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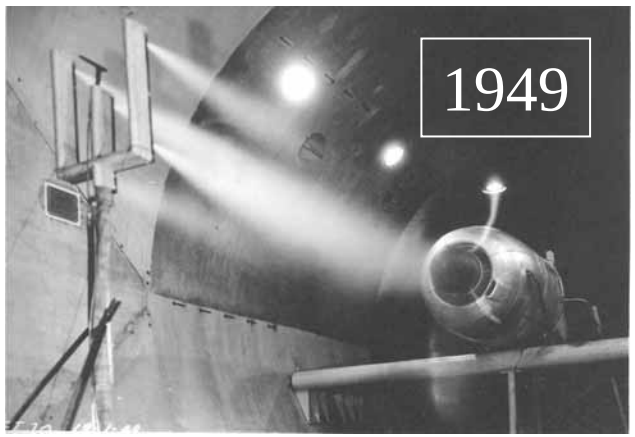
AIRA Research Thrust II: Propulsion System Icing



Icing Facilities

May 15, 2007

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National Research Council Canada
Conseil national de recherches Canada
Canada

Outline

- New Propulsion System Icing Requirements
- Ice Crystal Generation Issues
- Existing Engine Icing Certification Facilities
- Going forward – needs and opportunities
- Conclusion

New Icing Facility Requirements

FAR Part 33, Appendix X

- Supercooled liquid droplets: D_{50} > 100 micron

FAR Part 33, Appendix D

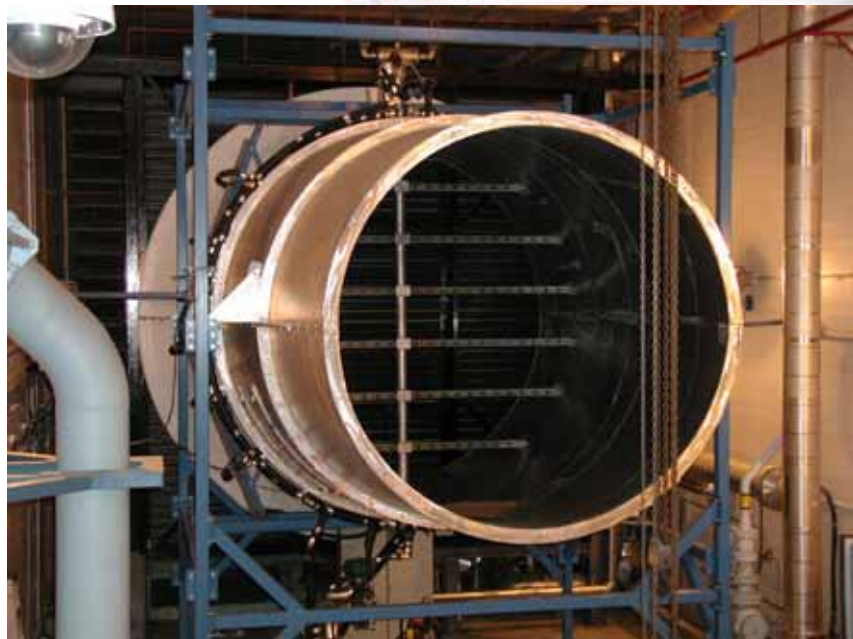
- Ice crystal size: 40-1000 micron (?)
- Total Water Content (TWC): < 10 g/m3 (?)

Ice Crystal Generation Issues

- Shaver versus spray nozzle
- Is the sprayed crystal supercooled?
- Is the particle morphology important?
- Residence time issue prior to entering engine

Existing Engine Icing Test Facilities

- Sea level:
  - GE Peebles (OH): 3600 pps, -8 C
  - NRC M-7 800 pps max, -25 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



Propulsion System Icing

NRC/GE MIRABEL

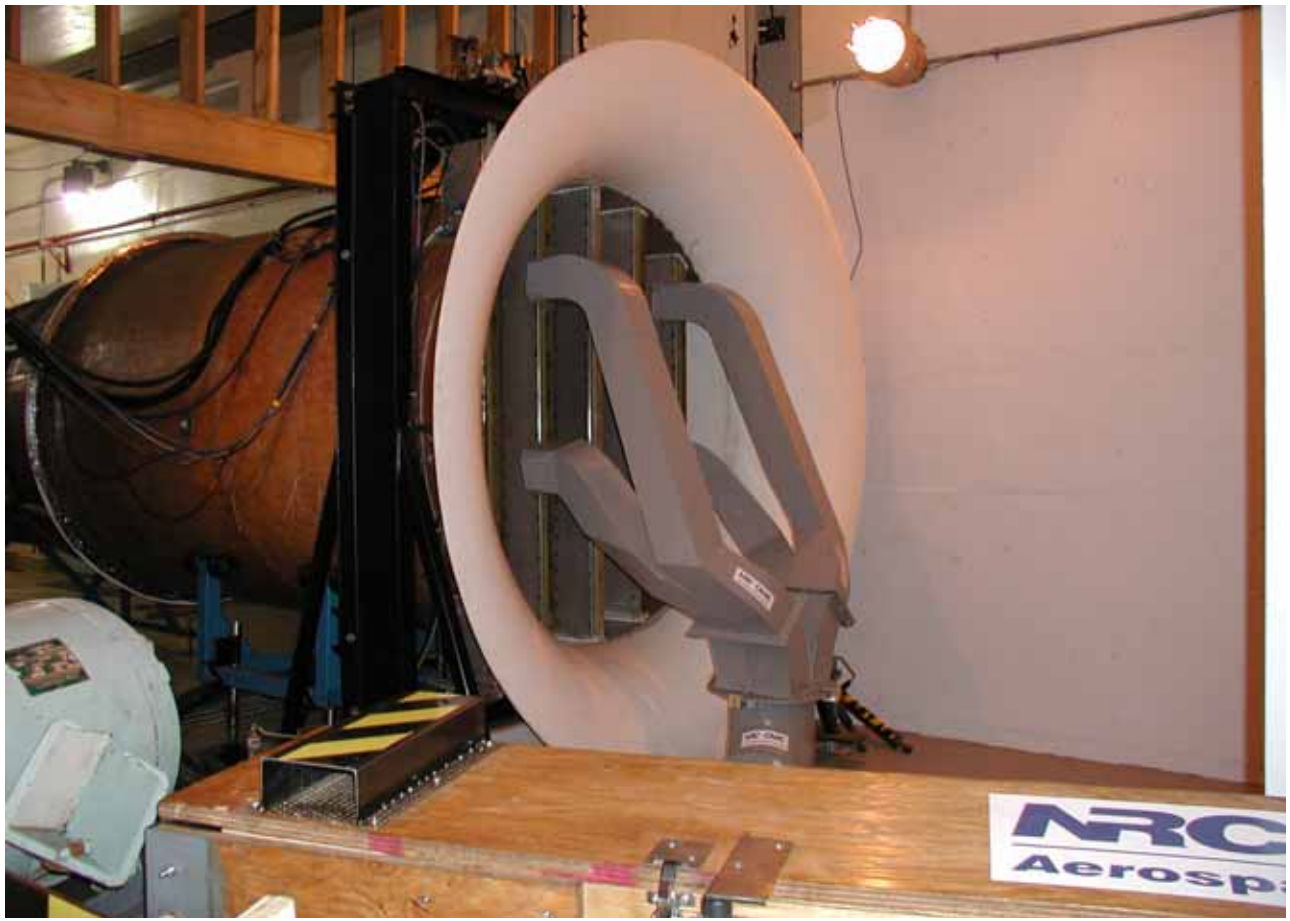
Propulsion System Icing

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 Shaver Blades

Ice/Snow Chutes



Ice Crystal Delivery System

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Ice Crystal Test Capabilities

- Maximum tunnel velocity 0.5 Mach
- Tunnel test section diameter: 34.5 inches
- TWC @ max velocity
  - Current: 5 g/m3
  - Upgrading for 2008: 15 g/m3
- Particle size variable between 100 - 1000 micron
- Maximum test duration
  - Current: 2-10 minutes depending on TWC
  - Upgrading for 2008: 30 minutes at 15 g/m3

Propulsion System Icing

Proposed Engine Icing Test Facilities with Ice Crystal Capability

- Sea level:
  - NRC M7-4: 800 pps max, -25 C (2009)
- Altitude:
  - NRC M-10: 10 pps, -20 C (2008)
  - NASA PSL: 600 pps, -40 C (2010?)

Current Research Efforts/Proposals

- Heated flat plate testing (NRC) 2006-2007
- Cascade rig test proposed (NRC) 2007
- Engine test (NRC) 2008?
- Rotating rig test proposed (NASA, AEDC,NRC) 2009?

Propulsion System Icing

Going Forward – Needs and Opportunities

Mixed Phase

- Determine altitude vs sea-level scaling factors
- Develop testing facilities both sea-level and altitude
- Understand physics of rapid ice crystal buildup within the compressor
- Need modeling of trajectories, ice buildup and shedding for engine internal flow paths

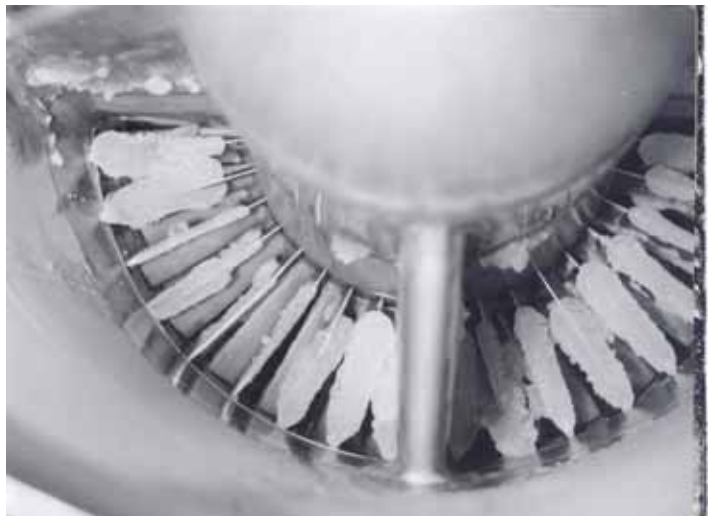
Going Forward – Needs and Opportunities

Need a Propulsion System Icing Research Plan

- Use information from the EHWG
- Ensure coordinated effort amongst OEM's, test labs and regulators.
- Funding from OEM and govt

Propulsion System Icing

Conclusions



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