Lessons from Icing Accidents and Incidents

Presentation of NTSB Board Member
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to the
Experimental Aircraft Association
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The NTSB is an independent US 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 will not be a problem for certificated aircraft - we deal with the uncommon occurrences
- NTSB has had recommendations on aircraft icing dating back to 1981
- Airframe Icing has been on the NTSB’s Most Wanted List of safety improvements since 1997
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

SLD
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
97-99%
MVD
SLD
15µ
40µ

NTSB
Lift Coefficient - $C_L$

Alpha (deg)

Stick Shaker

Buffet

Stall Break

Swept Wing

Straight Wing
Fatal Accidents

- Comair Embraer EMB-120
  Monroe, MI – January, 1997
  - 39 fatalities
Accident Sequence – COM 3272

- 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]
Fatal Accidents

- Numerous Cessna 208B Caravans
  - Totaling 47 fatalities
Cessna 208 Caravan Accident/Incident Assessment:

- Between 1987 and 2003, 26 icing related accidents and incidents
- 15 of 26 ice accumulated in-flight
  - 10 of 15 In-flight were during approach and landing phases
- 10 of 26 involved ice not removed before takeoff
Cessna 208 Icing

• As a result of the NTSB assessment of the Cessna 208 accident and incident history, NTSB issued 4 recommendations to FAA on December 15, 2004
• 8 fatal
• Accident occurred while on approach
• FDR and CVR equipped
• Leveled off at 4900 ft, and reduced airspeed with autopilot engaged
• Experienced roll excursions after autopilot disconnect
• No stall warning until after onset of roll
Cessna 208 – Moscow
November, 2005

• Resulted in three urgent recommendations
  – 120 knots minimum airspeed
  – Prohibit flight in icing conditions worse than light
  – Disengage autopilot in icing conditions

• All adopted by FAA
Fatal Accidents

- Circuit City Cessna 560
  Pueblo, CO – February, 2005
  – 8 fatalities
Altitude Time History – C560

Gray ice mentioned
De-ice boots operated
Clear ice mentioned
Stall
SLD
PUB
C560 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
C560 Accident Airplane Relevant Speeds

114 Knots
Approach speed in icing

90 Accident Stall Speed

86 “Ice” Stick Shaker

81 “Ice” Stall Speed

76 Clean Stall Speed

Knots
Safety Board Probable Cause

“The flight crew’s failure to effectively monitor and maintain airspeed and comply with procedures for deice boot activation on the approach, which caused an aerodynamic stall from which they did not recover…”
Comair Flight 5054 EMB-120 Incident  
West Palm Beach, FL - March 19 2001

• 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
FDR Data - Comair 5054

Airspeed

Autopilot
Disconnect

AOA

Master
Caution

Pitch Trim

NTSB
View from above Horizontal Stabilizer

Elevator

Stabilizer
Right Side Stabilizer, Inboard of Elevator
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
Incidents

• American Eagle Saab 340B
  San Louis Obispo, CA - January, 2006
  – Slowed on autopilot
  – Lost 5000 feet altitude
  – Nearly inverted
Lift Coefficient Extraction

Saab 340

Lift Coefficient - $C_L$

Alpha (deg)

Stall Warning

American Eagle 3008
Clean lift curve
Incident - Saab 340B

• Resulted in 4 recommendations
  – Minimum airspeed
  – Modify stall protection
  – Ice detection
  – Disengage autopilot in icing conditions, except in periods of high workload

• FAA working with Saab and EASA to determine response.

• FAA issued Safety Alert for Operators
Incidents

- Cessna 500 – Air Ambulance
  Beverly, MA – March, 2007
  - Uncommanded roll during landing
  - Struck wing on runway
Safety Board Recommendations

• Currently 12 open in-flight icing safety recommendations to FAA
  – 7 Open - Acceptable
  – 4 Open - Unacceptable
  – 1 Open – Await response

• NTSB Federal Most Wanted
  “Reduce Dangers to Aircraft Flying in Icing Conditions”
  – Condition RED (Unacceptable response)
Recent 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
What can pilots remember?

- AIRSPEED, AIRSPEED, AIRSPEED
- Deice boots for all equipped airplanes need to be operated as soon as airplane enters icing conditions
- Autopilot can mask changes to handling qualities and trim changes due to ice. When possible, disconnect autopilot in icing conditions.
Positive FAA Actions

• AD’s regarding operation in severe icing and identifying SLD
• AD’s regarding deice boot operation
• Part 25 performance and handling in icing conditions
• Part 25 ice protection system operation
• NPRM Part 121 ice protection system operation
• NPRM Part 25 to include SLD conditions
• Advisory material has been upgraded
What still needs to be done by FAA?

- Final rule for SLD icing conditions to be used in certification, including Part 23
- Ensure all airplanes certified for flight in icing conditions can either safely operate in SLD, or can detect it and exit safely
- Deice boots for all equipped airplanes need to be operated as soon as airplane enters icing conditions
Bombardier Challenger CL-600
Montrose, CO – November 29, 2004

- 3 fatalities, 3 seriously injured
- Crashed during takeoff in snow
Small, almost imperceptible accumulations