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

Advisory Circular

Subject: EXTENDED OPERATIONS (ETOPS) ELIGIBILITY FOR TURBINE ENGINES

Date: 1/21/10
Initiated by: ANE-111

AC No: 33.201-1

1. Purpose. This advisory circular (AC) provides guidance and acceptable methods, but not the only methods, for demonstrating compliance with the Extended Operations (ETOPS) eligibility requirements in accordance with Title 14 of the Code of Federal Regulations (14 CFR) part 33. Specifically, §§ 33.4, appendix A, A33.3(c), Instructions for Continued Airworthiness; 33.71(c)(4), Lubrication System; 33.90(b), Initial Maintenance Inspection; and 33.201, Design and Test Requirements for Early ETOPS Eligibility, are addressed by this AC.

2. Applicability

a. The guidance provided in this AC is directed to engine manufacturers, modifiers, foreign regulatory authorities.

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

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

3. Applicable Regulations.

a. Part 33, § 33.4, appendix A, A33.3(c), Instructions for Continued Airworthiness.

b. Part 33, § 33.71(c)(4), Lubrication System.

c. Part 33, § 33.90(b), Initial Maintenance Inspection.

d. Part 33, § 33.201, Design and Test Requirements for Early ETOPS Eligibility.

4. General. This AC provides guidance on acceptable methods of compliance to the applicable regulations. Compliance with these regulations does not result in an ETOPS type design approval for the engine model, but does provide type design eligibility for engines to be installed on ETOPS airplanes in accordance with § 25.1535. Compliance with these regulations is not necessary to obtain a type certificate for the engine model, but is required for an airplane/ engine combination to meet § 25.1535. For ETOPS eligible models, the Type Certificate Data Sheet (TCDS) for the engine should contain a note describing the model's ETOPS status.

5. Early ETOPS Eligibility - § 33.201.

a. General. The overall intent of § 33.201 is for engine manufacturers to demonstrate that their engine design minimizes the likelihood of an engine or propulsion system caused diversion. The rule applies to engines intended for installation in two-engine ETOPS airplanes that will be ETOPS-approved using the Early ETOPS method in part 25, appendix K, K25.2.1. Compliance with § 33.201, along with the maximum diversion time demonstrated, should be noted in the engine TCDS.

b. Section 33.201(a) Design Quality Process.

(1) This section requires that you use a design quality process that includes your proven best design and manufacturing practices, and knowledge obtained from field service lessons learned. The purpose of this requirement is to eliminate from your engine model known failure, malfunction, or design related maintenance error problems relevant to ETOPS. Such problems include loss of thrust control, in-flight shutdown (IFSD), or other power loss events that have occurred in your other relevant FAA type certificated engine models.

(2) You may show that your design complies with this section by showing that your design quality assurance process can eliminate from new models those causes of engine failures, malfunctions, and design related maintenance problems that occurred within your commercial engine experience base.

c. Section 33.201(b) Design Features.

(1) This section requires that your engine type design address known failures, malfunctions, and maintenance problems that have resulted in in-flight shutdown, loss of thrust control (LOTC) or other power loss, and that could affect ETOPS operations. Events occurring during taxi or maintenance ground runs must be included, if such an event could have occurred in-flight.

(2) We will apply a 10 year experience limit if you support your assessment with adequate historical data for that time period. If your database is inadequate, we will decide what additional data is required for the experience assessment of § 33.201(b), based on the following:

(a) Your level of experience in certifying engines installed on transport category airplanes,

(b) Your recent experience certifying new engines,

(c) Your design practices and manuals used in development of new engines, and

(d) Any other factors that you may choose to present to us.

Note: This additional or alternative data may go back farther than 10 years, and may also include any data necessary to show equivalent experience.

(3) You must also show how you prevented the problems identified in § 33.201(a) from recurring in your new engine model.

d. Section 33.201(c) Cyclic Endurance Test.

(1) You must subject your engine to a cyclic endurance test. This test utilizes a conservative test cycle to help identify problems or failures that might not otherwise occur when complying with the basic certification test requirements of part 33. You may conduct this test in any ground or altitude test facility acceptable to us. The test is generally conducted with the engine in the installed configuration [reference § 25.1535, appendix K, K25.2.2(d)], which requires coordination between the manufacturer and installer .

(2) Test Considerations. Table 1 provides guidance for several common situations for determining when an endurance test is required. New type certificates normally require a test. Amended type certificate actions may or may not, depending upon the level of similarity to existing models and the amount of related service experience accrued. For follow-on engine models, the following are important when deciding on the need for testing, to the extent that these items contribute to system dynamics or the vibratory signature of the engine:

(a) Assessing mechanical size or stiffness changes;

(b) Major structural changes;

(c) Changes in the dynamics of the engine;

(d) Changes to bearing spacing and arrangement;

(e) Changes to the number of structural frames;

(f) Changes to the engine mounting arrangement to the aircraft;

(g) Changes to external configuration hardware;

(h) Changes to the number of compressor or turbine stages;

(i) Changes to the diameter or mass of the fan;

(j) Changes to engine control system architecture (for example, supervisory to full authority type, or analog to digital);

(k) Changes to installation (for example, service bleed and power extraction); and

(l) New technology (for example, design, materials or manufacturing processes).

TABLE 1 - Engine Design and Installation Considerations for Cyclic Endurance Testing

SCOPE OF CHANGE	TYPE CERTIFICATE	RATINGS AND LIMITATIONS	BASIC ENGINE DESIGN FACTORS [2]	CYCLIC ENDURANCE TEST (§ 33.201(c))
New engine[1]	New	New	New	Yes
Derivative engine[3]	Could be new or amended	Either may be changed or unchanged and may be more severe	Could change, but not extensively	Yes, for the propulsion system of the aircraft if engine design factors[2] or system dynamics[4] change relative to baseline, such that the original test is not fully representative of the proposed model.
Major design changes[5]	No model changes	No change	No change	No

Note 1: Typically an engine model for which an application for a new type certificate is made in accordance with 14 CFR part 21. This model type is generally the first type in a new family/series of engines. However, for some programs, a new engine could be added to an existing type certificate.

Note 2: Engine design factors include, but are not limited to, mechanical size and stiffness, static structure (backbone), dynamics of engine, bearing arrangement, number of structural frames, mounting arrangement to aircraft, number of compression and turbine stages, and size and diameter of the fan, to the extent that these contribute to the system dynamics (see Note 4) of the engine.

Note 3: A derivative engine is a closely related follow-on model to an existing model family, and often involves new ratings and limits, product or technology improvements, minor or major design changes, and a new aircraft application. This model type is sometimes the first in a new series of models within an existing type certificate.

Note 4: System dynamics of the engine is the vibratory response signature (system critical frequencies and amplitudes). These can be a function of engine mass and stiffness, rotor speeds, and engine or aircraft mount and strut mass and stiffness.

Note 5: In general, major design changes following the initial ETOPS eligibility granting do not require a 33.201(c) cyclic endurance test, but do need to be evaluated for ETOPS suitability. For such changes, enhanced type certification work (other then a 33.201 cyclic endurance test) may be required to clearly show compliance with the applicable part 33 and part 25 requirements, and to show acceptable IFSD reliability for ETOPS operations. These major changes will be evaluated by the FAA on a case-by-case basis. The engine manufacturer should also coordinate with the installer concerning the propulsion system installation requirements for ETOPS. Therefore, major design change approvals should include a determination that the IFSD rates required by § 21.4(b) will be complied with in a service environment. For minor design changes, their scope is generally small compared to the baseline type design, and the normal type certification process adequately covers those changes for continued ETOPS eligibility.

(3) Maintenance. Maintenance performed while on test should be conducted in accordance with the Instructions for Continued Airworthiness (ICA), required under § 33.4. Validation of maintenance procedures for ETOPS significant systems are required under part 25, appendix K, and testing required under § 33.201 is normally subject to this requirement. The engine manufacturer should coordinate with the installer in this regard.

e. Section 33.201(c)(1) Test Cycle. The test cycle depends on the intended mission and aircraft application, as follows:

(1) Start-Stop Cycles.

(a) "Representative" service start-stop cycle, as used in the rule, is a representative mix of full rated and de-rated takeoff thrust missions that represent typical operations expected in the first two years of service for the specific model. The representative mission mix should consider airplane installation, operator and route structure effects. The various missions should be uniformly distributed over the course of the test. Your proposed test start-stop cycle should include the following flight profile segments: ground idle, taxi, takeoff, climb, cruise, descent (minimum idle), approach (approach idle and glide slope intercept), and landing (including thrust reverse if applicable for the installation). In addition to the noted flight profile segments, the test cycle should include engine start and shutdown. For engine shutdown, the main rotors speeds should not be greater than that due to windmilling rotation due to prevailing ambient wind conditions. Lastly, a minimum of 50 cold starts should be included in the test, where cold is defined as the engine being shutdown for a minimum of 3 hours.

(b) Your mix of rated thrust should include the maximum rated takeoff thrust, de-rated thrust as applicable, and maximum continuous thrust. By operating the engine from the minimum thrust to the maximum rated thrust, plus estimated use of de-rate thrust, your engine will be subjected to the full operating range expected for the airplane during the first two years of operation. Note the takeoff rating used for this test must be the highest takeoff rating for which ETOPS eligibility is sought for a family/series of engines. Any applicable thrust de-rates should be evaluated similarly.

(c) The test conditions must include typical engine bleed extraction (aircraft bleeds, anti-ice bleed, etc.), and power extraction (hydraulic loads, electrical loads, etc.) expected during the typical phases of flight operation. Approximately one-third of the 3000 test cycles should be performed with the engine anti-ice bleeds active if engine air bleed anti-ice systems are used. In developing the start-stop cycle profile, you must coordinate with airframe applicants to ensure the correct mission, thrust mix, bleeds, and power extractions are properly defined.

(d) Simulated Diversions. "Simulated diversions" as used in the rule means you must conduct three simulated diversions to the maximum diversion time (minutes) for which early ETOPS eligibility is sought at maximum continuous rated power or thrust (MCT). The simulated flight diversions must include typical engine bleed extraction (aircraft bleeds, anti-ice bleed, etc.), and power extraction (hydraulic loads, electrical loads, etc.) expected during a diversion. The simulated diversions should be approximately equally spaced apart during the endurance engine test; however, the last simulated diversion must be conducted within the last 100 cycles of the test. Note the MCT rating used for this test must be the highest MCT rating for which ETOPS eligibility is sought for a family/series of engines.

1. You must conduct the simulated diversions to the maximum ETOPS single engine diversion time sought (for example, 180 minutes, 240 minutes, and 270 minutes). The demonstrated diversion time must be described in the engine TCDS. The applicant should consider future operational service needs in choosing the ETOPS diversion test time.

2. The three simulated diversion cycles should include a 15 minute hold condition and a one minute go-around condition at the end of each test cycle. These additional conditions simulate the diversion profile assumed for ETOPS diversion route planning in § 121.646, and have been included in the ETOPS endurance test for past programs. The power levels for the hold and go-around conditions for this test are those associated with a typical one-engine inoperative condition.

3. Note that § 121.633 requires a 15 minute margin for diversion route planning purposes (that is, flying time margin to ETOPS Alternate Airport). This requirement is based on the diversion profile assumed in § 121.646 (see Note 2 above), and will reduce the operator's allowable diversion time by 15 minutes relative to the airplane's ETOPS Significant Systems time limitations. Inclusion of the 15 minutes hold and one minute go-around conditions into the endurance test as recommended in Note 2 above, could allow an additional 15 minutes of type design diversion authority to be applied to the propulsion system at the airplane level, when applicable. The engine TCDS will describe the demonstrated diversion time equal to the time of the MCT runs in the simulated diversion cycles plus the run time at a hold power condition. The engine manufacturer should coordinate with the installer in this regard, to assure that the simulated diversion cycles are conducted to a diversion time consistent with that desired for service.

f. Section 33.201(c)(2), Unbalance and Vibration Endurance.

(1) The engine's low speed and high speed main rotors are to be independently unbalanced to induce vibratory excitation greater than 90% of the applicant's recommended field service maintenance vibration level(s). This element of the test will account for potential service use unbalance operation. The intermediate rotor of a three-spool engine is to be independently unbalanced to greater than 90% of your recommended production acceptance level. This element of the test will account for potential near maximum peak vibration levels of newly delivered engines.

(2) You must maintain these rotor unbalance levels for the duration of the endurance testing, unless we approve a modification that accommodates unplanned vibration levels above or below that specified in the rule. The 90% value as used above represents the minimum equivalent vibration level to be demonstrated throughout the duration of the test. We recommend that rotor unbalance at the start of the test be 100% of the associated vibration limit to minimize the potential for any excursions falling below the 90% minimum, or for the need of penalty runs.

(3) You must conduct periodic vibration surveys to verify the required levels of rotor unbalance are maintained throughout the endurance test. These surveys must be equally spaced (+/- 50 cycles) and conducted at not more than 500 cycle intervals. The surveys must cover the entire operating speed range for each rotor for the highest thrust rating covered by this test.

a. The survey peak vibration levels must be determined using a slow acceleration and deceleration run of the test engine (approximately two minute acceleration and two minute deceleration), covering the main engine rotor operating speed ranges (minimum idle to maximum rated thrust rotor speed range for the test day ambient conditions). The value of the peak vibration levels observed during these vibration surveys must meet the minimum specified in the rule. The maximum vibration level that is identified from the survey is defined as the peak tracked order vibration (that is, peak channel hold once per rev vibration component), and is used to calculate equivalent vibration level amplitude.

b. It is known that certain engine factors can vary over the course of the test, and this may influence the amplitude and speed of the peak vibration value between surveys. The objective is to record the absolute peak for each rotor regardless of the rotor speed at which it occurs for each survey. This approach assumes the slow acceleration and deceleration vibration survey method is representative of the vibratory response of the engine during the endurance test and typical service operation. If this slow accel/decel method is not representative of actual engine operation, you should propose another method for our acceptance. For example, some engines, especially when operated at higher imbalance levels, may exhibit short duration transient high vibration peaks during certain other accel/decel conditions.

c. Another survey objective is to identify the peak vibration level that would reliably be observed by a flight crew during normal operations. It is important that accurate peak engine vibration levels be displayed to the flight crew; however flight deck vibration display units and scaling may differ from the endurance test parameters. Any concerns that the flight deck display units/scaling would prevent the crew from observing a peak (for example, that used to assess the equivalent amplitude), should be communicated to the FAA and its implication assessed.

The following equation, based on accelerated testing damage accumulation, provides an acceptable means to determine equivalent vibration level:

$$A_{equiv} = [\Sigma\{C_i\,(A_i^{\alpha})/C\}]^{1/\alpha} \geq 0.9\ A_{target}$$

Where:

C_i = Number of cycles between vibration survey observations (target is 500).

A_i = Average vibration amplitude for a single test increment, determined by averaging the start and end maximum vibration amplitudes for a given increment $C_{i.}$

C = The target number of cycles (typically 3000).

α = Constant equal to 5.68 based on industry experience with metallic materials (may require adjustment for new or novel materials or applications). If new or novel materials are proposed for engine rotor components, the applicability of this exponent will need to be assessed. See appendix A for additional information.

A_{equiv} = A constant value of unbalance amplitude at which the entire test could be run to produce the same cumulative damage that actually occurred during the test.

A_{target} = Target amplitude (for example, units in velocity, displacement, gravitational forces, etc.) is 100% of the applicant's recommended field service maintenance or production acceptance vibration levels, as applicable.

(a) At the completion of the test, the value of A_{equiv} must be equal to or greater than 90% of the target amplitude (A_{target}) in order to meet the requirements of § 33.201(c)(2).

(b) Minor adjustments in the rotor unbalance may be necessary during the test in order to meet the required average vibration level. Alternatively, you may avoid engine disassembly to adjust rotor unbalance if, using a method acceptable to us, you modify your test start-stop cyclic content (but at least 3000 cycles must be run), or the number of cycles per rpm step (up or down) to accommodate a vibration level that is marginally below 90% or above 100% of the vibration level required in order to comply with § 33.201(c)(2).

(c) If A_{equiv} falls below 90% of the target amplitude, but above 85% at the end of the standard test, then the applicant can propose to run additional penalty cycles at the existing levels of rotor unbalance to complete the test. In running these penalty cycles, the test must accrue at least the cumulative damage that would have been accrued if the test had been conducted at 90% of the target vibration level. The engine may not operate below 85% of target vibration during the penalty runs under this method. Also under this circumstance, the manufacturer may propose to redefine the [100%] recommended field service limit as equal to the demonstrated $A_{equiv.}$ This would allow the test to be considered complete with no penalty cycles. Or, alternatively, a new test could be conducted.

(d) If A_{equiv} falls below 85% of the target amplitude at the end of the standard test, then the applicant can propose to run additional penalty cycles to complete the test. However, rotor unbalance must be increased to 90% or greater to complete the test under this method. In running these penalty cycles, the test must accrue at least the cumulative damage that would have been accrued if the test had been conducted at 90% of the target vibration level.

(e) If the engine vibration levels measured during the test are exceeding 100% of A_{target}, then the applicant may propose reduced dwell time for the remaining cycles so that the accumulated damage does not exceed the accumulated damage associated with running the test at 100% A_{target}. However 3,000 cycles total are still required. Any reduction in dwell time will be based on the calculation of accumulated damage, and can be claimed up to 105% of A_{target}. No credit will be given for damage accumulation for cycles conducted at vibration levels beyond 105% of A_{target}.

(f) The endurance test must include vibration endurance speed steps of 60 rpm increments of the high speed rotor's operating range for the equivalent of three million (3E6) cycles for steady-state rotor speed points that represent takeoff, climb, cruise, descent, approach, landing and thrust reverse (reference § 33.201(c)(3)); and 300,000 (3E5) cycles for rotor operational speed points in the range between flight idle and cruise (reference § 33.201(c)(4)) not covered above. A maximum 200 rpm incremental step size may be run with the accumulation of 10 million (1E7) cycles for § 33.201(c)(3) and one million (1E6) cycles for § 33.201(c)(4) requirements. The maximum and minimum rotor speed boundaries defining this operating range must be established on the limiting conditions for the representative mission mix of § 33.201(c)(1).

(g) The Maintenance Manual recommended vibration limits selected by the manufacturer and specified for this test should be based on test and past experience, and their suitability should be evaluated as part of the test plan review.

g. Section 33.201(d), Calibration Test. Prior to starting the endurance test, you must complete an engine calibration test. The purpose of the calibration test is to establish the engine's power and thrust characteristics, which must meet approved ratings within approved limits. You will later compare these pre-test values to the results of a second calibration test (reference § 33.201(e)(1)) conducted at the end of the endurance test.

h. Section 33.201(e), Post-Test Inspection and Acceptance Criteria. The endurance test engine inspection and acceptance criteria are:

(1) Section 33.201(e)(1), Takeoff Power or Thrust and Engine Operating Characteristics. The pre and post-test calibration results must be compared. To be within approved limits, the engine must be able to produce rated takeoff power or thrust at a sea level hot-day corner point condition, without exceeding any operating limits when operated in accordance with the operating instructions required by § 33.5. In addition, the engine surge and stall characteristics observed over the test duration must be consistent with the requirements of § 33.65. Lastly, established engine operating limits should not be exceeded at any time during the conduct of the test.

(2) Section 33.201(e)(2), Visual Inspection at Test completion. This inspection is intended to document the engine condition with respect to the on-wing serviceability limits in the ICA. The inspection will also establish a correlation between the assembled engine condition and the condition of subassemblies and individual parts following the post-test disassembly.

(3) Section 33.201(e)(3)/(4), Hardware Inspection and Condition Disassembled. Hardware inspections must be accomplished in accordance with your ICA submitted under § 33.4, and must also be evaluated with respect to your design quality process and lessons learned data (reference § 33.201(a) and (b)). Applicable ICAs for this inspection include the engine maintenance manual or section, and the engine overhaul manual or section, as identified in appendix A to part 33. Certain component maintenance manuals (CMM) may also apply.

(a) Hardware conditions that could result in loss of thrust control, in-flight shutdown, or other power loss within a period of operation before the component, assembly, or system would likely have been inspected or functionally tested for integrity while in service, are not acceptable. Hardware conditions (including those not serviceable per the ICA) that would not likely result in the above power loss events had the part remained in operation, may be acceptable.

(b) For unusual or unexpected outcomes, engineering judgment and experience are necessary to assess engine hardware condition. For example, apparently minor hardware condition anomalies could be a precursor to a potentially major hardware condition should the engine be subjected to more operational time and cycles, or a broader range of operating conditions. In addition, hardware distress caused by disassembly of the engine is not generally cause for failure of the test. Parts considered expendable at disassembly, to be replaced with new parts at re-assembly (for example, certain fasteners), are also not cause for failure of the test.

(c) Your ICA must be revised to address any hardware distress condition not previously included, but found as a result of the test.

(d) We will decide if your proposed hardware corrective action plan, if necessary, is acceptable.

6. Initial Maintenance Inspection Test - § 33.90(b). This section describes a method for utilizing the Early ETOPS § 33.201 test to show compliance with § 33.90, initial maintenance inspection (IMI). Section 33.90(b) is intended to support establishment of the IMI required by § 33.90, by allowing use of the test conducted in accordance with § 33.201. This method allows you to conduct a single test on one engine build to demonstrate compliance with both regulations. After completing the full number of test cycles required for an IMI test performed in accordance with § 33.90(a), applicants may interrupt the § 33.201 test to conduct a complete on-wing or other inspection acceptable to the FAA in order to show compliance with § 33.90 requirements. Please note that this method of compliance requires the § 33.201 test to be completed in its entirety prior to entry into service (EIS). If an interim IMI inspection is completed and the Type Certificate is issued, failure to complete the remaining portion of the § 33.201 test is non-compliant with § 33.90(b) requirements, unless otherwise approved by the FAA. An acceptable on-wing inspection must include, but is not limited to, the following:

a. Full borescope inspection of accessible gas path stages or areas of the fan, compressor, combustor, and turbine modules to the serviceable limits of the ICAs.

b. For engine equipped with electronic controls, observe and interrogate the system for fault messages and status messages, both current and previously recorded, to the serviceable limits of the ICAs.

c. Inspect all oil system chip detectors and filters for contamination.

d. Inspect all fuel system filters for contamination.

e. Test (for example, spectrographic analysis) a sample of main engine oil for contaminants that might indicate impending internal failure.

f. Conduct a complete visual inspection of the inlet, exhaust, and externals to the serviceable limits of the ICAs.

g. Conduct a power calibration to show the engine can produce rated power or thrust at a sea level hot-day corner point condition within approved limits.

h. The general pass/fail criteria are fully serviceable in accordance with the ICAs, unless otherwise accepted by us.

> Note 1: Paragraph 6 (above) provides guidance relative to § 33.90(b). For further information on the overall method of compliance, refer to AC 33.90-1, titled "Initial Maintenance Inspection (IMI), 14 CFR § 33.90, Test for Turbine Engines", dated March 4, 2004.

Note 2: Complying with § 33.90 via § 33.90(a) requires use of maximum ratings throughout the § 33.90(a) test. However, compliance via § 33.90(b) accepts the mix of ratings allowed under § 33.201.

7. Instructions for Continued Airworthiness - § 33.4, Appendix A, A33.3(c). This regulation requires that you include special engine condition monitoring procedures in the ICA maintenance manual if ETOPS eligibility is sought. Also, this regulation applies to all engine models to be installed in ETOPS airplanes, regardless of the number of engines installed or by what method the airplane will be approved for ETOPS. The special monitoring procedures must allow the flight crew to determine, prior to flight, that maximum continuous thrust and necessary bleed air and power extraction levels are available simultaneously, within approved limits, for the relevant engine inoperative ETOPS diversion. For two-engine ETOPS airplanes, you must demonstrate that your proposed procedures can predict if the required thrust, and bleed air and power extraction levels, are available for varying levels of engine deterioration and varying ambient conditions before we will grant ETOPS type design eligibility.

Note: The engine condition monitoring procedures required under this engine type design regulation do not define all the elements of a complete engine condition monitoring program that an operator may need to comply with under the operating regulations (for example, parts 121 and 135). The engine ICA should be clear in this regard.

8. Oil Tank Design § 33.71(c)(4). If ETOPS eligibility is sought, § 33.71(c)(4) requires that you design the oil tank to prevent a hazardous loss of oil if the tank cap is not installed or installed incorrectly. Also, this regulation applies to all engine models to be installed in ETOPS airplanes, regardless of the number of engines installed or by what method the airplane will be approved for ETOPS. A hazardous oil loss includes a loss that could affect the safety of any portion of an ETOPS flight, including diversion, had the cap installation error occurred on one or more engines. An oil quantity loss that might result in or require that engine power be maintained below MCT, or the engine to be shutdown, is considered a hazardous loss of oil. Note the intent is to prevent hazardous oil loss, not necessarily any oil loss (for example, a small quantity determined to be non-hazardous may be acceptable). The most common method to accomplish this is inclusion of a check or flapper type valve in the oil fill feature of the tank. Other methods may be acceptable, such as a pressure fill port or any other design feature that will prevent the siphoning of a hazardous quantity of oil overboard. Also, the rule is not intended to allow compliance by maintenance procedure; the necessary physical features or characteristics must be part of the oil tank or engine design, and should be shown to function per design intent. In addition, incorporation of an oil tank quantity sight glass would help reduce the number of oil tank cap removals in service, and would indirectly support the overall safety intent of this requirement. Manufacturers should consider such a feature. Lastly, the ICA should contain inspection instructions for the feature(s) used for compliance to this requirement, to ensure availability of these functions in a service environment when they are needed.

9. Engine Rating and Limits - § 33.7. For all ETOPS eligible models, a TCDS note should be included to indicate eligibility. For models that comply with § 33.201 for Early ETOPS, the note should also describe the demonstrated diversion time. A sample note for each situation is shown below:

> "Model xxx has complied with the requirements of §§ 33.4(A33.3(c)), and 33.71(c)(4), and is therefore eligible for installation on Extended Operations (ETOPS) approved airplanes. Note that ETOPS eligibility does not constitute airplane or operational level approvals necessary to conduct ETOPS flights."

OR

> "Model xxx has complied with the requirements of §§ 33.4 (A33.3(c)), 33.71(c)(4) and 33.201, and is therefore eligible for installation on Extended Operations (ETOPS) and Early ETOPS approved airplanes. The demonstrated diversion time is xyz minutes at MCT *plus 15 minutes at hold power**. Note that ETOPS eligibility does not constitute airplane or operational level approvals necessary to conduct ETOPS flights.
>
> *Note the hold condition run time if included in the simulated diversion cycles of the § 33.201 endurance test."

10. Reliability Reporting for Two Engine Airplanes - § 21.4(b).

a. Reporting**.** Section 21.4(b) applies to both airplane and engine type certificate holders with two-engine ETOPS fleets. Section 21.4(b)(1) requires each type certificate holder to investigate IFSD events and submit a periodic (monthly or quarterly as applicable) ETOPS report for each ETOPS two-engine airplane model type design approved for ETOPS. The report must be transmitted to the cognizant FAA aircraft certification office, and must contain the following information:

(1) IFSD rates (world fleet 12 month rolling averages; engine basic and total installed);

(2) IFSD reports for the period (descriptions/findings); and

(3) ETOPS fleet utilization data (operators, diversions, diversion time authority, hours/cycles as available, etc.).

b. The world fleet IFSD rates include all operations of the ETOPS-approved airplane/engine combination, not just ETOPS flights. The submitted IFSD rate information may combine multiple engine models within a distinct family that are installed on ETOPS airplanes, if concurred with by the FAA. The IFSD reports should include a description of the event and investigation results. Note that reporting under § 21.4 can be combined with § 21.3 reporting, at applicant discretion.

c. Section 21.4(b)(2) defines the 12 month rolling average total IFSD rates required for each level of ETOPS airplane type design approval. These IFSD rates are the same as required under part 25 (appendix K) for airplane ETOPS type design approval. This section also requires the type certificate holder to publish service information that will enable operators to maintain the required airplane/engine combination world fleet IFSD rates. Service information can take the form of Service Bulletins, Service Letters, All Ops Wires, etc., published as necessary.

Francis A. Favara,
Manager, Engine and Propeller Directorate
Aircraft Certification Service

APPENDIX A. Equivalent Amplitude Fatigue Exponent Determination

a. Discussion. The Equivalent Amplitude Fatigue Exponent has its origin in the S.S. Manson Method for Universal Slopes [(1)]. Manson demonstrated that the fatigue exponents for many metals could be averaged and used to develop a universal fatigue exponent approximating either the low or high cycle capability of metallic materials. Although Manson used the approach to develop generic fatigue exponents representing a broad range of metals, the approach has been demonstrated to be applicable to characterizing the fatigue exponent for individual materials too [(2)(3)]. When the fatigue exponent is combined with cumulative damage calculations, it can be used to assess accelerated fatigue tests [(4)]. These various authors suggest the fatigue exponent may range from 4 to 20 depending on material and whether high cycle or low cycle fatigue is being evaluated. These authors also indicate that metallic materials typically exhibit high cycle fatigue exponents in the range of 4-8. The FAA determined that 5.68 is an overall acceptable value covering a variety of currently used turbine engine metals over a range of R-ratios for high cycle fatigue. If an engine design departs significantly from the use of conventional metals, then a reevaluation of the exponent in accordance with the references below may be required.

1. Manson, S.S., "Interfaces Between Fatigue, Creep, and Fracture", NASA Technical Memorandum, NASA TM X-52189, 1966.

2. Lampman, S.R, et.al, "Fatigue and Fracture" ASM Handbook, Volume 19, 1996.

3. Delgado, I.R., G.R. Halford, B.M. Steinet & C.M. Rimnac, "Strain-Life Assessment of Grainex Mar-M 247 for NASA's Turbine Seal Test Facility".

4. Fackler, W.C., "Equivalence Techniques for Vibration Testing", SMV-9, Shock and Vibration Information Center, US DoD, 1972.