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

Advisory Circular

Subject: TURBINE ENGINE CONTINUED ROTATION AND ROTOR LOCKING
Date: 07/23/03
Initiated By: ANE-110
AC No: 33.74/92-1A
Change:

1. PURPOSE. This advisory circular (AC) provides guidance and acceptable methods, but not the only methods, for demonstrating compliance with the continued rotation and rotor locking requirements of part 33 of Title 14 of the Code of Federal Regulations (14 CFR part 33). This AC addresses both §§33.74 and 33.92 and refers to §33.17, Fire prevention, and §33.19, Durability. This AC revises AC 33.74/92, Turbine Engine Continued Rotation and Rotor Locking, issued 2/14/97.

2. APPLICABILITY.

a. The guidance provided in this document is directed to engine manufacturers, modifiers, foreign regulatory authorities, and Federal Aviation Administration (FAA) engine type certification engineers and their designees.

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. The FAA will consider other methods of demonstrating compliance that an applicant may elect to present. Terms such as “should,” “shall,” “may,” and “must” are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance in this document is used. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. On the other hand, if the FAA becomes aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation as the basis for finding compliance.

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

3. RELATED REGULATIONS.

a. Part 33. Airworthiness Standards: Aircraft Engines; §§33.17(a), 33.19(a), 33.74 and 33.92.

b. Part 29. Airworthiness Standards: Transport Category Rotorcraft; §29.903(c).

c. Part 25. Airworthiness Standards: Transport Category Airplanes; §25.903(c).

d. Part 23. Airworthiness Standards: Normal, Utility, and Acrobatic Category Airplanes; §23.903(e)(2).

4. BACKGROUND. On June 4, 1996, the FAA published Amendment 17 to part 33, which updated and modernized the technical requirements for the type certification of aircraft engines. A new regulation addressing continued rotation was incorporated to be consistent with the safety objectives of the airplane requirements of §§23.903(e)(2) and 25.903(c). The existing §33.92 was revised to remove a specific continued rotation requirement for supersonic engines and to clarify the existing rotor locking test requirement language. The guidance in this AC replaces the continued rotation and rotor locking portions of AC 33-2B, Aircraft Engine Type Certification Handbook, Paragraph 63, Windmilling Tests.

5. DEFINITIONS. For the purposes of this AC, the following definitions apply:

a. Continued rotation. Continued rotation refers to a condition in which any main rotating system in an engine continues to rotate after the engine has been shut down. Continued rotation can be caused by windmilling or mechanical effects, or a combination of both. Windmilling is the rotation of a non-operating engine due to the airflow-induced forces on the blades caused by the forward motion of the aircraft. Mechanical effects include, for example, drive shaft clutch drag in some multi-engine rotorcraft installations, which may result in continued rotation of the engine after it has been shut down.

b. Rotor Locking Device. A rotor locking device is a mechanical device that prohibits the rotation of the engine rotor(s) when the engine is shut down.

6. CONTINUED ROTATION. The safety objective of §33.74 is to ensure that an engine that continues to rotate after shutdown will not create a hazard to the aircraft. This objective implies a design requirement that non-hazardous basic failure conditions or events must not develop into a hazardous event over a sustained continued rotation period. Compliance to this requirement can be by test, analysis, or any method determined to be acceptable by the Administrator.

a. Applicability. The requirements of §33.74 apply to turbine engines installed in aircraft and rotorcraft.

b. Installation assessment. Test or analysis data used to demonstrate compliance should represent all planned or intended aircraft installations for the engine. The applicant may need to use conservative assumptions in conducting tests or analyses to assure that the baseline certification addresses all intended aircraft applications. A new test or analysis may be necessary if a future installation is more critical than those assumed in the original certification basis (for example, two rather than four engine installation differences; extended operations (ETOPS); etc.).

c. Failure conditions. In general, the applicant should address any failure condition resulting in continued rotation.

(1) These conditions include, but are not limited to, the following items and any associated collateral damage:

(a) Loss of rotor centerline support (for example, main bearing failure, bearing support failure, fusing of frangible main bearing designs, etc.).

(b) Engine rotor airfoil loss and resulting effects, including §33.94 fan and turbine blade out conditions.

(c) Complete loss of engine oil supply (quantity or pressure).

(d) Basic non-hazardous in flight shut down (IFSD) (for example, fuel starvation).

(e) Supersonic to subsonic transition flight conditions (if applicable).

(f) Supersonic flight conditions (if applicable).

(2) Certain engine basic failures or events are not generally under consideration, such as main rotor structure failures (for example, disks, spacers, seals, and shafts), unless those failures are considered initially non-hazardous and would likely result in continued rotation of the engine. Failure of a rotor locking device is also not generally considered under §33.74. Also, there is no intent to consider airframe structure failures (for example, slat/flap ingestion) or significant airframe foreign object sources (for example, lavatory ice or wing/radome ice ingestion), because they are beyond the scope of part 33 certification. Section 33.74 is also not intended to evaluate the effects of engine continued rotation on other aircraft structures, systems or the flight deck. Note: For information on continued rotation engine unbalance requirements for aircraft see §§23.903(e)(2), 25.903(c), 29.903(c) and AC 25-24.

d. Operating conditions. The applicant should make an assessment of the flight conditions expected to occur during continued rotation operations. The assessment should consider, but is not limited to, the following:

(1) The maximum exposure time for continued rotation for an individual event and for the life of an engine. This determination must not be based on the probability of occurrence as a function of flight phase. The assessment should consider special operations such as ETOPS and should cover the possible diversion time of the airplane during such operations. A minimum diversion time of one hour should be assumed for all aircraft applications. If the maximum diversion time established exceeds one hour, a diversion flight of a duration equal to the maximum diversion time for the application should be used.

(2) Turbine rotor(s) rotational speeds within the one-engine inoperative flight envelope, assuming realistic aircraft flight conditions. This should take into account significant flight phases (climb, cruise, descent, approach, and landing) and consider the effect of engine damage on continued rotation rotor speeds.

(3) Unbalance levels as they apply to the failure condition being evaluated.

7. PASS/FAIL CRITERIA.

a. Section 33.74 states that engine continued rotation after shutdown must not result in any condition identified in §33.75(a) through (c) over the continued rotation period. The following are those conditions, which are considered hazardous to the aircraft:

(1) Catch fire;

(2) Burst (release hazardous fragments through the engine case); and

(3) Generate loads greater than those ultimate loads specified in §33.23(a).

b. Additionally, no other unsafe conditions should result from continued rotation, as specified in §33.19(a) (for example, failure of the main engine mount system). The hazard assessment should consider both the initial event and the duration of the continued rotation.

8. OTHER CONSIDERATIONS.

a. Fire hazard. Protection against fire is especially important during extended continued rotation periods. For example, rotor continued rotation speeds coupled with high unbalance levels could produce high stress levels in engine parts at sub-idle natural frequencies. Another possible consequence of a continued rotation unbalance condition is “rubbing” of titanium rotor and stator components. The applicant must assess the design against the fire protection criteria as required under §33.17(a) and noted in paragraph 7 of this AC.

b. Fatigue assessment. The applicant should perform a fatigue assessment for an installed engine over the assumed diversion profile. This assessment should account for transient exposure to peak vibrations (for example, initial event), as well as sustained exposure to vibration loads over the continued rotation period. Average material properties may be used. For each component being evaluated, the applicant should show the accumulated fatigue damage to be less than or equal to the fatigue damage to failure of the component, so that the conditions of §33.75(a) through (c) do not occur over the continued rotation period. No other unsafe conditions should occur, as specified by §33.19(a) (for example, fatigue failure of the main engine mount system).

c. Analysis methodologies. Analysis techniques must be able to provide sufficient detail to determine the continued rotation loads on the installed engine. These techniques must have shown the capability to predict dynamic results for the identified continued rotation conditions. The applicant may need to use conservative assumptions regarding installation to cover multiple installations.

d. Engine modeling. Any models used should:

(1) Have sufficient detail to accurately conduct transient and steady state analysis.

(2) Include all major static and rotating components of the engine.

(3) Provide for representative connections at the engine-aircraft interfaces.

e. Loads. The applicant should determine loads on engine structure by test, validated analysis, or both. The steady and vibratory loads should be determined for the significant phases of flight identified in paragraph 6.d.(2) of this AC and should consider the range of continued rotation frequencies for the various failure events, continued rotation periods, aircraft accelerations, and ambient temperature variation.

9. ROTOR LOCKING. The engine manufacturer has the option to incorporate a rotor locking device into the type design of the engine to comply with the safety objective defined in §33.74. Activation of the device stops and prevents subsequent continued rotation of the engine rotor(s) during flight when the engine is not operating. The device becomes part of the engine type design and should be subjected to the same test criteria as other components in the engine. In addition, the rotor locking device should satisfy the operational and endurance test requirements identified in §33.92 when the engine is subjected to the environmental conditions that result in the maximum rotational torque. The assessment of the maximum rotational torque should consider both damaged and undamaged engine rotors.

a. Reliability. The rotor locking device is expected to be used infrequently. Therefore, the applicant should show that under normal engine operating conditions the device would not deteriorate beyond serviceable limits enough to fail to perform the intended function.

b. <u>Design criteria</u>.

(1) The rotor locking device should be designed so that the flight crew is able to unlock the engine rotor(s) to initiate engine restart attempts. In the event that these attempts are unsuccessful, the flight crew should be able to relock the engine rotor(s).

(2) The applicant should consider the effect on continued safe flight and landing in the event of an uncommanded activation of the rotor locking device in flight. In addition, the applicant should consider the single failure and engine isolation provisions of the appropriate aircraft regulations.

(3) The applicant should evaluate environmental effects on rotor locking device performance for the engine operating envelope.

Original signed by F.A.F. on 7/23/03

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