Federal Aviation Administration

Memorandum

Date: December 2, 2010

To: Manager, Engine Certification Office (ECO), ANE-140

From: Manager, Engine and Propeller Directorate, ANE-100

Prepared by: Robert Green, Aerospace Engineer ANE-141

Subject: INFORMATION: Equivalent Level of Safety Finding for Induction System Icing on GEnx-1B54, -1B58, -1B64, -1B67, and -1B70 Engines, TD2826EN-E

ELOS Memo#: 8040-ELOS-10-NE03

Regulatory Ref: 14 CFR §33.68 (a)

This memorandum informs the certificate management engine 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 GEnx-1B54, GEnx-1B58, GEnx-1B64, GEnx-1B67, and GEnx-1B70 engine models (hereafter GEnx-1B engine).

Background

The latest GEnx-1B engine configuration is the GEnx-1B70 type design with a redesigned combustor and fuel system, revised high pressure compressor (HPC) compressor variable stator vane (VSV) schedule, tighter fan and HPC blade tip clearances, and new accessory air/oil coolers lining the fan duct. In addition, GE has expanded the use of HPC transient bleed and added a booster inlet lip anti-ice (BAI) system to improve the engine's performance in icing conditions.

GE initially proposed a finding of compliance to 14 CFR Part 33, §33.68 by test, consistent with AC 20-147. However, GE was only able to finish six of the eight planned FAA certification test points due to warming weather at their test facility.

In accordance with the provisions of 14 CFR Part 21, §21.21(b)(1), GE has requested an alternate method of compliance to the requirements of §33.68(a), Induction System Icing, through an ELOS demonstration for the GEnx-1B engine. An analysis supported by prior

engine and component tests has been provided as an alternate method of compliance to demonstrate acceptable engine performance at the two outstanding FAA certification test conditions. In summary, GE is proposing compliance through a combination of engine test and analysis in lieu of engine test; six of the specified certification points would be satisfied through engine test, the two remaining points would be assessed through analysis.

Applicable Regulation

14 CFR §33.68, "Induction System Icing" paragraph (a):

Each engine, with all icing protection systems operating, must--
(a) Operate throughout its flight power range (including idling) without the accumulation of ice on the engine components that adversely affects engine operation or that causes a serious loss of power or thrust in continuous maximum and intermittent maximum icing conditions as defined in Appendix C of Part 25 of this chapter; and …"

Regulation requiring an ELOS finding

14 CFR §33.68(a)

Description of compensating design features or alternative Methods of Compliance (MoC) which allow the granting of the ELOS (including design changes, limitations or equipment need for equivalency)

The GE analysis is an engine transient model comparison of tested baseline engines and the intended type design configuration.

A baseline engine transient model was calibrated to prior engineering and certification test data for ice-sheds during accelerations to takeoff power at the two outstanding FAA icing certification test conditions. The changes required to match the baseline transient model's simulation to demonstrated engine performance during the ice-shed events were applied to the intended type design transient model to evaluate that engine's tolerance to accreted ice sheds.

Both the rotor and booster inlet lip shed during the previously demonstrated engine accelerations. The transient model inputs for the rotor ice shed mass were the same as observed during the prior certification tests. The booster inlet lip ice shed mass was established from a heat transfer model of the booster inlet lip with BAI and projected accretion from the previously approved critical point analysis. The heat transfer model was validated by component test at icing conditions representative of the two FAA certification test points.

The intended type design transient model was run with the ice shed masses and shed characteristics observed during prior certification test for the two FAA conditions. The simulated engine performance for ice sheds were within demonstrated certification stall and flameout capability. The fan stability and core damage potential, and susceptibility to core damage were evaluated through certification points demonstrated by test.

In accordance with 14 CFR §21.21(b)(1), the FAA has determined that the transient model analysis may be used as evidence of compliance for the GEnx-1B providing the following compensating factors were met:

(1) The GEnx-1B baseline transient model is calibrated/scaled using prior engine icing certification test data from a vehicle that conforms or can be reconciled to the intended type design. An independent validation of the model is required.

(2) The GEnx-1B BAI heat transfer model is validated by system performance test data.

(3) The transient engine and heat transfer models only replicate existing certification test conditions and demonstrated ice shed characteristics.

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

In order to meet these compensating factors, GE will use the data from the prior GEnx-1B certification test (engine serial number (ESN) 956-007/1B) and engineering data (acquired on ESN 956-007/2D) to calibrate/scale the intended type design transient engine model. The data will be specific to the two outstanding certification test points.

GE will use the engineering test data from ESN 956-004/3 to establish the BAI system performance characteristics. Booster inlet component rig testing will validate the heat transfer coefficients on the external surface of the inlet lip at the icing conditions for the two remaining certification points. The validated analysis will establish the circumferential extent of accretion.

GE will use the Critical Point Analysis (CPA) accretion rates to establish the ice shed mass for the engine operating and icing conditions for the two remaining points.

GE will use the scaled transient model of the intended type design and ice accretions projected for each icing condition to assess engine accelerations from ground idle to takeoff power. Engine performance (compressor stall and flameout margin) will be evaluated in terms of the evaporative cooling of the ice through the core. The projected change in combustor discharge temperature will be evaluated against the capabilities previously established through successful certification ice-shed testing conducted on GEnx-1B ESN 956-004/3B and GEnx-2B ESN 959-004/2A.

FAA approval and documentation of the ELOS finding

The FAA has approved the aforementioned equivalent level of safety finding in project issue paper P-2. This memorandum provides standardized documentation of the ELOS finding that is nonproprietary 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 will be listed in the Type Certificate Data Sheet number E00078EN Revision 2 under the Certification Basis section.

Equivalent Level of Safety Finding has been made to the following regulation:

14 CFR §33.63, "Induction System Icing" paragraph (a), (documented in ELOS Memo#: 8040-ELOS-10-NE03)

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Manager, Engine and Propeller Directorate, Aircraft Certification Service — Date

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