Federal Aviation Administration

Memorandum

Date: April 2, 2010

To: SEE DISTRIBUTION

From: Manager, Engine and Propeller Directorate, Aircraft Certification Service

Prepared by: John Fisher, ANE-111 (781) 238-7149 or john.fisher@faa.gov

Subject: **ACTION**: Guidance for Rain and Hail Ingestion Testing for Turbine Engines, § 33.78 [ANE-2007-33.78-1]

1. Purpose. This policy memorandum provides guidance to applicants, aircraft certification offices (ACOs) and the Engine Certification Office (ECO) when evaluating compliance with the rain and hail ingestion standards of Title 14 of the Code of Federal Regulations (14 CFR) part 33. It clarifies FAA policy regarding those standards for turbine engines, specifically addressing two areas where the FAA identified shortfalls in hail ingestion compliance: (1) high Hail Water Content (HWC) for short durations; and (2) ice accretion within the engine.

2. Background

a. During the past several years, aircraft have lost all engine power after flying through hail concentrations that exceeded those test levels used to show compliance with § 33.78, Rain and hail ingestion, as defined in Appendix B to part 33. In one instance, an aircraft experienced a dual-engine flameout as a result of an extreme rain and hail encounter and ditched.

b. We developed the 30-second hail duration standard in Appendix B based on the assumption that the primary engine vulnerability to hail was bleed valve clogging over time; not a very short duration high intensity burst of hail. The incidents noted above indicate, however, that both are threats. Higher HWC levels than those described in Appendix B of part 33, are therefore, possible. In response to those incidents, we requested that industry assist us in evaluating the rule, Appendix B of the rule, and guidance for turbine engine rain and hail ingestion.

c. Industry, including the Aerospace Industries Association (AIA), confirmed that higher HWC levels than those described in part 33 Appendix B are possible. Industry recommended that we issue additional guidance. We agreed and this policy memorandum is part of that guidance.

d. Additionally, during the conduct of a recent § 33.78(a)(2) hail certification test, we learned of ice accretion within the engine, a condition not previously associated with our hail certification testing requirement. Ice accretion within the engine can result in operability problems, damage, and possibly power loss from flameout. Since ice accretion into the low pressure compressor stage could occur during hail ingestion, this condition should be evaluated as part of the § 33.78(a)(2) hail certification test.

e. We note that we have not previously issued policy concerning ice accretion in the low compressor section. This memo, therefore, also provides policy on conducting compliance assessments and tests to address potential ice accretion. Appendix 2 of this memo contains additional information on the issue of internal ice accretion.

f. We also recommend the ECO and ACOs consider writing issue papers on rain and hail ingestion, when appropriate, for each new certification program to address the issues within this policy memo.

3. Related Documents.

a. Results of the Aerospace Industries Association (AIA) Propulsion Committee Study, Project PC 338-1; June 1990.

b. Aerospace Industries Association: Inclement Weather Project Group Final Report; April 14, 2006.

c. Advisory Circular 33.78-1, Turbine Engine Power-Loss and Instability in Extreme Conditions of Rain and Hail; February 8, 2000.

4. Policy.

a. High Hail Water Content for Short Durations.

(1) Applicants conducting compliance demonstrations to § 33.78(a)(2) for new turbine engine type certificates are required to submit assessments of the impact of a 30-second hail concentration. We strongly recommend that ACOs and the ECO emphasize to applicants that operational experience shows a higher hail concentration can occur for short durations. Therefore, applicants who limit their demonstration to the 30-second requirement may not be providing the highest level of safety to which the public is entitled. Further, ACOs and the ECO should strongly encourage applicants when developing their compliance plans to include in their 30-second duration demonstration the short burst, high concentration, 13 gm/m^3 HWC at 15,000 foot altitude for 5 seconds identified in the AIA study.

(2) Applicants can assess engine operation against this elevated threat, either integrated within the current 30-second test point or separately using test or analysis. Applicants may also

propose alternatives to assess similar short-term, high concentration threats. Appendix 1 of this memo, based on a 2006 AIA report (see reference in paragraph 3.b.), provides atmospheric hail concentrations which vary by time rather than being based on the fixed 30-second time frame assumed by Appendix B of part 33. Applicants, therefore, may find Appendix 1 useful in developing those alternatives to assess short-term, high concentration threats.

b. Ice Accretion within the Engine.

(1) Ice accretion within an engine caused by hail has not been addressed by previous guidance. Therefore, ACOs and the ECO should suggest that applicants evaluate ice accretion within the engine when using the excess water methodology for compliance demonstration.

(2) Periodically applicants have shown compliance to the hail standards of § 33.78(a)(2) by simulating hail ingestion through excess water ingestion. Historically, applicants have not addressed ice accretion within the low pressure compressor for this demonstration. Prior compliance testing using hail, however, has shown that ice accretion can occur and result in downstream engine damage within the high pressure compressor. For manufacturers that utilize excess water methodology for compliance demonstration, certification offices should ensure through applicant’s test or analysis that potential ice accretion within the engine resulting from an engine ingesting the certification standard hail concentration does not result in unacceptable engine damage or adverse operability. See Appendix 2 for detailed guidance on conducting compliance demonstrations.

5. Effect of Policy.

The general policy stated in this document does not constitute a new regulation or create what the courts refer to as a “binding norm.” The office that implements policy should follow this policy when applicable to the specific project. Whenever an applicant's proposed method of compliance is outside this established policy, it must be coordinated with the policy issuing office. Similarly, if the implementing office becomes aware of reasons that an applicant's proposal that meets this policy should not be approved, the office must coordinate its response with the policy issuing office.

[signature] for

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

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Appendix 1. Short Term Hail Concentration

1. The HWC defined by § 33.78(a)(2) includes consideration for the duration of the storm encounter. On this basis, the maximum HWC level of 10 gm/m^3 specified in Appendix B of part 33 is consistent with the 30-second test demonstration requirement of the rule. Consideration for this encounter period is intended to confirm that the effects of thermodynamic lag and ice blockage of engine bleed systems are accounted for during engine certification. The relationship between maximum HWC and storm encounter duration is provided in figure 1 below for the range of storm penetration speed used to establish the 30-second duration requirements.

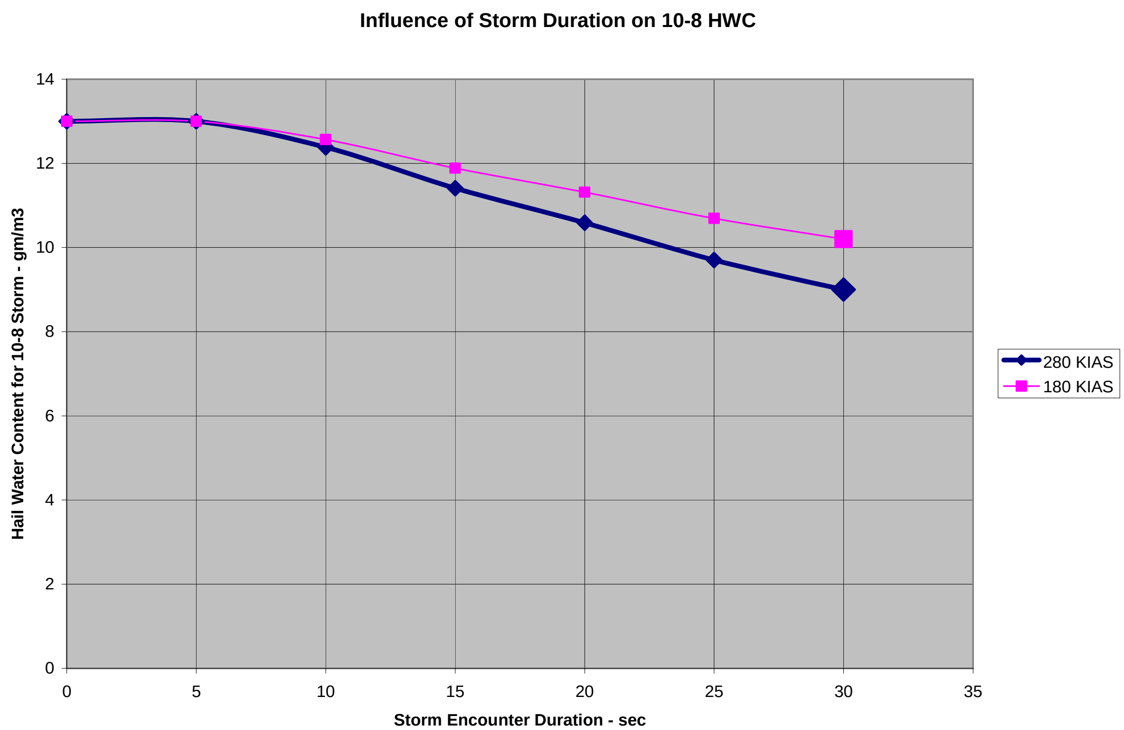

Figure 1. Maximum HWC Threat Relation to Storm Encounter Duration

2. As shown in the figure above, encounters shorter than 30 seconds may exceed 10 gm/m^3 and are influenced by the operating manual storm penetration speed guidelines for the engine installation.

Appendix 2. Ice Accretion within the Low Pressure Compressor

1. This appendix provides additional guidance on possible compliance methodologies while addressing ice accretion within the low pressure compressor of the engine as part of the § 33.78 hail storm demonstration.

2. When conducting hail ingestion tests at sea level in compliance with § 33.78(a)(2) and Appendix B to part 33, applicants should consider an adjustment to the HWC to account for the higher air density at sea level compared with altitude flight conditions. On this basis, the maximum 30-second HWC level of 10 gm/m^3 specified in Appendix B of part 33 is amplified by a factor typically on the order of 2X (the specific amplification factor depends upon the critical flight condition and the sea level test conditions). This amplification is intended to validate the engine's ability to tolerate the cycle effects (for example, reduced stall margin, increased fuel flow requirements, and degraded combustion flameout margin) associated with hail ingestion by providing the same water-to-air ratio within the engine core at sea level that is experienced during a hail flight encounter. See Appendix 3 of this memo for more information on pressure altitude density and flight airspeed effects on water-to-air ratio.

3. Ice accretion within the low pressure compressor, however, depends on the absolute HWC level rather than water-to-air ratio within the engine. It is possible, then, that the pressure altitude density effect on HWC for the sea level test may result in ice accretion within the engine that would not occur in flight. Note that flight airspeed effects must still be applied to the engine test simulation. If certification testing reveals an issue with ice accretion during the § 33.78(a)(2) testing with amplified HWC, the manufacturer may need to repeat the testing at 10 gm/m^3 to evaluate the true ice accretion threat. Alternatively, the manufacturer may choose to run an initial test at 10 gm/m^3 to clear the engine for ice accretion before running the higher HWC operability test.

4. If an engine manufacturer proposes using excess water in lieu of an actual hail ingestion test, they should address the issue of inter-compressor bleed (e.g., plane 2.5 bleed) clogging and also the possibility of ice accretion within the compression system (e.g., low pressure compressor stator vanes). Accretion within the engine resulting from ingesting the certification standard hail content of Appendix B of part 33 should not result in unacceptable engine damage or adverse operability, including flameout, rundown, or continued or non-recoverable surge or stall.

Appendix 3. Pressure Altitude Density and Airspeed Effects on Hail/Water to Air Ratio

1. This appendix provides background information on how applicants typically determine the test levels of hail that are ingested into the engines as part of the § 33.78 hail storm demonstration.

2. Typically, applicants perform rain and hail ingestion testing in a static sea level engine test cell and must account for both forward airspeed and pressure altitude effects. This means applicants must adjust the ambient environmental rain and hail levels defined in Appendix B of part 33 when performing a sea level static engine test.

a. Air Density Effects. Example of determining the pressure altitude density effects on the test HWC at sea level:

> The HWC of 10 gm/m^3 at 15,000 ft shown in figure B1 of Appendix B of part 33 results in a water-to-air ratio of 0.0130; the 10 gm/m^3 HWC divided by the air density of 771.0 gm/m^3. To maintain the equivalent HWC (15.89gm/m^3) for sea level testing, the water-to-air ratio at 15,000 ft (0.0130) must be multiplied by the sea level air density (1225.3 gm/m^3).

b. Flight Airspeed Effects. Additionally, the scoop factor or hail concentrating flight effects as defined in AC 33.78-1 must also be applied to the engine test simulation. See section 1, paragraph 7, of AC 33.78-1 for additional guidance.

c. For rain and hail simulation testing, the goal of certification testing is to match the in-flight rain and hail water to air ratio in the core compressor. Inter compressor bleed extraction should be representative of the in-flight condition.