

Future Rulemaking, Policy and Guidance - Engine Icing

Ice Crystals and Turbine Engines

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and Engine Icing

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Federal Aviation
Administration



Agenda

- **The Case for Rulemaking - Incident History**
- **The Ice Crystal Environment**
- **Its Effect on Engines**
- **Mitigating Its Effects**
- **New Engine Icing Certification Rulemaking**
- **Challenges**
- **Research & Development Needs**



Engine Incident History Mixed Phase & Ice Crystals

Overall Fleet

A total of 139 power-loss events identified

- EHWG developed database of 97 Engine Events in 16-years (1988-2003)
- 42 Additional Events Recently Identified (as of July 2007)

Engine Incident History

Mixed Phase & Ice Crystals

– 139 –power loss events

- 68 -descent, 62 -climb/cruise events, 9 -ground events (mixed phase)
- 11 -total power loss events from flameout
 - 1 -forced landing (crystal)
 - 1 -forced landing, engine damage (snow)

– 28 -engine damage events (Crystal)

- 4 -operational effects

Ice Crystal Environment

- Typically near convective weather.
- Turbulence
- Rain reported on windshield.
- Ice Detector does not detect ice.
- Total Ambient Temperature (TAT) probe indicates 0° C. This does not consistently occur.



Ice Crystal Effects on Engines

- Can accrete deep within engine where air temperatures could be as high as 90°F.
- Accretion can:
 - **choke off core air flow.**
 - **Accrete and shed during throttle-up.**
 - **Cause blockage in engine inlet probes.**
- Operability effects:
 - **Compressor stall.**
 - **Compressor blade damage.**
 - **Combustor flameout (quench)**
 - **Power rollback**



Mitigating the Ice Crystal Threat

Design & Ops

- **Operations:**
 - Pilot education
 - No over-flying convective systems
 - Avoid convective systems by 30 km
 - Turn on all aircraft bleed systems to increase fuel/air ratio
- **Engine Design:**
 - Variable bleed valve scheduling.
 - Add anti-ice heat to affected area.
 - Increase fuel-air ratio in combustor for improved quenching blow-out margin:
 - Increased core stability air-bleed
 - Increase core horsepower extraction

Icing Certification Rules

- **14 CFR, part 25, Appendix C (current)**
 - Small Supercooled Droplet Icing
 - 15 to 50 Micron Diameter
 - 0 C to -30 C
- **Proposed 14 CFR, part 25, Appendix X**
 - Large Supercooled Droplet (SLD) Icing
 - Representative of freezing rain & freezing drizzle
 - Size ranges up to 2 mm diameter, with about 10% of the mass is in drops of diameter greater than 1 mm (1000 microns).
- **Proposed 14 CFR, part 33, Appendix D**
 - Glaciated (ice crystal) & Mixed Phase Icing
 - See following slides for environmental definition

Proposed New Engine Icing Certification Rulemaking



FAR 33.68 (Engine Icing)

➤ **Proposed Rule Changes:**

- Add Glaciated Ice to Critical Point Analysis
- Add new Part 33 appendix
 - Appendix D, Part 33 defines glaciated ice envelope
- Add Super Cooled Large Droplet (SLD) ground icing point
 - Appendix X, Part 25 defines SLD envelope.

➤ **Accommodations for Rule Changes:**

- Allowance for test or analysis for new items (SLD & Glaciated and Mixed Phase).

➤ **Phased-in approach to rule implementation to address available technology**

Rulemaking Activity

- **Rule drafting completed September 2005**
- **Currently in FAA internal coordination.**
- **Affected Engine & Installation Rules:**
 - FAR 33.68 (Engine Icing), FAR 33.77 (Ice Slab Ingestion)
 - FAR 25.1093 (Installation Icing Protection), FAR 25.903 (Applicability)



Proposed
Appendix D, FAR 33

**Engine Glaciated (Ice Crystal)and Mixed
Phase Environmental Conditions**

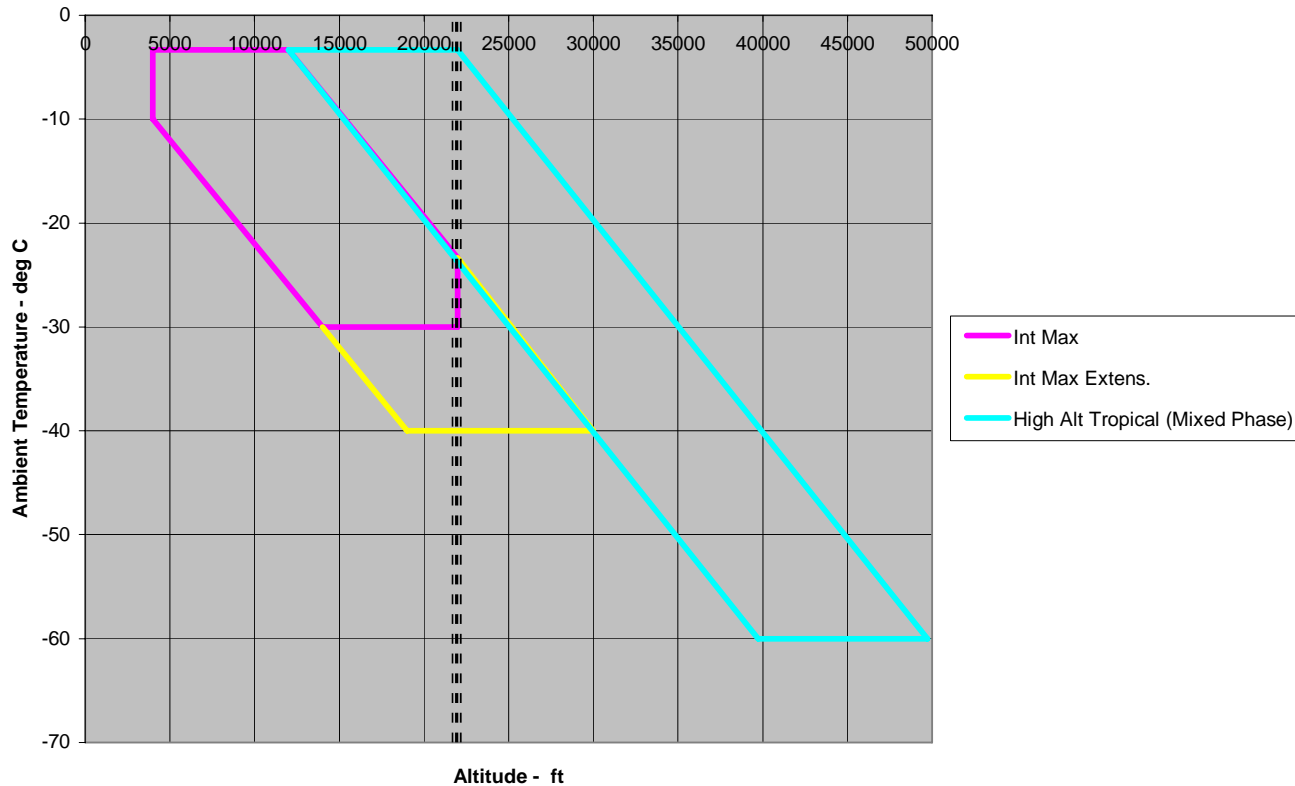


FAR Part 33

Proposed Appendix D

Ice Crystal Icing Envelope

FAR 33 Appendix D Icing Envelope Limits

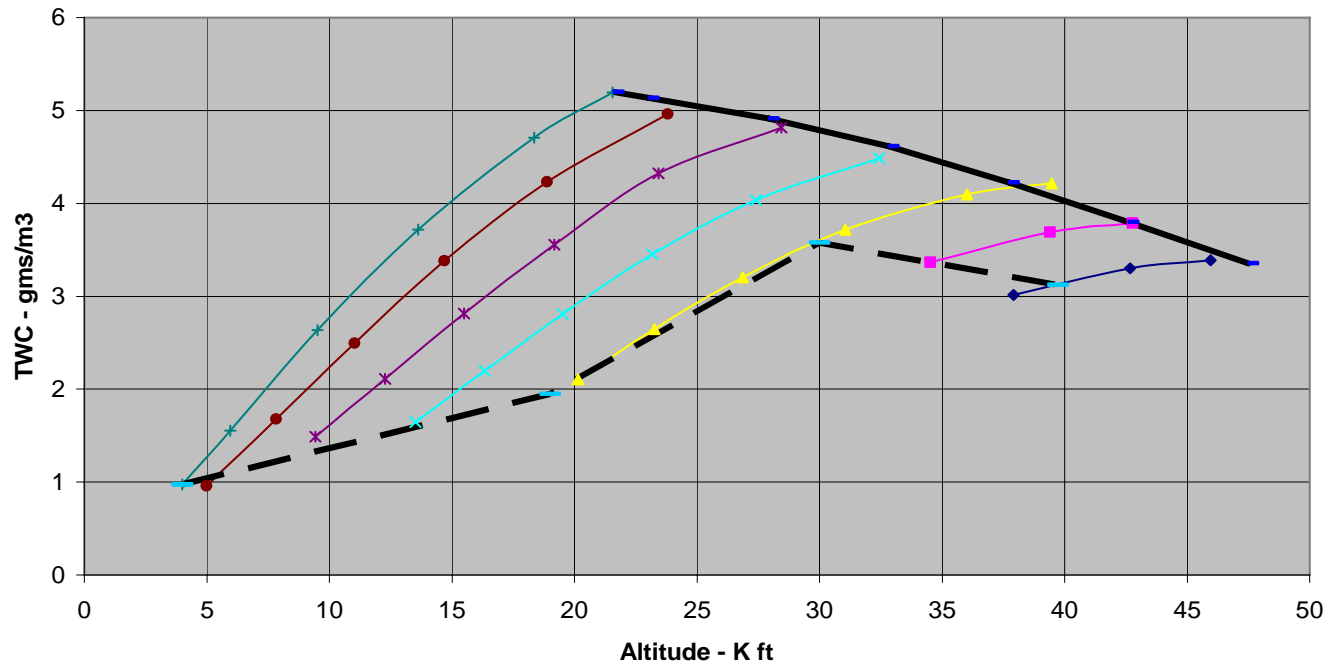
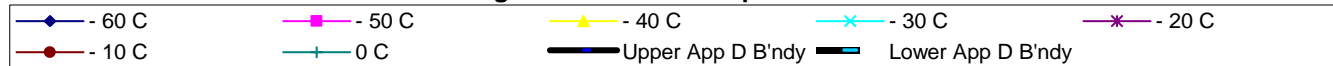


FAR Part 33 Figure D-2

Total Water Content

TWC Levels: Standard Exposure Length of 17.4 Nautical Miles
(Scaled from Adiabatic Lapse from Sea Level @ 90% Relative Humidity)

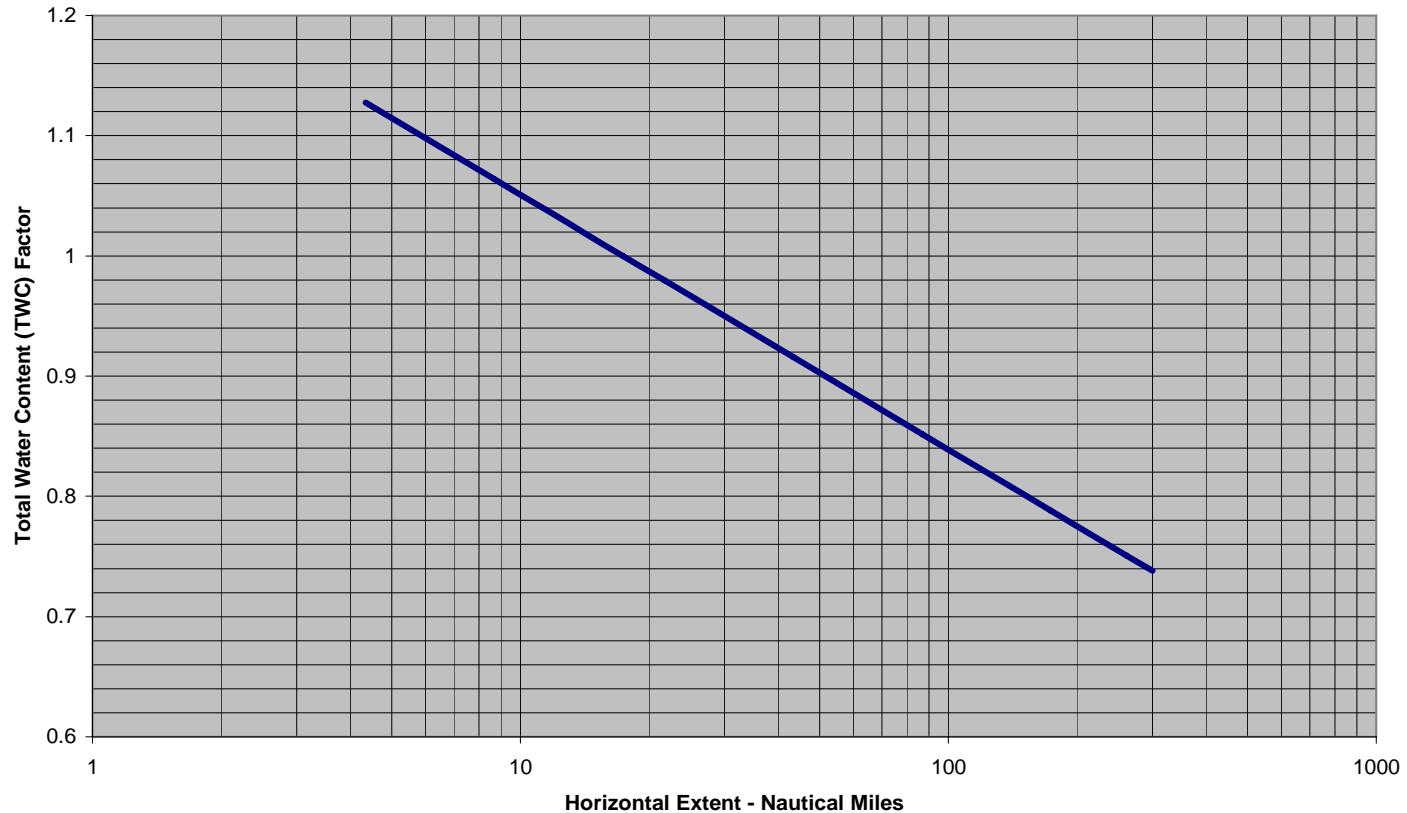
Legend : Ambient Temperature



FAR Part 33 Figure D-3

Exposure Length Influence on TWC

Altitude Ice Crystal Conditions
Total Water Content Distance Scale Factor



Policy & Guidance

- Safety Information Bulletins (**SAIB**) issued for some engine models.
- FAA Advisory Circular (**AC**) **91-74** revisions drafted in March 2007 which included ice crystal effects on turbine engines.
- **FAA Memo** to ACO's issued 1/25/05, requesting engine Type Certification applicants consider glaciated and mixed phase ice threat.

Challenges

- **Characterization of Mixed Phase & Glaciated Conditions**
 - Current TWC ice probe accuracy concerns.
 - Limited database of research aircraft flights in convective clouds (thunder heads) to characterize this environment.
- **Engine icing test cells are not currently equipped to allow for glaciated ice or mixed phase full-engine testing.**
- **Analytic tools need to be developed to predict glaciated ice effects on engine operation.**

Research & Development Needs

- **Ice crystal detection probe robustness, range and accuracy needs development**
 - EC/NASA/NRC/FAA, 4th Qtr CY07.
 - Various designs being evaluated
 - Airspeed limitations
- **Research flights in convective clouds to develop glaciated database so that glaciated conditions can be characterized more confidently. ('07-'10)**
 - NASA S3 Viking:
 - 24 month campaign in Cleveland, East Coast USA, Costa Rica, Darwin Australia ('09-'10).

Research & Development Needs

Continued

- **Full Engine Test Cell development to simulate glaciated ice conditions**
 - NASA Glenn, NRC Ottawa and possibly NRC Manitoba
- **Ice Crystal Simulation**
 - Cox Wind tunnel
 - Shaved Ice (200-300 micron, irregular shapes)
 - Snow Gun (~100 microns, round shape)
 - Problems with re-ingestion and low velocity.
 - Spray Rig (currently ~ 8-25 microns, round shape)
 - NRC shaved ice

Questions?

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