NTSB Focus Area – Inflight Icing

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Board Member

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The NTSB is an independent U.S. Federal agency charged with determining the probable cause(s) of transportation accidents, making recommendations to prevent their recurrence, conducting special studies and investigations, and coordinating resources to assist victims and their families after an accident.
NTSB view of Airframe Icing

- Majority of icing conditions encountered are not a problem for certificated aircraft - we deal with the uncommon occurrences
- NTSB recommendations on aircraft icing date back to 1970
- Airframe icing has been on the NTSB’s Most Wanted List of safety improvements from 1997 to 2011
Accidents: October 31, 1994
Roselawn, IN, American Eagle ATR-72

- 68 fatalities
- Involved Supercooled Large Droplets
- Created ridge of ice aft of deice boots
- Caused ailerons to deflect, resulting in loss of control
Why is SLD important to consider?

- Accretions can cause stall or control anomalies at higher airspeed than normally expected.
- Ice can accrete aft of ice protection system.
- Sometimes difficult to see or detect.
- Pilots may not detect an unsafe condition.
Effect of SLD on ice accretion

Wing leading edge cross section

Appendix C

Direction of flight
Resultant Ice Shapes

Front Edge of Wing

Rough Ice
Resultant Ice Shapes

Front Edge of Wing

Rough Ice
Part 25 Appendix C
Continuous Maximum Icing

LWC vs. MVD

97-99%

SLD

15µ

40µ
NTSB Recommendations: Roselawn

Summary

• Icing conditions beyond current Part 23 & 25 certification requirements exist

• Continued flight in some icing conditions not possible

• Part 23 & 25 Appendix C certification requirements inadequate for SLD

• Training for Part 121 and 135 needed

• Research into SLD and development of detection and protection needed
Accidents: January 9, 1997
Monroe, MI – Comair Embraer EMB - 120

- 39 fatalities
- Operated in icing conditions near lower end of operating airspeed envelope (flaps retracted)
- Issues: use of ice protection, airspeed and configuration information, stall warning/protection system capabilities, use of autopilot, aircraft icing certification
Accident Sequence

• Approach to DTW with autopilot engaged
• Ice accreted for 4 ½ to 5 minutes (some SLD)
• De-ice boots not operated during approach
• Airplane rolled to 45 deg left roll despite autopilot right roll input
• Rapid roll left when autopilot disconnected due to stick shaker
• Presence of an estimated ¼ to 1/2 of an inch of ice created a rolling moment the A/P could not counteract.
• Airplane did not recover in the 3000 feet agl available
ENTERING THE LEFT TURN
START OF A/P WHEEL TO RIGHT
AUTOPilot Disconnect

FDR: ["AUTO-PILOT" DISCONNECT]
2 SECONDS AFTER A/P DISCONNECT

CAM: [STICK SHAKER "ON"]
FDR: ["AUTO-PILOT" DISCONNECT]
NTSB Recommendations: Monroe

Summary

• Both thin and imperceptible, as well as rough ice can be hazardous

• Boots need to be activated when entering icing conditions

• Minimum maneuvering speeds for all turbine airplanes, all flight conditions
  – Effects of various types, amounts & locations of ice accumulations
  – Address SLD, rough ice & tailplane icing

• Training for minimum maneuvering operations

• Review/revise AFM & OPS Manuals
NTSB Recommendations: Monroe (Cont’d)

• Further development of effective detection & protection systems necessary

• Cockpit warning systems for stall in icing conditions
  – Aural warnings
  – Stick shaker/pusher

• Hand fly in icing conditions with icing protection systems operating

• Review/revise certification testing requirements
  – Incorporate realistic certification ice shapes
Incidents: March 19, 2001
West Palm Beach, FL – Comair Flight 5054
EMB-120

• Pilot reported using de-icing boots (3 minute activation cycle) ; SAT = -4 Deg C
• Autopilot engaged
• Indications from FDR, CVR Ice Detector was active
• Loss of control in icing conditions
• 8000 ft altitude loss, structural damage to horizontal tail and elevator
• Intercycle Ice case
Comair 5054 - March 19, 2001
FDR/Radar Altitude Comparison During Event

UTC Time
USAF RADES Radar Altitude
FDR Altitude

Altitude
23:23:00 23:24:00 23:25:00 23:26:00 23:27:00 23:28:00
8000 10000 12000 14000 16000 18000

(FDR SFRN 162952) (FDR SFRN 162472)

(FDR SFRN 162472) (FDR SFRN 162952)
Comair 5054
Lift Coefficients Determined from FDR Load Factors
18:15:00 through 18:25:00

Calculated Lift Coefficient
"Clean" Cl-Alpha relationship from FDR data earlier in flight

Mach Number range: 0.22 - 0.28
Reynolds number range: 6.4 million - 8.2 million
View from above Horizontal Stabilizer

Elevator

Stabilizer
Right Side Stabilizer, Inboard of Elevator
NTSB Recommendations: West Palm Beach

• No new recommendations on icing issued
  – nothing new to recommend
Accidents:  February 16, 2005
Pueblo, CO – Cessna 560

- 8 fatalities
- Issues: airspeed and deice boot activation
Altitude Time History

- Gray ice mentioned
- De-ice boots operated
- Clear ice mentioned
- Stall
- SLD
- PUB
Accident Sequence

• Airplane slowed below $V_{\text{approach}}$
• De-ice boots not operated in second icing layer
• Presence of an estimated 1/6 of an inch or less of ice accreted in SLD conditions caused the airplane to stall prior to stick shaker
• Airplane entered a rapid left roll prior to stall warning
• Airplane did not recover in the 1,500 feet agl available
<table>
<thead>
<tr>
<th>Speed (Knots)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>114</td>
<td>Approach speed in icing</td>
</tr>
<tr>
<td>90</td>
<td>Accident Stall Speed</td>
</tr>
<tr>
<td>86</td>
<td>&quot;Ice&quot; Stick Shaker</td>
</tr>
<tr>
<td>81</td>
<td>&quot;Ice&quot; Stall Speed</td>
</tr>
<tr>
<td>76</td>
<td>Clean Stall Speed</td>
</tr>
</tbody>
</table>

**Accident Airplane Relevant Speeds**
NTSB Recommendations: Pueblo

Summary

• In icing conditions – increase speed and operate boots
• Activate boots when entering icing conditions
• Incorporate automatic boot cycling capability
• Review all boot equipped airplanes against revised certification standards when complete
• Specific modifications of Cessna 560 stall warning system regarding both thin & rough ice
Incidents: January 2, 2006
San Luis Obispo, CA - American Eagle Saab 340B

- Slowed on autopilot
- Lost 5000 feet altitude
- Nearly inverted
Lift Coefficient Extraction

Saab 340

Lift Coefficient - $C_L$

Stall Warning

Alpha (deg)

American Eagle 3008
Clean lift curve
NTSB Recommendations: San Luis Obispo

- NTSB issued 4 recommendations
  - Minimum airspeed
  - Modify stall protection
  - Ice detection
  - Disengage autopilot in icing conditions, except in periods of high workload
Accidents: January 27, 2009
Lubbock, TX – ATR42-320

- Unstable approach
- Failure to go round
- Airspeed
Flight Path
Crash During Approach to Landing
Empire Airlines doing business as FedEx ATR-42-320
Lubbock, Texas
January 27, 2009
CEN09MA142
NTSB Recommendations: Lubbock

- Simulator fidelity for ice accretion should be consistent with icing accidents and incidents.
- Flight crew simulation training for icing should include:
  - Recognizing changes in flight characteristics as icing develops.
  - Monitoring and maintaining appropriate icing speeds.
  - Stalls and approach to stalls with and without ice protection systems.
- Performance monitoring system.
Accidents and Incidents Demonstrate:

- Icing continues to be a threat to aviation safety
- Airplanes are operating in SLD environments for which they are not certified, particularly in lower layers of the atmosphere
- Rough ice shapes and intercycle ice shapes can cause large aerodynamic penalties, larger than some ice shapes currently used in certification
- Updating simulator models and incorporating previous icing incident/accident data to ensure accuracy can help to mitigate the icing threat
- Consideration by airplane manufacturers of an aircraft performance monitoring system for better flight crew awareness of severe icing encounters (like ATR's)