

AIRA Research Thrust II: Propulsion System Icing



AIRA Icing Research

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Outline

- EHWG Recommendations
- Part 33 Appendix D: Mixed Phase
- Existing Engine Icing Certification Facilities
- Ice Crystal Facilities, Existing/Proposed
- Current Research Efforts/Proposals
- Going forward – needs and opportunities
- Conclusion

EHWG Recommendations

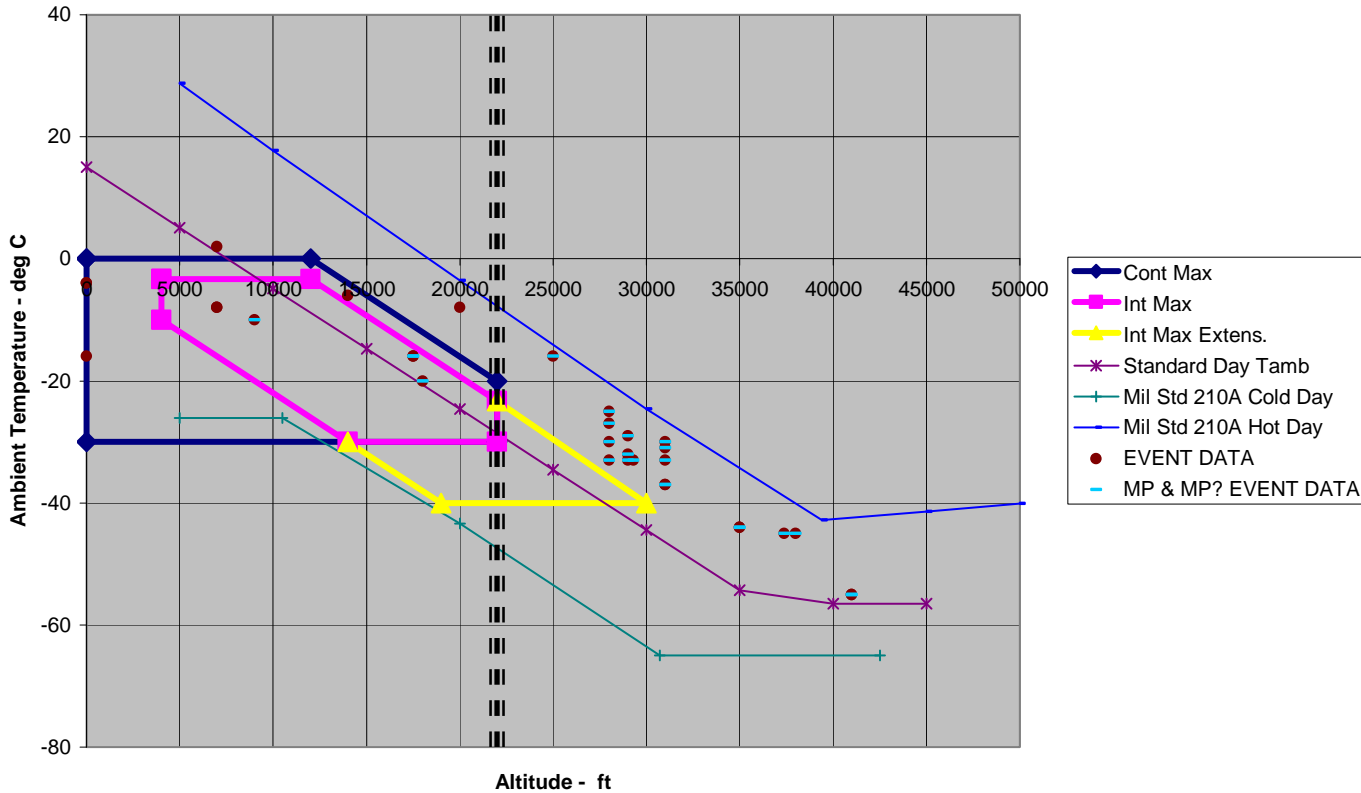
- 1) Develop new instrumentation to accurately quantify total water content
- 2) Perform flight testing to measure and define the extent of the Appendix D envelope for glaciated or mixed phase icing conditions
- 3) Determine through experimentation and simulation the effect of ice crystal on the performance of internal engine components both on a microscopic and macroscopic scale
- 4) Develop test facilities to simulate glaciated and mixed phase icing environments to allow compliance with new FAR requirements

FAR Part 33 Appendix D

- Over 100 known engine events since 1980 outside App C
- Ice Crystals or Mixed Phase
- Serious threat to engine: Surge, flameout or rollback
- New envelope, Appendix D proposed
- Method of compliance not currently available

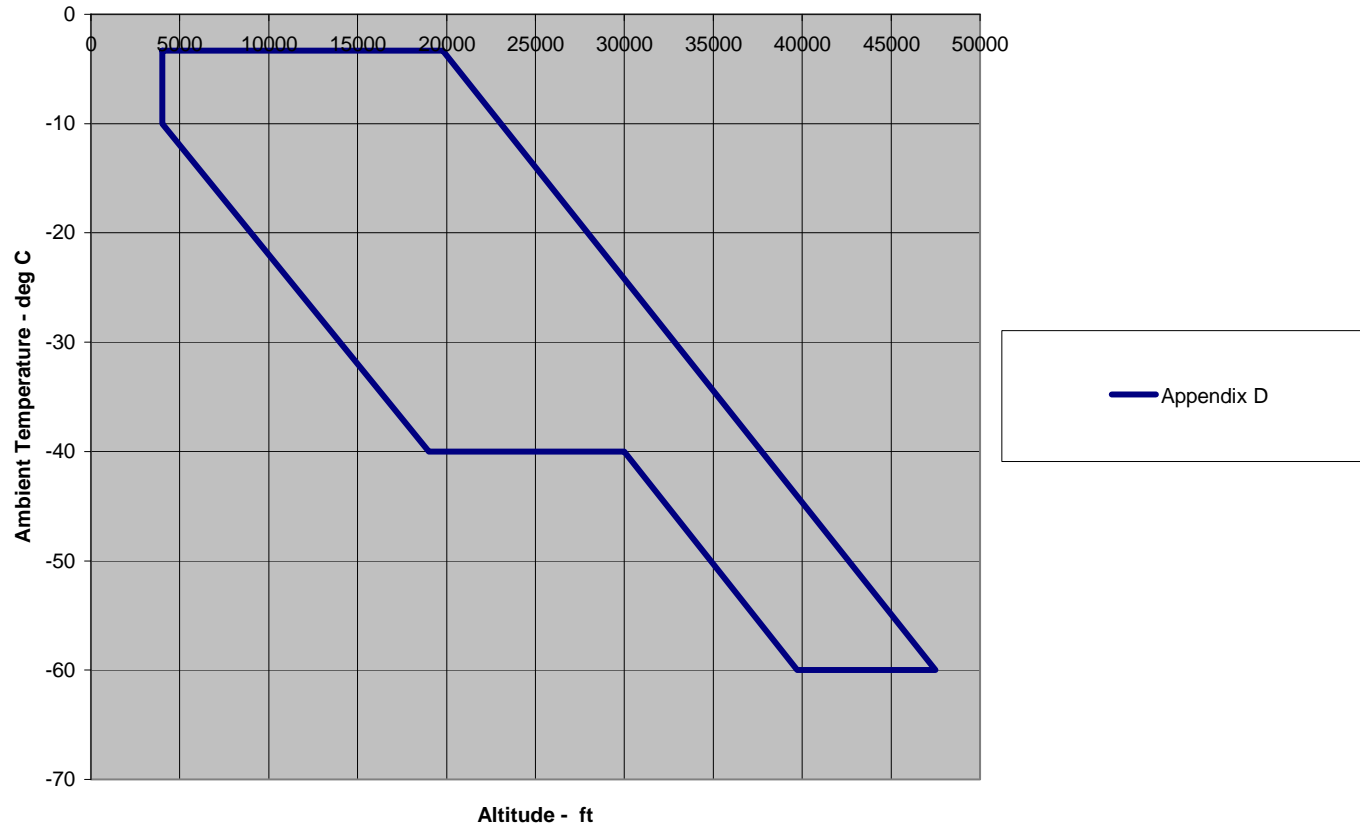
FAR Part 33 Appendix D

Commercial Service Data Base of Icing Events compared with FAR Part 25 Appendix C Icing Envelope Limits



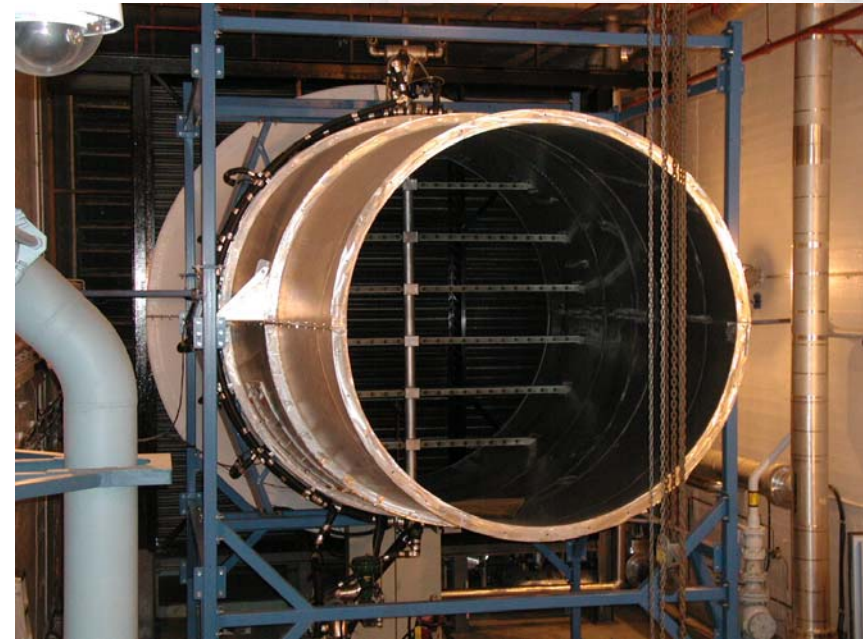
FAR Part 33 Appendix D

FAR 33 Appendix D Icing Envelope Limits



Existing Engine Icing Test Facilities

- Sea level:
 - NRC M-7 800 pps max, -25 C
 - GE Peebles (OH): 3600 pps, -8 C
 - NRC/GE Mirabel 3000 pps, -25 C
- Sea level refrigerated:
 - McKinley (FL): 250 pps, -40 C
- Altitude:
 - AEDC (TN): 1600 pps, -20 C
 - CIAM (Russia): 600 pps, -20 C
 - CEPR (France) 400 pps, -20 C
 - NRC M-10 10 pps, -20 C TBD



NRC/GE MIRABEL



Existing Engine Icing Test Facilities with Ice Crystal Capability

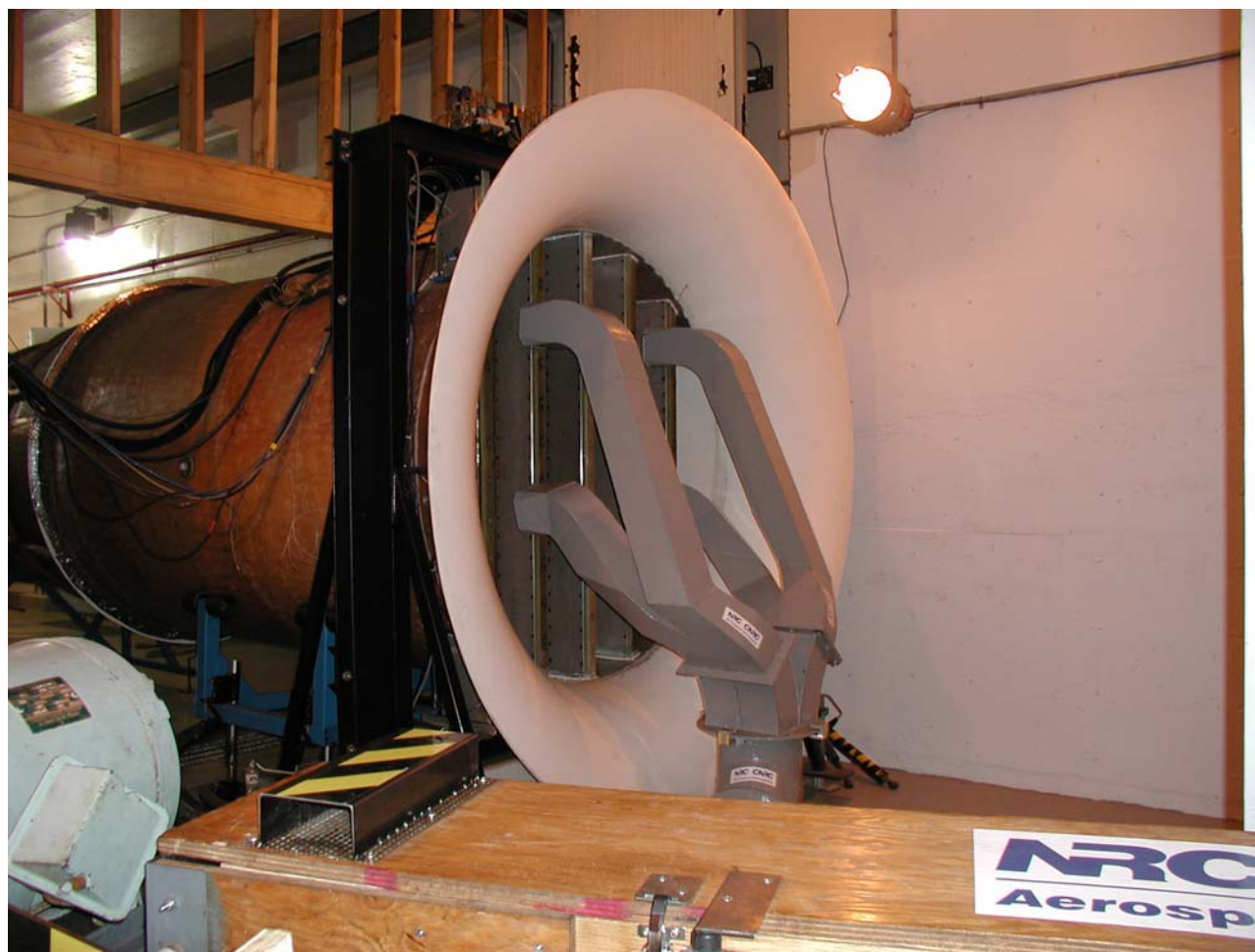
- Sea level:
 - NRC M7-5 250 pps max, -25 C
 - GE Peebles (OH): 3600 pps, -8 C
- Altitude:
 - AEDC (TN): 1600 pps, -20 C



Ice Crystal Delivery System



Ice/Snow Chutes



Ice Shaver Blades



Ice Crystal Test Specifications

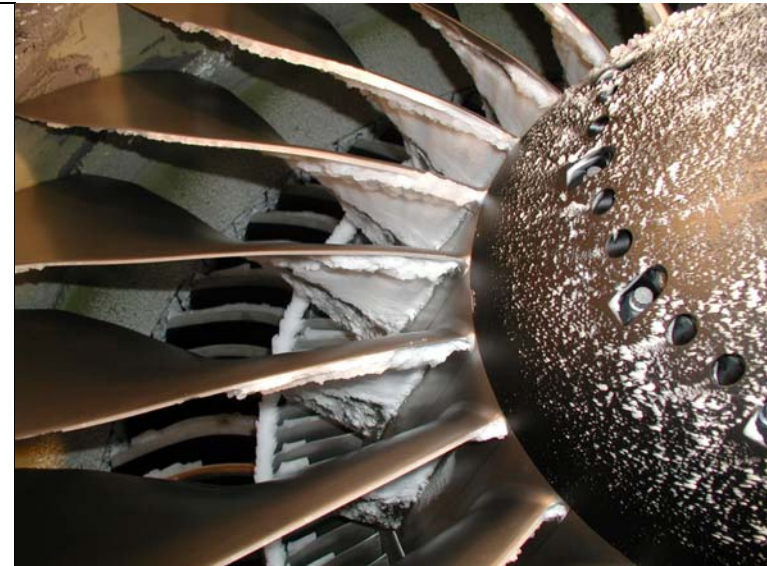
- Maximum tunnel velocity 0.5 Mach
- Tunnel test section diameter: 34 inches
- TWC max 5 g/m³ @ max velocity
- Particle size variable between 60 - 500 micron
- 5-10 minute test duration per ice block
- New ice grinder system with continuous feed operation and improved distribution system currently being bench tested; installation in Mar 08, full operation Jan 09

Ice Crystal Test 1.5 g/m³, 150m/s



Proposed Engine Icing Test Facilities with Ice Crystal Capability

- Sea level:
 - NRC M7-4 800 pps max, -25 C
- Altitude:
 - NASA PSL (OH): 600 pps, -40 C
 - NRC RATFac 10 pps max, -25 C



Current Research Efforts/Proposals

EHWG 1: New Instrumentation

- Isokinetic TWC probe (NRC)2007-2008
- SEA Robust TWC probe (currently being tested @NRC)
- Ice Crystal Detector (Thermal) 2008
- Electrostatic Ice Crystal Detector 2008
- Calibration of Nevzorov and CVI probes 2008

Current Research Efforts/Proposals

EHWG 2: Flight Testing

- NASA S-3 – Costa Rica 2008-2009
- NASA S-3 – Australia 2010

Current Research Efforts/Proposals

EHWG 3: Fundamental Physics

- Heated Plate testing (NRC) 2007-2008
- S-duct single blade test (NRC) 2008
- Cascade testing (warm air-NRC) 2009
- Instrumented engine test (NRC) 2009?
- FENSAP-ICE, TSIICE consortium- TURBO-ICE, 2008-2009

Current Research Efforts/Proposals

EHWG 4: Facilities for Compliance Testing

- NRC Sea-level only
- NASA PSL is essential to the development of SL-altitude scaling factors to allow SL compliance testing
- CEPr (France) ?

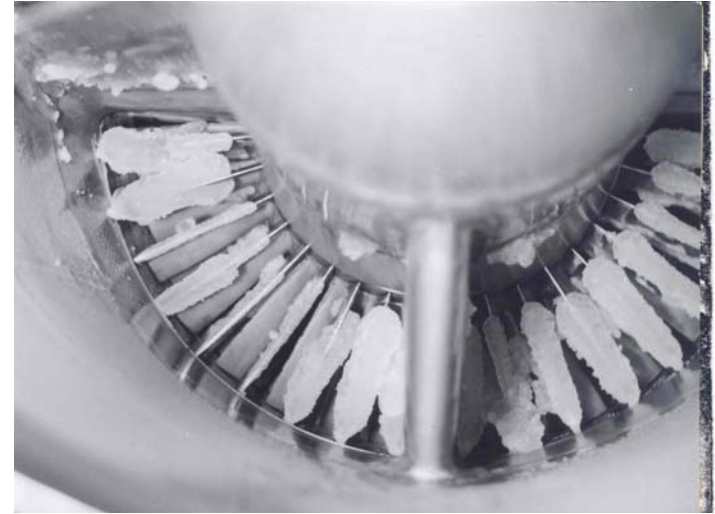
Going Forward – Needs and Opportunities



Need a Propulsion System Icing Research Plan

- Start with EHWG report
- Coordinated effort
- Funding from OEM and govt
- Develop testing facilities both sea-level and altitude

Conclusions



- Lack of specialized icing test facilities worldwide
- Lots of opportunities in engine icing research and technology in the areas of:
 - 1) Test facilities for mixed phase
 - 2) Determination of ice crystal behavior within a compressor
 - 3) Modeling of mixed phase in an engine environment