U.S. Department of Transportation
Federal Aviation Administration

Memorandum

Subject: **INFORMATION**: Policy for 14 CFR §33.87, Endurance test.

Date: **[DRAFT - public comments]**

From: Manager, Engine and Propeller Directorate, Aircraft Certification Service

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Policy No. ANE-2000-33.87-R3[DRAFT]

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Manager, Chicago Aircraft Certification Office, ACE-115C
Manager, Propulsion Branch, ACE-118C
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1. PURPOSE.

a. This policy establishes a uniform approach for Aircraft Certification Offices (ACOs) to evaluate and approve a 2-minute gas temperature limit caused by:

- thermal mismatch of engine hardware; or
- flight conditions during acceleration to takeoff power.

b. This policy supersedes FAA policy number 2000-33.87-R2, "Policy for Determining Compliance to 14 Code of Federal Regulations (CFR) §33.87," issued April 21, 2000.

c. This policy applies to all classes of turbine engines governed by part 33.

2. BACKGROUND.

a. The FAA has been asked to consider a 2-minute gas temperature limit approval within the 5-minute time limit associated with the takeoff power or thrust rating established under §33.7, for certain engine operating conditions. This 2-minute approval addresses a condition in which a gas temperature overshoot occurs due to a decrease in turbine efficiency caused by a difference in the thermal growth rate of the turbine case and rotor. This condition is more pronounced when an engine is accelerated to takeoff from a cold state. When the turbine case and rotor temperatures reach steady state levels, this overshoot disappears.

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

(2) For turbine engines installed on fixed-wing aircraft, such overshoot excursions would not be expected to occur regularly during takeoff operation, due to the time spent from engine start, through push back and taxi, to takeoff. However, the acceleration of turbine engines on a fixed-wing aircraft from low Mach number during hot day conditions, such as certain corner points of the flight envelope or aircraft go-around operation, may result in the gas temperature overshoot due to the aircraft inlet ram effect and the operation of a hot soaked engine.

b. The FAA will consider proposals for a 2-minute gas temperature overshoot limit within the 5-minute maximum steady state gas temperature time limit proposed for the takeoff power or thrust rating. The 2-minute limit addresses the gas temperature excursion during engine acceleration from a cold state, in which the maximum differential of hardware growth between engine outer case and rotor occurs, which is about 60 seconds from start for most turbine engines. The additional 60-second duration is a margin to account for any variation of the temperature overshoot associated with engine design or other flight conditions in which an overshoot slightly longer than 60 seconds may occur.

(1) However, this 2-minute limit is not intended for normal everyday takeoff operation nor for allowing additional on-wing time due to engine deterioration from operation above certified steady state limits.

(2) An engine should be removed from an aircraft for maintenance whenever the engine fails to produce rated takeoff thrust or power within its certified 5-minute steady state temperature limit.

c. In reviewing §33.87(a)(3), the FAA has determined that the phrase, "must be 100% of the value associated with the particular engine operation being tested," may be applied to cover the proposed gas temperature overshoot. Therefore, the FAA has revised this policy to provide guidance for demonstrating a 2-minute gas temperature limit, in compliance with §33.87(a)(3), within the 5-minute time limit associated with the takeoff power or thrust rating. Paragraph 4.f. of this policy provides a means for demonstrating compliance through test for this additional 2-minute gas temperature limit and identifies regulations whose means of compliance would be affected by this policy.

3. HISTORY.

a. Recently, several engine manufacturers have proposed the incorporation of more service representative type tests in place of the endurance cycle defined for engines in §33.87. However, the intent of §33.87 is not to simulate in-service operation, but to require an accelerated severity test to demonstrate a level of engine operability and durability within the engine ratings and limitations.

b. Since the origination of endurance testing, the test cycles and operating limits requirements have remained virtually unchanged. Yet a review of recent and past data shows that the FAA has accepted various alternative approaches to the very specific requirements of this rule, some of which deviate too much from the rule to continue to be acceptable. For example, running the "more than one test" allowance of §33.87(a)(3) on multiple hardware sets instead of a compiled demonstration on one set of engine hardware is unacceptable.

c. On October 1, 1974, the FAA published Amendment 6 to part 33, which revised §33.87(a) and added subparagraphs (1) through (9) to update the requirements for turbine engines. For §33.87(a)(8), the need to develop requirements to evaluate transient overshoots was based on the type of engine control used on turbine engines at that time. Those controls were primarily proportional hydromechanical control systems, which exhibited transient overshoot characteristics due to limitations in the methods for gain compensation. Today's controls have technology that includes proportional plus integral systems, permitting a high gain and compensation in the control loop and minimizing transient overshoot characteristics.

d. The intent of §33.87(a)(8) is to define a method for certifying rotor speed and gas temperature transient overshoots associated with proportional hydromechanical control systems while conducting the endurance test required by §33.87. However, §33.87(a)(8) has been used inappropriately to substantiate limits for gas temperature exceedences of periods up to 120 seconds. There have also been cases in which transient limits greater than 30 seconds have been used as supplementary limitations for engine power-setting purposes. Specifically, §33.87(a)(8) is intended to evaluate rotor speed and gas temperature transient overshoots for periods of 30

seconds or less. Paragraph 4.e. of this policy restates the intent of §33.87(a)(8) and identifies how rotor speed and gas temperature limits, other than transient overshoots, may be certified.

e. Although it could be argued that the requirements of §33.87 are outdated, industry has accumulated over 39 years of service experience based on the successful completion of a §33.87 endurance test as part of the overall certification requirements of part 33.

4. POLICY STATEMENT. The following methods provide an acceptable means of compliance with §33.87 for the situations specified:

a. New Type Certificate. Run the standard 150-hour endurance test as prescribed in §33.87 with no deviations.

b. Amended Type Certificate. Run the standard 150-hour endurance test as prescribed in §33.87 with no deviations, unless the following applies:

(1) Derivative model with no or minor design changes and the same or lower ratings or operating limitations, such that the original 150-hour demonstration still applies.

(2) Derivative model with design changes and the same or lower ratings or operating limitations. These changes, if viewed individually or in combination, would have no impact on engine operability or durability within the approved ratings and limitations; data from the original test would fully substantiate the proposed changes.

(3) Derivative model with major design changes and the same or lower ratings or operating limitations, for which the ACO has determined that a repeat demonstration of the test prescribed in §33.87 is needed to substantiate the design change. Run the standard 150-hour endurance test cycle as prescribed in §33.87(b) through (f), as applicable, with no deviations. Compliance with all subparagraphs of §33.87(a) is required. The ACO will determine which subparagraphs of §33.87(a) are affected by the proposed changes and require reevaluation by test and which subparagraphs are covered by existing data from an applicable §33.87 test, from which compliance findings by similarity can be made.

(4) For all other cases, a standard 150-hour endurance test as prescribed in §33.87, with no deviations, is required. The above exceptions are based on the assumption that a 150-hour endurance test has been conducted on the original model or subsequent derivative model, in accordance with the requirements of §33.87, such that data from that previous test would apply. If this is not the case, the ACO should contact the Engine and Propeller Standards Staff to determine an acceptable approach for compliance.

c. Major Design Change. If the ACO determines that a major design change will require a repeat demonstration of §33.87, then the standard 150-hour endurance test cycle as prescribed in §33.87(b) through (f), as applicable, with no deviations, must be run. Compliance with all subparagraphs of §33.87(a) is required. The ACO will determine which subparagraphs of §33.87(a) are affected by the proposed changes and require reevaluation by test and which subparagraphs are covered by existing data from an applicable §33.87 test, from which compliance findings by similarity can be made.

d. Engine Operating Limitations.

(1) Section 33.87(a)(3) allows multiple tests if all limits associated with the engine operating condition (that is, takeoff, maximum continuous, one engine inoperative (OEI), etc.) being demonstrated cannot be held simultaneously. If multiple tests are necessary, the additional test(s) must be run in accordance with the prescribed test sequences of §33.87(b), (c), (d), (e), or (g), applicable to the operating condition being demonstrated, and must be run on the same engine hardware presented for certification. For example, for engines other than certain rotorcraft engines (§33.87(b)), testing the takeoff rating may require a second test to demonstrate the fan speed limit, if core rotor speed limit and gas temperature limit have been demonstrated simultaneously during the first test. The second test would run at fan rotor speed limit and gas temperature limit, simultaneously, in accordance with the test sequences defined in §33.87(b)(1), (b)(2)(ii), and (b)(5). This second demonstration would accumulate an additional 42.5 hours of testing, resulting in a total time of 192.5 hours on the same engine hardware for this endurance test.

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

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

(4) The limits included in the engine type certificate data sheet as required by §33.7 must be less than or equal to those demonstrated during the endurance test for each engine operating condition evaluated.

e. Transients.

(1) Section 33.87(a)(8) states that the transient conditions must be demonstrated during the acceleration cycles required by §33.87(b) through (f), as applicable. The following are the acceleration cycles of (b) through (f):

- (b)(1) and (b)(5);
- (c)(1), (c)(2) and (c)(5);
- (d)(1), (d)(3) and (d)(6);
- (e)(1) and (e)(2); and
- (f)(1), (f)(2) and (f)(6).

Advisory circular (AC) 33-2B describes a transient as a rotor speed or gas temperature value that exceeds the approved limit for a period of 30 seconds or less for transients associated with the takeoff, continuous OEI, and 30-minute OEI ratings. Transients associated with the 2.5-minute, 2-minute, and 30-second OEI ratings should be limited to very brief periods, on the order of 5 to 10 seconds maximum. These transient limits for rotor speed and gas temperature may not be used as supplementary limitations, regardless of their duration, for engine power setting purposes.

(2) After a detailed review of the requirements of §33.87(a)(8), the Engine and Propeller Directorate has concluded that §33.87(a)(8) is intended, and remains a suitable method, to evaluate rotor speed and gas temperature transient overshoots for periods of 30 seconds or less.

f. Two-Minute Gas Temperature Limit.

(1) To demonstrate a 2-minute gas temperature limit in compliance with §33.87(a)(3), the applicant must demonstrate the proposed gas temperature limit value for at least the first 2 minutes of each 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.

(2) For example, an applicant proposes a 2-minute gas temperature limit as part of the 5-minute limit proposed for rated takeoff. The applicant would be required to demonstrate 6 hours and 35 minutes of the 18.75 hours required by §33.87(b)(1), (b)(2)(ii), and (b)(5), at the 2-minute limit. The type certificate data sheet would then specify:

(a) A 2-minute and a 5-minute steady state gas temperature limit for the takeoff rating; and

(b) A note that indicates that:

(i) The 2-minute temperature limit (of the 5-minute takeoff time) is intended to cover engine temperature overshoot characteristics, which occur during engine stabilization at constant thrust.

(ii) The engine must produce rated takeoff thrust or power within its certified 5-minute steady state redline limits.

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

(4) For approval of a gas temperature limit that exceeds 2 minutes, the applicant must demonstrate the overshoot temperature value for the entire 18.75 hours, as defined in §33.87(b)(1), (b)(2)(ii) and (b)(5).

5. CONCLUSION AND RECOMMENDATIONS.

a. This policy:

(1) Does not preclude the endurance testing of the accessory gearbox or any accessory drive or mounting attachment on a separate rig as allowed in §33.87(a)(6);

(2) Does not prohibit the allowance of a 500-hour controlled flight test, as defined in AC 20-24B, as an acceptable alternative to the requirements of §33.87(a)(4) for fuels and lubricants; and

(3) Does not prevent the pursuit of an exemption in accordance with part 11.

b. Testing that the FAA has previously approved in support of §33.87 that falls outside the acceptable approaches provided in this policy has resulted in confusion and the ultimate rejection of that testing by the Joint Aviation Authorities (JAA) in support of Joint Aviation Requirements-Engines (JAR-E) 740. Presently, the requirements of §33.87 and JAR-E 740 are generally accepted as equivalent. Therefore, the Engine and Propeller Directorate strongly recommends that the applicant be informed that previous testing that falls outside the approaches in this policy should be coordinated with the JAA early in the program if JAA validation is desired. The JAA may determine that additional testing is required to comply with JAR-E 740.

c. The Engine and Propeller Directorate recommends the implementation of this policy upon receipt. Any applicant proposals outside the scope of this policy should be coordinated with the Engine and Propeller Standards Staff.