NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

September 1, 1998

Addendum 4 to

Group Chairman's Factual Report

OPERATIONS/HUMAN PERFORMANCE

DCA97MA017

A. ACCIDENT

Operator:	COMAIR Inc.
Location:	Monroe, Michigan
Date:	January 9, 1997
Time:	1554 Eastern StandardTime (EST)[1]
Airplane:	EMB-120RT, N265CA Serial number 1257

B. ADDENDA

Attached is a February 19, 1997 facsimile of a January 26, 1996 internal Federal Aviation Administration (FAA) draft memorandum concerning EMB-120 roll upset events. The memorandum was provided at the request of the investigator-in-charge and was never formally adopted by the FAA.

[1] All times are Eastern Standard Time based on a 24-hour clock, unless otherwise noted. Actual time of accident is approximate, determined by the Flight Data Recorder (FDR) and Air Traffic Control (ATC) transcript.

Facsimile Cover Sheet

To: RICHARD RODRIGUEZ
Company: NTSB (AS-10)
Phone: [redacted]
Fax: 314-6319

From: BOB HENLEY
Company: FAA (AAI-100)
Phone: [redacted]
Fax: 267-5043

Date: 02/19/97
Pages including this cover page: 12

Comments: ROD, I SPOKE WITH STREETER. HE LEFT BOTH PACKAGES AT THE 6th RECEPTION DESK, ONE FOR LEBO AND ONE FOR YOU, WITH YOUR NAME AND ROUTING SYMBOL WRITTEN ON IT.

BH

U.S. Department of Transportation

Federal Aviation Administration

Memorandum

Subject: ACTION: National Transportation Safety Board Request Regarding Embraer Model 120 Airplane Roll Upset Events (Request #97-020)

Date: FEB 05 1997

From: Manager, Project Support Office, ACE-112

Reply to Attn. of: John Dow

To: Recommendation Quality Assurance Division, AAI-200
ATTN: Theresa Payne

This is in reply to your January 28, 1997 memo requesting a statement of issues regarding Embraer Model 120 Airplane Roll Upset Events.

Attached is the information that you requested. If there are any questions, please contact Mr. John Dow at 816-426-6934

for [redacted]
Larry Malir

Attachments

cc:
AIR-120
AAI-210

D R A F T

SUBJECT

Statement of issues regarding the EMBRAER Model 120 airplane roll upset events.

SUMMARY

There are three issues relating to the EMB-120 in icing conditions:

- a history of roll upset events;
- high roll control force characteristics that were identified in the screening program conducted as part of the FAA's overall actions following the ATR-72 accident of October 31, 1994; and,
- evidence of possible uncleared and undetected ice on the tailplane which suggests extending an existing AFM limitation to flaps 25° (which now only addresses a partial — but annunciated — failure of the tail ice protection system).

This paper addresses only the roll upset event issue. While the first two issues may have some elements in common, for the purpose of this document, they are considered separate.

Roll upset events: The ATR accident prompted a review of in-service accidents and incident reports involving roll axis control in known or suspected icing conditions. Of the approximately 50 events that were found, six involve the EMB-120. Based on available information of the six roll events and one speed decay event (see Event History following), it appears that the EMB-120 has demonstrated in-service:

- after the ATR-42/72 and the MU2B, the highest number of reported loss of control (not including tailplane) events;
- unexpected rapid onset of unusually high drag with ice accretion visible but not considered significant enough by the crew to warrant operation of the deicing boots;
- total or partial wing stall resulting in roll excursions in icing conditions;
- that the 160 KIAS recommended holding speed[1] may not provide adequate margin above stall when considering maneuvering loads, turbulence and gust encounters with certain kinds of ice accretion;
- that buffet onset with certain kinds of ice accretion may not be present in advance of stall and that the stall protection system may not provide sufficient margin above contaminated wing stall for certain probable icing conditions;

[1] The *EMBRAER NATURAL ICING CONDITIONS FLYING QUALITIES EVALUATION* report states: "*It was found that the holding speed to be maintained in natural icing conditions in turbulent air should be greater than 160 kt. As a function of the flying conditions and the pilots discretion.*" But, there is no advice to the pilot on how much greater than 160 knots or how to make that determination.

- that the autopilot design features (in the presence of the above conditions) apparently do not provide sufficient characteristics to provide time for the pilot to react, as claimed by the manufacturer, to prevent roll upset;
- a roll characteristic associated with ice that appears to be caused by a different mechanism than the one associated with the Roselawn ATR-72 accident ; but,
- a similar history to other ATR-42/-72 events insofar as the EMB-120 airplane with certain kinds of ice accretion may not provide an adequate stall margin for airline pilots of average alertness, skill or strength.

CONCLUSIONS

The EMB-120 has experienced seven icing incidents, some with induced stalls resulting in pitch and roll upsets without natural aerodynamic buffet in advance of stall or adequate artificial stall warning annunciation. The causes for these incidents are not completely understood as they occurred operationally, where sufficient data could not be recorded for thorough analysis. It is suspected that they resulted from a rapid buildup of ice on critical surfaces, protected and unprotected by the anti/deice systems, that caused a rapid deceleration or a disruption of airflow on the wing that led to a partial or full wing stall. The stalls were exacerbated by a higher speed due to irregular, extended ice shapes, turbulence, autopilot inputs, control movements, and maneuvering.

It was shown in the recent ATR accident investigation that adverse icing conditions, beyond the certification requirements, can occur operationally without pilot awareness. Subsequent artificial icing tests, on the ATR and EMB-120, have shown that large droplets and in some cases Appendix C icing conditions are capable of producing sharp edge ice shapes that are attached to the wings beyond the active part of the deicing boots on both upper and lower surfaces of the wing, that can severely disrupt the local airflow. These disruptions can cause high aileron forces, aileron self-deflection, and roll upsets/oscillations prior to a complete wing stall. The signs or cues that may warn a pilot that these dangerous icing conditions exist were identified for these two airplanes during the artificial icing test. These visual cues are now being used in crew recognition training, so the hazardous atmospheric conditions can be recognized and exited. This is a satisfactory approach until the extent of the conditions is known and then means to protect airplanes against this hazard, or reliable means to evade these conditions can be thoroughly evaluated for adequacy.

RECOMMENDATIONS

For the long term the following EMB-120 specific issues should be addressed in the context of the Phase III agenda.

1. Handling characteristics be examined at speeds approaching stick pusher thresholds during flight test with acceptable artificial ice shapes[2] to determine if adequate stall warning margins exist with unclearable ice that would accumulate in freezing rain, freezing drizzle, or runback ice conditions.
2. If adequate stall warning margins do not exist with unclearable ice, develop appropriate corrective means to prevent ice formation or remove ice on those critical surfaces to maintain safety margins at acceptable levels.
3. If inadequate stall warning margins are found to exist that cannot be corrected by preventing ice from forming or removing it periodically, then reliable means must be provided for the crew to assess conditions on critical surfaces of the airplane so that they can take appropriate action before hazardous degradation of performance or control occurs.
4. Mandate the appropriate actions by Airworthiness Directive.

[2] Discussed in a separate document.

EVENT HISTORY

Date:	April 1995
Place:	Tallahassee, FL
Airplane:	Unspecified
Operator:	Unspecified
Source[3]:	ASRS[4]: 302910
Summary[5]:	Both pilots observed trace icing on wing outboard leading edge IMC and then airspeed decayed from 180 knots to 140 knots and attitude increased 5 degrees nose up while there was no visual evidence of an increase of amount of trace ice on wing leading edge. Crew activated pneumatic boots after which speed increased and pitch decreased. Crew suspected tail ice in greater quantity than wing leading edge.
Comments:	• Drag increased rapidly and disproportionately to ice cues available to crew. • There was no report of a loss of control. The report is not clear if the pilot is inferring that more tail ice would mean more drag, or simply speculating about the state of ice on the tail. • Given that the speed increased after operation of the boots, it is logical to assume that most of the ice that caused the drag increase accreted on the boots and not beyond them because the speed returned after boot operation. • Loss of thrust due to propeller ice accretion is not suspect in this case. • One of the manifestations of large droplets are small ice "feathers" which some pilots characterize as "rime" ice. A combination of these feathers, and clear ice, difficult to see at night, possibly forming protuberances on or aft of the wing boots, may account for the characteristics described.

[3] Source of information about event.

[4] Aviation Safety Reporting System (ASRS) by NASA. The reports are identified by "accession number".

[5] Information edited for non-pertinent detail.

D R A F T

Date:	October 16, 1994
Place:	Elko, Nevada
Airplane:	Unspecified
Operator:	
Source:	ASRS: 286127 & Skywest Airlines Crew Information Bulletin (10/28/94)
Summary:	Aircraft stabilized at 160 knots at 13,000 feet and both pilots checked for ice on the wings and spinner, but did not see a significant amount at that time. With aircraft on autopilot, the pilot changed heading 35° and observed the "clicker" and the pusher almost simultaneously, then the airplane rolled over steeply to the right (close to 90°) and pitched [down]ward. Pilot took over manual control of the airplane and advanced both power levers, rolled the wings to the level position and increased pitch to bring the nose to the horizon. The F/O reported that the airspeed was approximately 150 knots and the bank angle approximately 10 to 20° when the departure occurred and assisted the pilot in controlling the airplane. The airplane rolled second time after which power was increased to maximum. The crew recovered in IMC. Crew observed clear icing on the leading edges of the wings and spinner and what appeared to be significantly more ice on the horizontal stabilizer. The deicing boots were not operated because the crew did not believe the ice thickness was of sufficient thickness. Pilot believes that speed should be stated at no less than 170 knots when clear ice is present. The reporter says that the airplane is critical in CG when loaded heavy in the tail. In post flight crew observed clear ice on lower leading edges and tail. Additional information notes that the shaker came on prior to the upset but does not mention the pusher.
Comments:	• Crew believed ice on the tail caused the problem, but it is not clear if they are inferring a tail stall or simply a drag increase. A tail stall is not likely in the cruise configuration in the conditions described. • Clear ice is difficult to see at night. Crew may have not examined upper surface of the wing beyond the boots. Upper wing surface may have been out of the view of the crew on the ground. • During the recovery, the crew may have exceeded the engine torque and/or temperature limits.

D R A F T

Date:	April 23, 1993
Place:	Pine Bluff, Arkansas
Airplane:	N24706
Operator:	Continental Express, Inc.
Source:	NTSB
Summary:	While climbing in a non-recommended vertical (attitude-hold) autopilot mode, the airplane stalled and suffered an upset and subsequent separation of propeller blades. The pilot held the control wheel aft through multiple firings of the stick pusher. "The Safety Board believes that an accretion of ice on the wing is the only reasonable explanation for the occurrence of the stick shaker activation and loss of control at higher-than-expected airspeeds. The Safety Board believes that only a small amount of ice could have a significant effect on the aerodynamic performance..." "During this accident, ice accretion on the wing significantly reduced the margin between stick shaker onset and the loss of control. The FDR and CVR correlation shows that within 2 seconds of stick shaker onset and autopilot disconnect, the airplane entered into a sudden and uncontrollable roll oscillation. The data then show that instead of relaxing control column force, the captain increased back force to hold the control column aft and introduced roll commands through the control wheel that were initially out of phase with the proper corrective deflections. Thus, the captain's initial control deflections following the stick shaker onset and the almost immediate loss of control aggravated, rather than corrected, the out-of-control maneuvers."
Comments:	• The pilot's actions in this accident appear to some extent like the ATR-42 accident in Italy in October 1987 holding nose-up control pressure against the stick pusher. • No turbulence was reported by passengers. • Drizzle was observed in the area of the accident and occasional moderate icing in clouds in precipitation was forecast for the area in a range of altitudes that the upset occurred in. One passenger recalled seeing a "whitish" substance that appeared to be snow about 8 to 10 inches above the windshield wipers. Testing at Edwards AFB in both Appendix C and SLD conditions produced ice accretion on the upper part of the windshield. • The aircrew did not recall seeing evidence of icing before the loss of control.

D R A F T

Date:	November 22, 1991
Place:	Clermont-Ferrand, France
Airplane:	F-GFEP
Operator:	Air Littoral
Source:	BEA/EMBRAER
Summary:	The Captain made the descent with the autopilot engaged and at 200 feet above the authorized altitude considered the descent rate too high and disconnected the autopilot manually, stabilizing the airplane at 4,500 feet. At this moment as airspeed decreased through 150 knots, the stick shaker operated and the airplane rolled right three times approximately 60° losing 1000 feet. Engine power was increased to well over 100%, airspeed increased and the boots were cycled by the first officer. The airplane landed without further incident and the crew observed 30 mm of ice on the horizontal stabilizer and wing tips and 5 mm on the inboard sections of the wing. There was no report of a failure indication on the deicing system monitor (DSM) that the boots failed to operate, or that there was any malfunction found with the ice protection system or the DSM. • Analysis of the air mass yielded an estimate of liquid water content of 1 to 1.2 g/m^3 at a temperature of -5 ° to -7° C. • The ice was clear and difficult to see at night. • The crew did not realize that ice was accreting on the airframe. • The weather forecast did not mention the severe icing conditions inside the cloud layer. • The estimate of the icing conditions was more severe than those taken into account during certification.
Comments:	• As described, the deicing boots were probably operated when the ice on the wing was 25 mm or one inch. The manufacturer reports that there was no problem with the airplane with over an inch of ice on the airfoils during natural icing flight testing. The maximum recommended thickness before operation of the boots is ¼ to ½". • It is not clear why there was ice on the tail. It is not stated if a DSM failure light(s) illuminated. It is not clear if the DSM was operating properly. • The manufacturer advises that small holes in the deicing boots can allow water to be inspired then subsequently freeze the boots not allowing them to inflate. That failure will not be detected by the DSM.

DRAFT

Date:	September 1991
Place:	FSM Arkansas
Airplane:	Unspecified
Operator:	Unspecified
Source:	ASRS 189745
Summary:	Aircraft was in level cruise with autopilot engaged at FL190. Both pilots felt vibration through floorboards, slid seats forward, and turned on [ice] inspection lights. Wings, prop spinner, and engine inlets did not appear to have excessive amounts of ice. About 30 seconds later after the first vibration, the stick shaker fired and Captain took control of the aircraft and called for all anti-ice equipment on. The aircraft did not respond to rudder/elevator inputs. [Airplane] was in a right bank, nose down at about 1000 FPM [descent]. At about 16,000 feet pilots regained control of aircraft. Crew believed tailplane had stalled in patch of severe ice. When de-ice boots operated, a failure light illuminated on the rudder and elevator boots. Crew reported that they were fatigued.

- Crew believed tail had stalled. No mention of flaps, speed, power, or gust encounter, but tail stall in the cruise configuration is unlikely.
- Initially, ice accretion was observed by the crew to be of insufficient thickness to be of concern, or even warrant operation of the ice protection system. Buildup of ice occurred without crew knowledge of severity to a point where control of the airplane was compromised.
- From the use of the term "vibration," it is possible that propeller vibration — not airframe buffet — alerted the crew, especially since there was no mention of control wheel vibration or buffet. Propeller vibration caused by mass imbalance has been reported on the Hamilton Standard propeller resulting from anti-icing failure of one blade.
- Stall protection system threshold did not prevent event.
- Manual operation of the flights controls did not prevent event.
- Additionally ice protection system of the tail reported inoperative, but is not believed to be a factor in the event.
- Turbulence is not mentioned.

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[6] Airplane identified by internal evidence. It is the only low-wing, t-tail airplane with ice-failure lights. Beech 200/1900 have lights which illuminate when the ice protection system pressure reaches a pressure switch activation threshold.

D R A F T

Date:	June 28, 1989
Place:	Klamath Falls, Oregon
Airplane:	N275UE
Operator:	United Express?
Source:	FAA SDR & ASRS 115422
Summary:	Aircraft at 16,000 in light icing and light turbulence. F/O was PF and while captain was out of seat, F/O descended to 15,000 and observed light mixed rime and clear ice and light turbulence. When captain returned he observed precipitation and a rapid decrease in airspeed from 180 to 160 knots. F/O increased power and stick shaker activated as speed was decreasing. Pilot took control and applied maximum power. The aircraft rolled left 30° then right 30 - 40° twice. Airplane was in precipitation, heavy icing and turbulence with rime ice visible on the wings. PIREP was heavy rime icing. Aircraft stabilized at 12,000 feet. Conditions were daylight, IMC.
Comments:	• Drag increased more rapidly than expected. • No indication of use of ice protection equipment. • No indication of vibration or buffet. Roll occurred after pilot took control of aircraft. • Description by pilot suggests freezing drizzle, freezing rain, mixed conditions, or some combination thereof.

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DRAFT

Date:	?
Place:	Elko, Nevada
Airplane:	
Operator:	
Source:	Operator report
Summary:	Reported event similar to Elko event of 10/16/94
Comments:	Data sheet misplaced

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