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Federal Aviation Administration

Memorandum

Date:	October 28, 2010
To:	Manager, Chicago Aircraft Certification Office, ACE-115C
From:	Manager, Engine & Propeller Directorate, ANE-100
Prepared by:	John Tallarovic, ACE-118C
Subject:	INFORMATION: Equivalent Level of Safety (ELOS) Finding for Williams International's Model FJ44-4A Engine, FAA Project No. AT6306CH-E
ELOS Memo #:	8040-ELOS-09-NE03
Regulatory Ref:	14 CFR Part 33, § 33.83 Vibration Test

This memorandum informs the Chicago Aircraft Certification Office of an evaluation made by the Engine and Propeller Directorate on the establishment of an equivalent level of safety (ELOS) finding for the FJ44-4A engine.

Background

Williams International (WI) has proposed to show compliance to 14 CFR § 33.83 Vibration Test (Amendment 17) by a combination of vibratory test surveys of FJ44-4A hardware, tests on similar engines, and analysis as the method of compliance. Since this is not direct compliance via a vibration survey test of the FJ44-4A, an equivalent level of safety (ELoS) is required.

Applicable Regulation(s)

14 CFR § 33.83 Vibration Test
(a) Each engine must undergo vibration surveys to establish that the vibration characteristics of those components that may be subject to mechanically or aerodynamically induced vibratory excitations are acceptable throughout the declared flight envelope. The engine surveys shall be based upon an appropriate combination of experience, analysis, and component test and shall address, as a minimum, blades, vanes, rotor discs, spacers, and rotor shafts.

(b) The surveys shall cover the ranges of power or thrust, and both the physical and corrected rotational speeds for each rotor system, corresponding to operations throughout the range of ambient conditions in the declared flight envelope, from the minimum rotational speed up to 103 percent of the maximum physical and corrected rotational speed permitted for rating periods of two minutes or longer, and up to 100 percent of all other permitted physical and corrected rotational speeds, including those that are overspeeds. If there is any indication of a stress peak arising at the highest of those required physical or corrected rotational speeds, the surveys shall be extended sufficiently to reveal the maximum stress values present, except that the extension need not cover more than a further 2 percentage points increase beyond those speeds.

(c) Evaluations shall be made of the following:

(1) The effects on vibration characteristics of operating with scheduled changes (including tolerances) to variable vane angles, compressor bleeds, accessory loading, the most adverse inlet air flow distortion pattern declared by the manufacturer, and the most adverse conditions in the exhaust duct(s); and

(2) The aerodynamic and aeromechanical factors which might induce or influence flutter in those systems susceptible to that form of vibration.

(d) Except as provided by paragraph (e) of this section, the vibration stresses associated with the vibration characteristics determined under this section, when combined with the appropriate steady stresses, must be less than the endurance limits of the materials concerned, after making due allowances for operating conditions for the permitted variations in properties of the materials. The suitability of these stress margins must be justified for each part evaluated. If it is determined that certain operating conditions, or ranges, need to be limited, operating and installation limitations shall be established.

(e) The effects on vibration characteristics of excitation forces caused by fault conditions (such as, but not limited to, out-of balance, local blockage or enlargement of stator vane passages, fuel nozzle blockage, incorrectly schedule compressor variables, etc.) shall be evaluated by test or analysis, or by reference to previous experience and shall be shown not to create a hazardous condition.

(f) Compliance with this section shall be substantiated for each specific installation configuration that can affect the vibration characteristics of the engine. If these vibration effects cannot be fully investigated during engine certification, the methods by which they can be evaluated and methods by which compliance can be shown shall be substantiated and defined in the installation instructions required by Sec. 33.5.

Regulation(s) requiring ELOS finding

14 CFR § 33.83 Vibration Test

Description of compensating factors or alternative Methods of Compliance (MoC) which allow the granting of the ELOS finding (including limitations need for equivalency).

There are six compensating factors that enable an ELOS finding to be made, as follows.

1. The FJ44-4A engine is similar to other engines that were tested.
2. Component vibratory stresses are similar between tested engines.
3. Component steady stresses are similar between tested engines.
4. Engine cycle and operating conditions are similar between tested engines.
5. The material high cycle fatigue (HCF) strength is the same between tested engines.
6. Component details that do not have exact similarity to the tested engine have been adequately reconciled such that adequate similarity can be established.

Each of the compensating factors is further discussed below.

1. Similarity: The -4A engine is similar to other WI engines that were used as the test basis for compliance with § 33.83. Specifically, the similarity is with regard to:

a. Geometry of the components identified in § 33.83(a) and the engine assembly or configuration affecting those components' vibratory stresses, such as upstream and downstream flowpath geometry,
b. The test conditions maintained during vibratory surveys, including thrust, and mechanical and corrected speeds as required by § 33.83(b), and
c. The engine operating characteristics with regard to customer bleeds, accessory loading, and the most adverse inlet airflow distortion required by § 33.83(c)(1)

2. Vibratory stresses equivalency: The vibratory stresses equivalency is demonstrated by analysis and validated by both engine and bench tests performed on the -4A engine and a similar engine.

3. Steady stresses equivalency: The steady stresses equivalency is demonstrated by analysis and validated by both engine and bench tests performed on the -4A engine and a similar engine.

4. The engine cycle and operating conditions: WI provided substantiation that -4A engine components are similar to those of another engine for the declared engine operating conditions identified in § 33.83(b) and (c). Of particular significance are those operating conditions that affect the component temperatures, pressures, and excitation forces. The operating temperatures are required by § 33.83(d); the effects of airfoil pressures and excitation forces are seen in the resulting vibratory amplitude responses.

5. HCF fatigue strength: The HCF material properties are shown to be the same between the -4A engine and similar engines.

6. While the components that are the focus for this rule (blades, stators, and disks) have exact similarity, the overall engine needs to be considered as a system. The engine system behavior may impact the vibratory response of blades, stators, and disks. In considering the entire system, some components may not be exactly similar to components on the engine models being tested. The impact on the overall system response of any of those differences has been adequately reconciled.

Explanation of how compensating features or alternative Methods of Compliance (MoC) provide an equivalent level of safety to the level of safety intended by the regulation

The safety objectives of § 33.83 are to ensure that for blades, vanes, rotor discs, spacers, and rotor shafts:

1. The vibration characteristics (mechanically or aerodynamically) are acceptable throughout the declared flight envelope,

2. The vibration characteristics, when combined with the appropriate steady stresses, must be less than the endurance limits of the materials concerned, and

3. The effects of excitation forces caused by fault conditions shall be shown not to create a hazardous condition.

The FAA concurred with WI's proposal to use a combination of vibratory test surveys of FJ44-4A hardware, tests on similar engines, and analysis to show compliance. WI evaluated the vibratory characteristics of the FJ44-4A engine. The FAA agreed that WI's combination of vibratory test surveys of FJ44-4A hardware, tests on similar engines, and analysis demonstrated an equivalence to testing all relevant components on an FJ44-4A, therefore meeting the criteria of § 33.83.

FAA approval and documentation of the ELOS Finding:

The FAA has approved the aforementioned equivalent level of safety finding in project issue paper G-2. This memorandum provides standardized documentation of the ELOS finding that is non-proprietary and can be made available to the public. The Engine and Propeller Directorate has assigned a unique ELOS Memorandum number (see front page) to facilitate archiving and retrieval of this ELOS. This ELOS Memorandum number should be listed in the Type Certificate Data Sheet under the Certification Basis section (TC's & ATC's). An example of an appropriate statement is provided below.

Equivalent Level of Safety Findings have been made for the following regulation:

14 CFR § 33.83 Vibration Test (documented in ELOS Memo 8040-ELOS-09-NE03)

Original signed by **November 1, 2010**

Francis A. Favara, Manager,
Engine & Propeller Directorate, ANE-100

Date

ELOS Originated by ACO: Chicago ACO	ACO Manager: Charles L. Smalley	Routing Symbol: ACE-115C