or thrust test runs instead of §§ 33.87(b)(2) through 33.87(b)(4). Sections 33.87(b)(2) through 33.87(b)(4) today specify the testing at maximum continuous, takeoff, and incremental cruise power or thrust. The CAR part 13 teardown inspection under § 13.256 required a complete engine disassembly and detailed inspection of the tested engine to check for fatigue and wear.

b. CAR 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 thrust," respectively, which made these two essentially the same as the FAR §§ 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.

(c) The addition of maximum gas temperature and oil temperature requirements at all engine rating runs during the test, which is same as the equivalent requirements in § 33.87(a)(7).

c. CAR part 13, amendment 13-2, effective May 17, 1958. This amendment revised the specification of power and 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. CAR 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 engines used in rotorcraft. The technical content of this new schedule is essentially the same as the FAR part 33.87(c), "Rotorcraft engines for which a 30-minute OEI power rating is desired."

e. CAR part 13, amendment 13-6, effective April 22, 1964. This amendment established a 2½-minute power rating for a one engine inoperative (OEI) event at any instant after the start of takeoff for multi-engine rotorcraft. This 2½-minute power rating 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 the same as § 33.87(e), except:

(1) Section 33.87(e)(2) allows three OEI rating combinations for rotorcraft performance needs, while the CAR § 13.254(c) allowed only the following option (b). The options allowed by FAR § 33.87(e)(2) are:

(a) 2½-minute OEI/maximum continuous,

(b) 2½-minute OEI/30-minute OEI, and

(c) 2½-minute OEI/continuous OEI ratings.

(2) Section 33.87(e)(2) requires that the last 5 minutes of the 30-minute OEI in one of the endurance test cycles be run to 2½-minute OEI power, while the CAR § 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.

3. 14 CFR, part 33 – Airworthiness Standards: Aircraft Engines.

a. Part 33, effective February 1, 1965.

(1) The new 14 CFR part 33 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 the CAR part 13, except for an additional requirement that the engine power control is 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 the CAR part 13, except for minor editorial differences.

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

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 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 in response to the increasing complexity of airframes, engines, and their interfaces. This amendment added § 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. Section 33.87 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 the 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 a 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 the endurance test.

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

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

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

(c) A new requirement was added to specify that the rated 2½-minute OEI power must be applied during the last 25^{th} cycle of the endurance test. Specifically, the 2½-minute OEI power must be applied during the last 5 minutes of the 30-minute run for the rated 30-minute OEI.

(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 use. 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).

f. Part 33, amendment 25, effective October 17, 2008. This change amended the endurance test and tear down inspection requirements for certain OEI ratings. This amendment was the result of a harmonization effort of a working group comprised of representatives of the FAA, the Joint Aviation Authorities (JAA), Transport Canada, and industry. The European Union Aviation Safety Agency (EASA) subsequently adopted these new requirements as part of its Certification Specifications for Engines.

(1) Revised § 1.1, General definitions, for all rated OEI powers by adding a second condition, an engine shutdown, to the failure condition that defines an OEI. Also revised the use for the 2½-minute OEI rating from “a period of use” to “periods of use” to be consistent with the usage definitions of 30-second OEI and 2-minute OEI ratings.

(2) Revised § 33.87(a)(6) to allow the applicant to run the tests under §§ 33.87(f)(1) through (f)(8) without loading the accessory drives and mounting attachments if the applicant can substantiate that the durability of any accessory drive or engine component is not significantly affected and if the equivalent power is added to the output drive shaft.

(3) Revised § 33.87(a)(5) to exempt engines with 30-second and 2-minute OEI ratings from testing with maximum air bleed if the applicant can show by testing, or analysis based on testing, that the validity of the endurance test is preserved.

(4) Added a requirement that the test schedule for 30-second and 2-minute OEI ratings in § 33.87(f) be run continuously without stopping.

(5) Clarified the test schedule in § 33.87(f)(4) related to 30-second and 2-minute OEI ratings.

(6) Revised the test schedule in § 33.87(c) related to 30-minute OEI rating to agree with the schedule in EASA’s certification specifications for engines. The result harmonizes the endurance test schedule for engines with a 30-minute OEI rating.

(7) Clarified the idle condition of § 33.87(f)(8) as flight idle.

(8) Revised § 33.93(b)(2) by replacing the parts or components identified as, “mounts, cases, bearing supports, shafts, and rotors,” with, “the engine,” to emphasize that after the test, the applicant needs to inspect and consider deterioration of any engine component that could affect the structural integrity of the engine, not just those listed above.

g. Part 33, amendment 30, effective November 2, 2009. This amendment added the transient engine overtorque and maximum engine overtorque. This amendment harmonized FAA and EASA standards and simplified airworthiness approvals for the import and export of turbopropeller and turboshaft engines with free power turbines.

(1) Added in § 1.1, General definitions, the maximum engine overtorque.

(2) Added new engine limitations in § 33.7(16) for transient engine overtorque and § 33.7(17) maximum engine overtorque for turbopropeller and turboshaft engines incorporating free power turbines.

(3) Added new section, § 33.84, engine overtorque test that contains requirements for testing performed under § 33.87 endurance test.

(4) Revised § 33.87(a)(8) by adding the transient engine overtorque.