# Memorandum

U.S. Department
of Transportation

**Federal Aviation Administration**

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| Subject: | **ACTION**: Review and Concurrence, Equivalent Level of Safety | Date: | May 4, 2001 |
| From: | Manager, Chicago Aircraft Certification Office, ACE-115C | Reply to Attn. of: | J. Tallarovic<br>847-294-8180 |
| To: | Manager, Engine and Propeller Directorate, ANE-100 | | |

This memorandum requests that your office review and provide concurrence with the proposed FAA Equivalent Level of Safety (ELOS) finding to the max continuous, take-off, continuous OEI (one engine inoperative), and 30 minute OEI ratings requirements of 14 CFR part 33.87 for gas generator speed (N1).

**Background:**

The limits listed in the Type Certificate Data Sheet must be demonstrated during the 150 Hour Endurance Test as prescribed by 14 CFR 33.87.

Compliance with these requirements would normally be shown by operating the test engine at the maximum operating limits simultaneously. These include torque, measured gas temperature (MGT), gas generator speed (N1), and power turbine speed (N2). Rolls-Royce Corporation (at the time of certification, the Allison Engine Company) has demonstrated all of the above ratings during the endurance test specified by Section 33.87, with the exception of the maximum rotor speed for the gas producer. The maximum demonstrated was 102% during the 30 minute OEI portion of the test, compared to the maximum operating limit of 105% N1.

**Applicable Regulations:**

Section 33.7(c)(1) (Engine Ratings and Operating Limitations) requires that engine ratings and operating limitations be established and included in the type certificate data sheet for turbine engines. These operating limitations include engine speeds for all ratings, including max continuous, take-off, continuous OEI, and 30 minute OEI power. The operating limitations demonstrated during the engine block tests, including the 150 hour endurance test, are published in the type certificate data sheet.

Section 33.87 (Endurance Test) requires that the engine complete an endurance test, where the engine completes a prescribed series of runs depending upon the type and contemplated use of the engine.

**FAA Position:**

Since the shortfall in N1 was offset by exceedences in other parameters which subjected the engine to even greater distress, the FAA supports documenting acceptance by means of an ELOS, as discussed below.

**Discussion:**

Due to the model 250-C40 engine operating characteristics and adjustment features, it is extremely difficult to operate the engine at all of the maximum limits simultaneously without changing turbine hardware and control software to the extent that it is no longer representative of the type design. It is not uncommon for this to be the case and Advisory Circular 33.2B states "…it may not be possible to simultaneously exercise to its respective speed limitation each rotor of a multiple rotor engine during endurance test running. During such a case,…the required substantiation may be shown by test replication as necessary, and/or valid analysis." In this situation analysis was combined with additional test time beyond that required by Section 33.87. Rolls-Royce Corporation and the FAA identified three areas of concern regarding the 105% N1 maximum operating limit; stress rupture, rim cracks, and shaft torque. Each of these aspects is discussed below.

Stress rupture is a function of speed, temperature, and time, with some ability to trade one parameter for another. The stress rupture damage to the rotor which would have been caused by doing the endurance test literally as required by Section 33.87 was compared to what was accumulated from actual endurance tests on the engine. The data shows that while the test N1 speed was not at 105%, the damage accumulated on the hardware (there were two sets of hardware due to a blade clearance problem) from the actual tests exceeded that which would have occurred during an ideal endurance test with N1 at 105%. An FAA endurance test conducted with all limits at the maximum would have used about 30% of the mean blade life. The testing Rolls-Royce Corporation completed resulted in the use of 56% on one set of hardware and 21% on the other. In terms of stress rupture, the testing competed by RRA appears to satisfactorily demonstrate an ELOS.

Rim cracks are a function primarily of MGT and the thermal stress gradient. All of the endurance tests were completed at higher than required MGTs. As a result, the testing completed was harsher on the hardware than if the test had been completed at 105% N1 with temperatures at the minimum required. The post test condition of the parts was well within acceptable limits of the overhaul manual.

Engine power is a function of shaft torque and speed. The N1 shaft was turning approximately 5% below the target speed during the tests. Since the engine was producing the required power or greater, the N1 shaft was transmitting about 5% more torque than it would have at the higher speeds. From a torque standpoint, the actual testing completed on the engine was more severe than had the endurance test been done at 105% N1.

Moreover, service history supports the 105% N1 limit. Gas producer disc integrity at 105% has been accepted for all previous 250 models, including the -C47B and -C47M. The gas producer maximum rotor speed of 105% has been certified on all previous models of 250 Series IV engines. Also, N1 speeds for sustained periods up to 105% have been approved for Model 250-C20 and all subsequent models since April 1970. Since that time Rolls-Royce Corporation has delivered more than 27,000 engines that have achieved over 125,000,000 flight hours (which excludes Series I models) with no problems related to turbine stress rupture life and subsequent blade failure.

Rolls-Royce Corporation maintains that the intent of the Part 33.87 has been met and requests an FAA Equivalent Level of Safety finding.

**ACO Recommendation:** The Chicago ACO concludes that the testing completed with the additional analysis satisfactorily demonstrates a maximum operating limit of 105% N1 for max continuous, take-off, continuous OEI, and 30 minute OEI ratings.

*/Original Signed by Royace Prather, 5/4/01/*

Royace H. Prather
Manager, Chicago Aircraft
Certification Office

Concur

*/Original Signed by Thomas Boudreau, 5/10/01/*

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Manager, Engine & Propeller Standards Staff, ANE-110

Date:_____

Concur

*/Original Signed by Francis A. Favara, 5/11/01/*

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Manager, Engine & Propeller Directorate, ANE-100

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