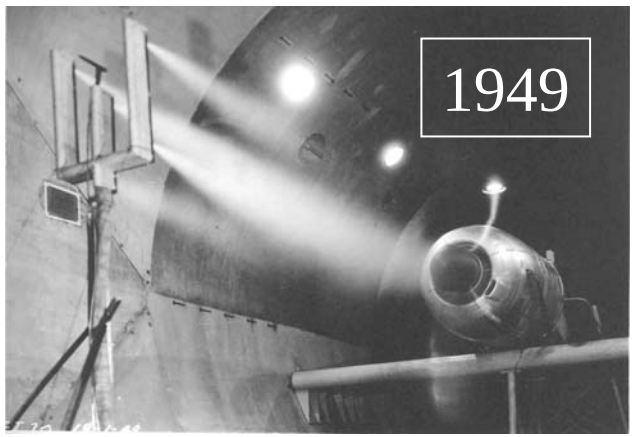
NRC·CNRC
NRCaerospace.com

Engine Icing Research



ASME
Barcelona, SPAIN

May 10, 2006

Jim MacLeod, NRC Tom Bond, NASA

NASA

Outline

- Icing Requirements
- New Icing Appendices
- Existing Engine Icing Facilities
- Going forward – needs and opportunities

New Requirements

The 1994 ATR 72 crash resulted in a NTSB recommendation to:

- Expand the Appendix C icing certification envelope to include:
- Freezing drizzle/freezing rain and,
- Mixed water/ice crystal conditions, as necessary.

<u>In response to the NTSB safety recommendations</u>,

the FAA tasked the Icing Protection Harmonization Working Group(IPHWG)

to develop new rules, along with the Engine Harmonization Working Group(EHWG)

FAR Part 25 Appendix X

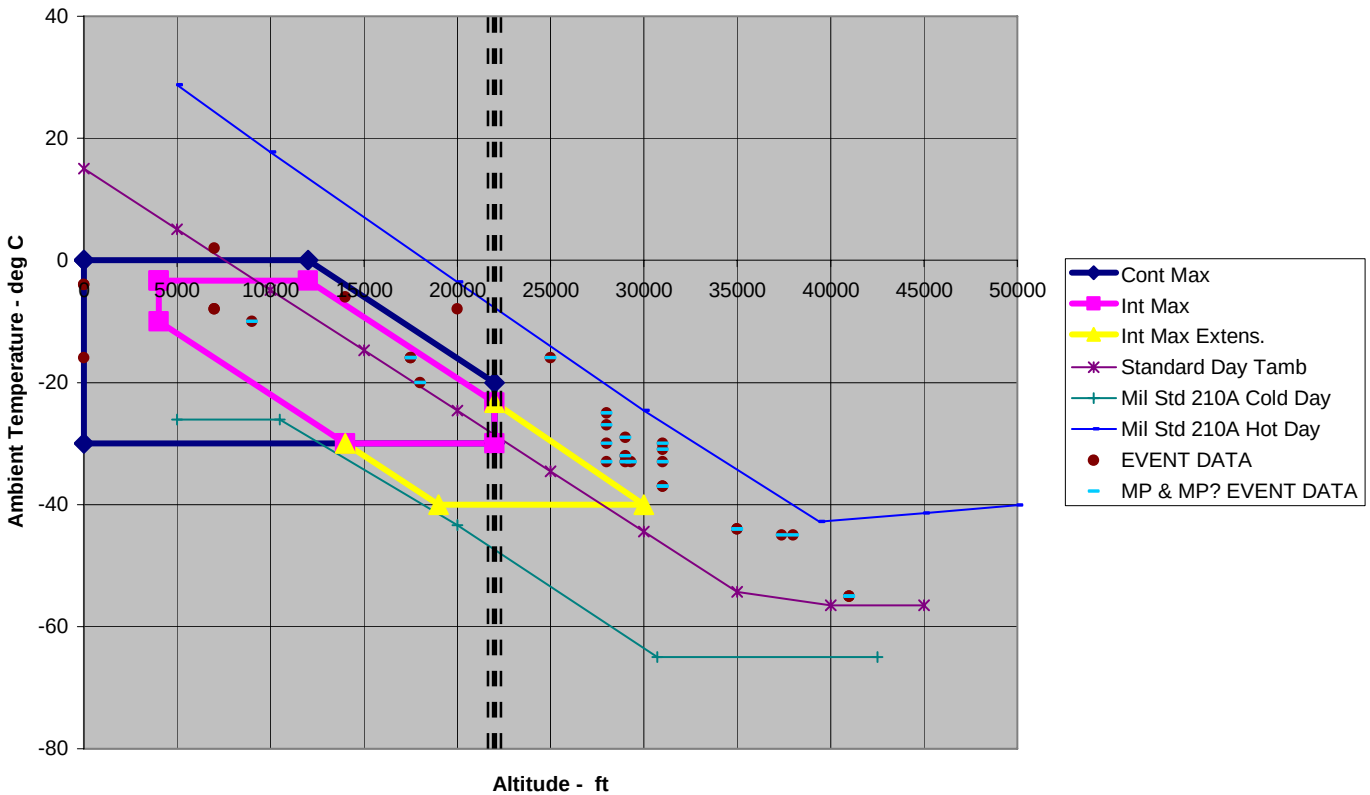
- SLD: Supercooled Large Droplets
- Freezing Drizzle > 250 microns
- Freezing Rain > 500 microns
- Not considered an issue for engine icing, except on ground, or taxi
- CPA required, new “table” point: 0.3 g/m^3, > 100 microns
- Modified Part 33.77 ice slab ingestion

FAR Part 33 Appendix D

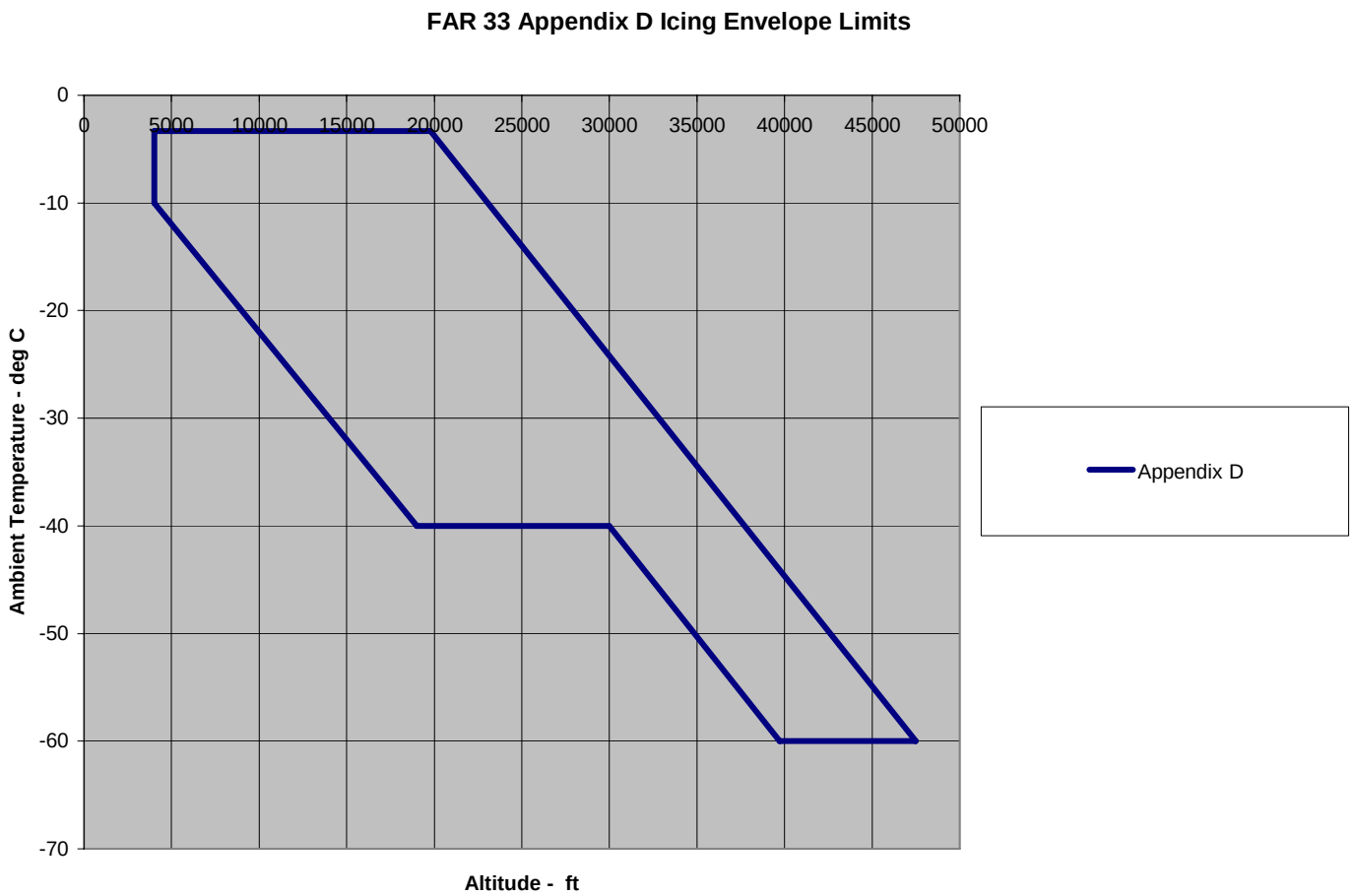
- 62 % of 260 icing events outside Appendix C envelope
- Ice Crystals or Mixed Phase
- Serious threat to engine: Surge, flameout or rollback
- New envelope, Appendix D proposed
- CPA required, new “table” point: 0.9 g/m^3 snow
- Method of compliance not currently available

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

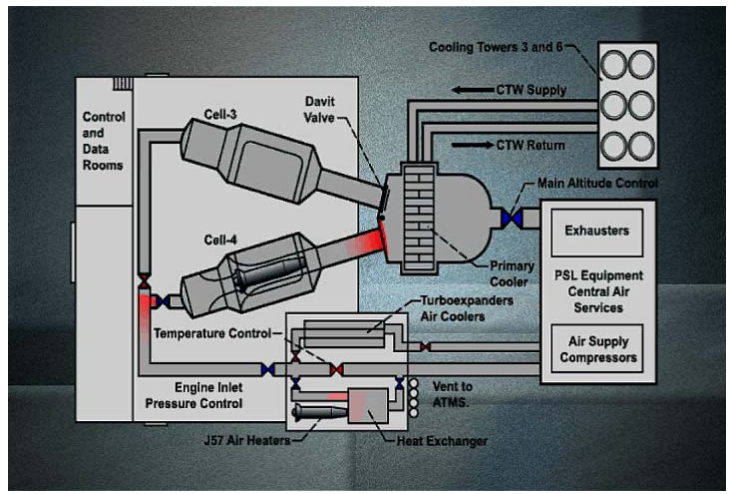


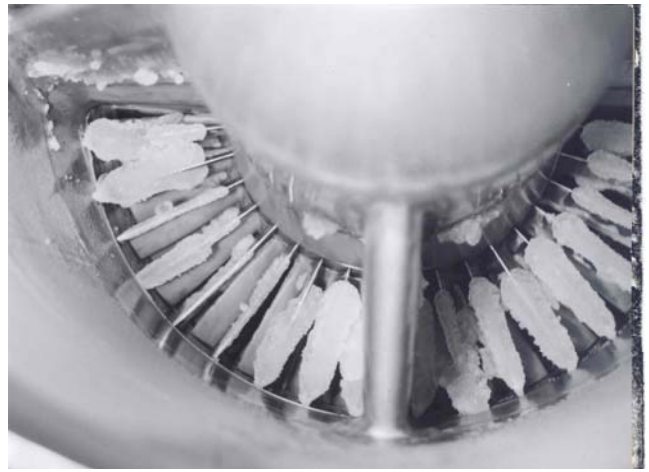
Existing Engine Icing Test Facilities

- Sea level:
  - NRC M-7 800 pps max, -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
  - In development - NASA Glenn PSL

M-7, NRC

PSL, NASA





Facility Challenges

Supercooled Large Droplets

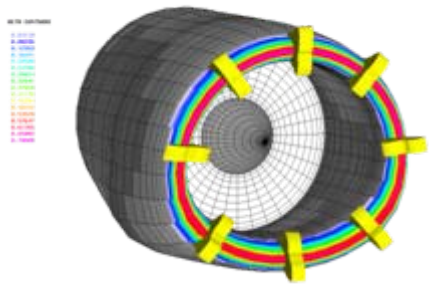
- Develop large droplet spray nozzles
- Overcome problem of supercooling of large droplets (residence time)
- Develop sea level to altitude transfer function (mixed phase too)

Mixed Phase

- Determine mixed phase cloud characteristics to better define App D and develop simulation methods for ground facilities
- Develop ice shaver and/or spray nozzles
- Develop instrumentation and measurement capabilities

Experimental Approaches

- Cascade
  - Static facility test to evaluate supercooled droplet and ice crystal accretion melting, splashing, and sticking
- Rotating Rigs
  - Dynamic facility testing to evaluate trajectory, erosion, shedding and rotational accretion studies
- Complete engine test
  - Fully instrumented (surface & air temperatures, visual, etc.) to monitor realistic engine evaluations



Analytical Capabilities

- Develop models/correlations of ice crystal formation mechanisms inside engine based on experimental evidence
- Couple ice accretion codes with internal flow code(s)
- Develop engine icing CFD tools for design and certification
  - Need modeling of trajectories, ice accretion, erosion, and shedding for engine internal flow paths from Appendix C, SLD, and ice crystals

Summary

Lots of opportunities in engine icing research and technology development in the areas of:

1) Test facilities - icing capabilities development for research and certification SLD
2) Engine icing physics - droplet and ice crystal behavior
3) Analytical modeling - develop of robust engineering tools

Interested in collaborative, partnered research relationships…..