FLIGHT SAFETY FOUNDATION

Accident Prevention

Vol. 56 No. 3 *For Everyone Concerned with the Safety of Flight* March 1999

Thin, Rough Ice Accumulation Causes Twin-turboprop Aircraft Upset

The U.S. National Transportation Safety Board said that the absence of adequate aircraft-certification standards and operating procedures for flight in icing conditions was a probable cause of the accident, and that the flight crew's acceptance of a relatively low airspeed restriction while operating in icing conditions was a contributing factor.

FSF Editorial Staff

On Jan. 9, 1997, an Empresa Brasileira de Aeronautica (Embraer) EMB-120RT Brasilia operated by COMAIR Airlines (Comair) was in a left turn at 4,000 feet when the autopilot disconnected. The airplane rolled into a nearly inverted attitude and descended rapidly to the ground near Monroe, Michigan, U.S. The 29 occupants were killed, and the airplane was destroyed.

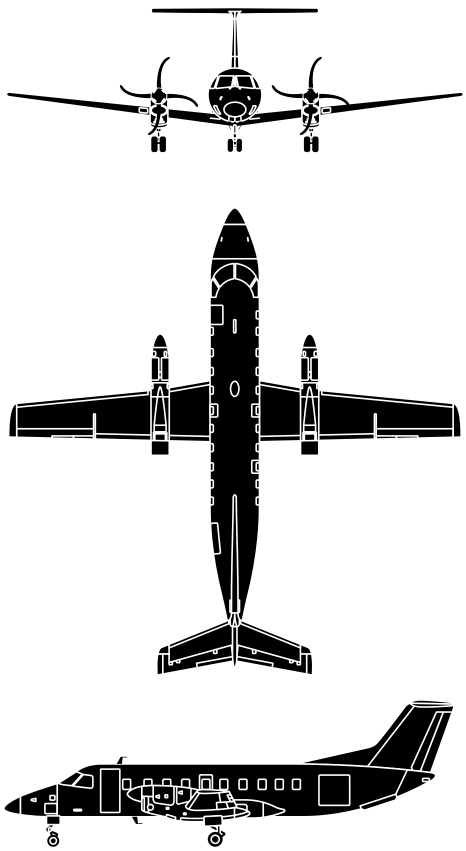
The U.S. National Transportation Safety Board (NTSB) said, in its final report, that the probable causes of the accident were: "the Federal Aviation Administration's (FAA) failure to establish adequate aircraft-certification standards for flight in icing conditions, the FAA's failure to ensure that a Centro Tecnico Aeroespacial/FAA-approved procedure for the accident airplane's deice system operation was implemented by U.S.-based air carriers, and the FAA's failure to require the establishment of adequate minimum airspeeds for icing conditions, which led to the loss of control when the airplane accumulated a thin, rough accretion of ice on its lifting surfaces." (Centro Tecnico Aeroespacial [CTA] is the aircraft-airworthiness authority in Brazil, where Embraer is based.)

"Contributing to the accident were the flight crew's decision to operate in icing conditions near the lower margin of the operating-airspeed envelope (with flaps retracted) and Comair's failure to establish and adequately disseminate unambiguous minimum-airspeed values for flap configurations and for flight in icing conditions," said the report.

The airplane was on a scheduled passenger flight (Flight 3272) from Cincinnati/Northern Kentucky International Airport in Covington, Kentucky, U.S., to Detroit (Michigan, U.S.) Metropolitan/Wayne County Airport.

Comair was founded in April 1977 as a commuter airline and became a Delta Connection air carrier in 1984. "At the time of the accident, Comair employed about 850 pilots and operated seven Saab 340, 40 EMB-120 and 45 Canadair CL-65 [Regional Jet] airplanes throughout a route system that primarily encompassed Florida and the north-central United States," said the report.

The captain, 42, was hired by Comair in February 1990. He had an airline transport pilot certificate and type ratings in the



Embraer EMB-120RT Brasilia

Empresa Brasileira de Aeronautica (Embraer) began designing the T-tail, twin-turboprop EMB-120 Brasilia regional airplane in 1979. The first production version in 1985 had Pratt & Whitney Canada PW115 engines, each rated at 1,500 shaft horsepower (shp; 1,119 kilowatts [kW]) and four-blade Hamilton Standard propellers. The EMB-120 was replaced in 1985 with the EMB-120RT (reduced takeoff) version, which had PW118 engines, each rated at 1,800 shp (1,342 kW).

The airplane has a two-pilot flight deck and cabin accommodations for 30 passengers and a flight attendant.

Maximum takeoff weight is 25,353 pounds (11,500 kilograms). Maximum cruising speed at 25,000 feet is 300 knots (556 kilometers per hour). Power-off stall speed with flaps retracted is 117 knots (217 kilometers per hour). Power-off stall speed with flaps extended is 87 knots (161 kilometers per hour).

Source: *Jane's All the World's Aircraft*

EMB-120, CL-65, Fairchild SA-227 and Boeing Vertol 234 helicopter. He had 5,329 flight hours, including approximately 1,097 flight hours as an EMB-120 pilot-in-command.

"Comair's director of operations (DO) described the captain as 'an absolute genius in mathematics … very detail oriented, professional and serious about his job,'" said the report. "According to the DO, the captain's goal with the airline was to direct the performance-engineering department when the company grew to the point at which it could support such a department."

The captain was a CL-65 flight instructor and check airman in 1994 and 1995. His duties as a CL-65 flight instructor included teaching unusual-attitude recognition and recovery. When he returned to line flying in December 1995, he was assigned as captain of the EMB-120.

The report said, "The DO stated that when he spoke with the captain on the day of the accident, the captain indicated that he planned to transition from the EMB-120 to the CL-65 in February 1997 (when his seniority position permitted him to make that transition)."

The first officer, 29, was hired by Comair in October 1994. He had a commercial pilot certificate and a flight instructor certificate. He had 2,582 flight hours, including 1,494 flight hours as an EMB-120 second-in-command.

The report said, "A line-check airman who had flown with the first officer … was impressed by his proficiency and demeanor. The line-check airman [told] the first officer that when he had more experience in line operations, the line-check airman would recommend the first officer for an instructor position."

In September 1996, the captain and first officer completed recurrent training in the EMB-120. The training included cockpit resource management training and unusual-attitude training. The unusual-attitude training, which included classroom training sessions and simulator training sessions, was not required by FAA and was not a testing item for Comair pilots.

"The upset training was considered a demonstration and familiarization item," said the report. "[The] goal was to help flight crews recognize upset situations and to know what to expect and how to respond to an upset. … The training addressed the following scenarios:

- "Autopilot limitations/modes;
- "Control-wheel displacement;
- "Stall series to stick pusher and stick shaker;
- "Unusual attitudes;
- "Slow/fast indicator demonstration; [and,]
- "Yaw demonstration with rapid power-lever advancement."

The accident airplane was manufactured by Embraer and purchased by Comair in 1991. At the time of the accident, the airplane had 12,752 service hours, including 12,734 cycles.

The airplane had a four-channel cockpit voice recorder (CVR) and a 98-parameter flight data recorder (FDR). The report said that some flight-control-position data recorded by the FDR were "anomalous, spurious or out of calibration," and that similar data discrepancies were found during the investigations of seven previous EMB-120 accidents.

"The [FAA's] current EMB-120 [FDR] system inspection procedure is inadequate because it allows existing flight-control-sensor anomalies to go undetected, and thus uncorrected," said the report.

During the morning of Jan. 9, 1997, the flight crew flew another EMB-120 from Covington to Dayton, Ohio, U.S., and back to Covington. Flight 3272 was scheduled to depart at 1430 hours local time, but the accident airplane arrived in Covington at 1427. The airplane was serviced, and the crew taxied it from the airport-terminal gate at 1451.

"An additional delay was encountered because the weather conditions (light snow) necessitated airframe deicing before takeoff," said the report. The airplane was deiced at 1457 with Type 1 deicing fluid, which is a 50/50 mixture of ethylene glycol and heated water.

The airplane departed from Covington at 1509. The report said, "Review of [air traffic control (ATC)] and [CVR] transcripts … indicated that the captain was performing the radio communications and other pilot-not-flying duties, while the first officer was performing the pilot-flying duties … ."

The final cruise altitude requested on the instrument flight rules flight plan was Flight Level (FL) 190. Nevertheless, the captain requested and received clearance from Indianapolis Air Route Traffic Control Center to climb to FL 210 because of turbulence at FL 190. He said that the flight had encountered occasional light chop while flying through cloud tops at FL 190 and that the flight conditions were smooth at FL 210.

At 1533 (approximately eight minutes after the airplane entered level flight at FL 210), Cleveland Air Route Traffic Control Center (Cleveland Center) told the crew to descend to 12,000 feet. At 1539, Cleveland Center told the crew to descend to 11,000 feet and to fly a heading of 030 degrees to join the MIZAR Standard Terminal Arrival Route to Detroit Metropolitan Airport.

At 1540, the CVR recorded the airport's automatic terminal information system (ATIS) broadcast. The ATIS broadcast said, in part, that the wind was from 070 degrees at six knots, visibility was one mile (1.6 kilometers) in light snow, ceilings were 1,400 feet broken and 2,100 feet overcast, and that the instrument landing system (ILS) approach to Runway 3R was in use.

When Runway 3R was in use at Detroit Metropolitan Airport, standard ATC procedure was for Cleveland Center controllers to issue instructions to position inbound turboprop airplanes at 11,000 feet and inbound turbojet airplanes at 12,000 feet at or near MIZAR Intersection before handing off the flights to Detroit Approach Control (Detroit Approach). (MIZAR Intersection is approximately 38 nautical miles [70 kilometers] southwest of the airport.)

At 1542, Cleveland Center handed off the EMB-120 to Detroit Approach. At 1543, Detroit Approach told the crew to depart MIZAR on a heading of 050 degrees; the controller said that the heading was a vector for the ILS 3R final approach course. The controller then told the crew to reduce airspeed to 190 knots.

Approximately 14 seconds later, the crew of America West Flight 50 ("Cactus 50") made initial radio contact with Detroit Approach and advised that their aircraft was at 12,000 feet. The report said, "During postaccident interviews, the Detroit [Approach] controller [said] that although Comair Flight 3272 appeared on his radar display and frequency before Cactus 50, he decided that Cactus 50, an Airbus A320, would precede Comair 3272 on the approach to Runway 3R because Cactus 50 was faster and had a more direct path to the inbound radar fix."

The EMB-120 was approximately five nautical miles (nine kilometers) from MIZAR when, at 1545, the controller told the crew to descend to 7,000 feet. The airplane was over MIZAR and was being turned to the assigned heading of 050 degrees when the controller told the crew to fly a heading of 030 degrees. The controller said that the heading was a vector for sequencing. At 1547, the controller told the crew to turn to a heading of 055 degrees.

The report said that the airplane was descending through approximately 8,600 feet when, at 1547, the first officer called for the descent checklist. "The descent checklist included an ice-protection prompt (to be accomplished before the airplane entered icing conditions), to which the first officer responded, 'windshield, props, standard seven,'" said the report.

"The term 'standard seven' refers to switches for the following anti-ice system items: angle-of-attack (AOA) sensors (left and right sides of the fuselage), side slip sensor (top center of the fuselage, aft of the windscreen), total air temperature sensor, and the pitot/static system (left, right and auxiliary). …

"The CVR did not record any flight-crew discussion of ice accumulation or leading-edge deicing boot activation during the airplane's approach to the Detroit area."

At 1548, the first officer began an approach briefing, which is the first item on the approach checklist. He said that he would make a coupled approach (autopilot engaged). The approach briefing was interrupted when the controller told the crew to fly a heading of 070 degrees. The first officer then completed the approach briefing and asked the captain if he had any questions or comments.

"No questions [pause in conversation], 21, 14 and 43 are your bugs," said the captain. The captain was stating that the

Cockpit Voice Recorder Transcript
Comair Flight 3272; Embraer Brasilia; Monroe, Michigan, U.S.; Jan. 9, 1997

(FSF editorial note: The following transcript is from the U.S. National Transportation Safety Board accident report. The FSF editorial staff has added notes to define some terms that may be unfamiliar to the reader. Times are local.)

Time	Source	Content
1543:03	**RDO-1**	good afternoon detroit approach ... comair thirty-two seventy-two one one eleven thousand hotel.
1543:07	**DTW**	comair thirty-two seventy-two detroit approach ... depart mizar heading zero five zero vector to ILS runway three right final approach course ... runway three right braking action reported poor by a DC niner.
1543:16	**RDO-1**	roger depart mizar heading zero five zero comair thirty-two seventy-two.
1544:11	**DTW**	comair thirty-two seventy-two maintain one niner zero knots ... if unable advise.
1544:15	**RDO-1**	roger, one niner zero knots comair thirty-two seventy-two.
1544:44	**INT-1**	I think there's your —
1544:46	**INT-2**	ah thanks.
1544:48	**INT-2**	whoops.
1544:49	**INT-1**	stand by.
1544:50	**INT-2**	and five miles for ah ... for ah mizar.
1545:46	**DTW**	comair thirty-two seventy-two descend and maintain seven thousand.
1545:49	**RDO-1**	seven thousand comair thirty-two seventy-two.
1545:53	**INT-1**	and seven's in the altitude alerter.
1545:56	**INT-2**	seven's verified ... there's mizar and we're turning zero five zero.
1546:12	**DTW**	comair thirty-two seventy-two turn left heading zero three zero vector for sequencing.
1546:14	**RDO-1**	zero three zero comair thirty-two seventy-two.
1546:57	**DTW**	northwest two seventy-two information alpha is current ... winds zero six zero at six ... visibility one and one half ... light snow ... ceiling six hundred broken one thousand one hundred broken ... two thousand one hundred overcast ... altimeter's two niner one niner ... runway three right RVR three thousand five hundred ... braking action reported poor by DC niner.

airspeed-indicator references for the approach and for a missed approach were 121 knots (V_{REF}, final approach reference speed), 114 knots (V_2, takeoff safety speed) and 143 knots (V_{FS}, final segment speed).

The crew then continued the approach checklist. At 1549, they were interrupted by instructions from Detroit Approach to fly a heading of 140 degrees and to reduce airspeed to 170 knots. The crew did not conduct the last two items on the approach checklist, which were to notify the flight attendants of arrival and to extend the flaps 15 degrees.

"[Nevertheless,] according to several Comair EMB-120 pilots interviewed after the accident, the last two approach-checklist items would typically be accomplished later during the approach when the airplane was closer to its destination airport," said the report.

At 1550, the crew was told to contact Detroit Approach on a different radio frequency. The frequency change was accomplished, and the controller told the crew to reduce speed to 170 knots, descend to 6,000 feet and fly a heading of 140 degrees.

At 1551, the captain told Comair's operations office that the airplane would arrive at the gate in approximately nine minutes and 48 seconds, and would require fuel before departing on the next scheduled flight.

At 1552, Detroit Approach told the crew to descend to 4,000 feet. At 1553, the controller told the crew to fly a heading of 180 degrees and reduce airspeed to 150 knots. The controller then told the crew to fly a heading of 090 degrees and to plan to be vectored across the ILS localizer course.

FDR data showed that the airplane began a left turn at about 1554:05. "At 1554:10, at an airspeed of 156 knots, the airplane's roll attitude had steepened to about 23 degrees of left bank, and the [control wheel position (CWP)] began to move back to the right; however, the airplane's left roll attitude continued to steepen," said the report.

The CVR recorded sounds similar to elevator-trim servo operation, and the FDR recorded data showing that engine power was increased from flight idle. "At 1554:17, the FDR began to record split engine-torque values, with higher torque values recorded for the right engine than [for] the left, which continued until the autopilot disengaged," said the report. FDR data also showed that the left bank continued to steepen and that the CWP moved farther to the right.

At 1554:20.8, the captain said, "Looks like your low-speed indicator."

The report said, "The low-speed indicator referenced by the captain is the fast/slow indicator system, which consists of diamond-shaped indicators located on the left side of the electronic attitude director indicator. The fast/slow indicator is an angle-of-attack-based indicator that indicates deviations from the optimum approach speeds; up = fast, down = slow, and center = 1.3 V_S.” [V_S is stall speed or minimum steady-flight speed at which the airplane is controllable.]

The CVR recording of the first officer’s response was unintelligible. At 1554:23.6, the captain said “power,” and the FDR recorded increasing engine torque values.

“FDR data indicated that at 1554:24.1, the airplane was at an airspeed of 146 knots and [in] a left bank angle that was steepening beyond 45 degrees, and that the autopilot disconnected,” said the report. “The CVR transcript indicated that, about that time, a sound similar to the stick shaker [stall-warning clacker] started.”

The report said, “FDR data indicated that in … less than two seconds after the autopilot disconnected … , the following changes occurred:

- “The airplane’s CWP moved from about 18 degrees right to about 19 degrees left;
- “The roll attitude increased from about 45 degrees left bank to about 140 degrees left bank; and,
- “The pitch attitude decreased from nearly two degrees nose up to about 17 degrees nose down.”

The report said, “According to FDR data, the airplane’s left roll attitude was increasing to more than 140 degrees, and the pitch attitude was decreasing to nearly 50 degrees nose down by 1554:29. … At 1554:31, a sound similar to the stick shaker started and continued to the end of the tape.” The CVR recording ended at 1554:40.

“The airplane struck the ground in a nose-down attitude at a high rate of speed and came to rest … in a field adjacent to a church campground,” the report said. “The accident site was approximately 19 [nautical] miles [35 kilometers] southwest of the destination airport.

“Fragmented airplane wreckage was found in and around three impact craters, with airplane debris located up to 340 feet [104 meters] from the largest (center) impact crater. The largest impact crater was about 15 feet 7 inches [4.8 meters] wide, 25 feet [7.6 meters] long, and four feet [1.2 meters] deep at its deepest point and contained most of the fuselage wreckage and human remains. The two smaller impact craters were located on both sides of the larger (main) impact crater and contained the right and left engines and their respective components.”

The report said, “[A] postimpact fire consumed the portions of the airplane wreckage in which fuel was present and melted

1547:17	**CAM**	[sound of three clicks]
1547:18	**DTW**	comair thirty-two seventy-two turn right heading zero five five.
1547:20	**CAM**	[sound of two clicks]
1547:21	**RDO-1**	zero five five comair thirty-two seventy-two
1547:32	**INT-2**	[sound similar to that of a human sniffle]
1547:47	**INT-2**	let’s run the descent check.
1547:49	**INT-1**	ice protection?
1547:51	**INT-2**	windshield, props, standard seven.
1547:53	**INT-1**	ignition?
1547:54	**INT-2**	auto.
1547:55	**INT-1**	pressurization?
1547:55	**INT-2**	it’s ah reset for landing in detroit ... six thirty-nine ... looks good.
1548:01	**INT-1**	altimeters?
1548:03	**INT-2**	ah twenty-one.
1548:04	**INT-1**	set left.
1548:05	**INT-2**	set right.
1548:06	**INT-1**	landing lights?
1548:06	**INT-2**	landing lights on.
1548:07	**INT-1**	seatbelt sign?
1548:08	**INT-2**	on.
1548:09	**INT-1**	PACKS and bleeds?
1548:10	**INT-2**	four lows.
1548:11	**INT-1**	crossfeed?
1548:12	**INT-2**	crossfeed’s off.
1548:12	**INT-1**	that completes that.
1548:14	**INT-2**	okay ... a thousand to go ... uhm ... we’re going to do an ILS to runway three right ... it’ll be a coupled approach ... flaps twenty-five ... frequency is one one one point five ... that’s set ... might as well set that in there ... inbound course is zero three five.
1548:38	**CAM**	[sound of three tones similar to that of the altitude alerter]
1548:43	**INT-2**	we’re going to intercept the top somewhere ah whatever altitude he gives us ... ah ... twenty-seven hundred’s the intercept to the glide slope.
1548:47	**DTW**	comair thirty-two seventy-two turn right heading zero seven zero.
1548:50	**RDO-1**	zero seven zero comair thirty-two seventy-two.
1548:55	**CAM**	[sound similar to increase in engine/prop noise]

1549:13	**INT-2**	it's ah two hundred foot approach with the decision altitude of eight thirty-three ... you've already got that set in there ... missed approach will be published climb to eleven hundred ... and a climbing right turn to three thousand direct to the ah DM locator outer marker "Spencer" * which is ah two twenty-three that's set ... and hold ... that will be a teardrop entry ... questions, comments.
1549:38	**INT-1**	no questions ... twenty-one, fourteen, and forty-three are your bugs.
1549:43	**INT-2**	twenty-one, fourteen, forty-three ... set.
1549:48	**INT-1**	autofeather?
1549:50	**INT-2**	armed.
1549:51	**INT-1**	nav radios.
1549:53	**INT-2**	nav radios are ah set eleven point five.
1549:54	**DTW**	comair thirty-two seventy-two turn right to a heading of one four zero ... reduce speed to one seven zero.
1549:59	**RDO-1**	heading one four zero speed one seven zero comair thirty-two seventy-two.
1550:11	**INT-1**	I'll be on two.
1550:11	**INT-2**	alright.
1550:15	**RDO-1**	good afternoon detroit ... comair thirty-two seventy-two.
1550:28	**INT-1**	nobody likes to answer me ... I'm back.
1550:28	**DTW**	comair thirty-two seventy-two contact approach one two five point one five so long.
1550:32	**RDO-1**	one two five point one five comair thirty-two seventy-two, good day.
1550:36	**COM**	[sound of tone similar to that of frequency change]
1550:38	**INT-2**	maybe you should try being abusive with them.
1550:40	**INT-1**	huh?
1550:41	**INT-2**	gotta try being abusive with them.
1550:43	**INT-1**	that's right.
1550:43	**INT-2**	answer the phone, dummy.
1550:44	**INT-1**	yeah.
1550:45	**RDO-1**	good afternoon detroit approach comair thirty-two seventy-two seven thousand.
1550:49	**DTW**	comair thirty-two seventy-two detroit approach ... reduce speed to one seven zero and maintain six thousand.
1550:54	**RDO-1**	speed one seven zero ... descend and maintain six thousand comair thirty-two seventy-two.
1550:57	**CAM**	[sound of three tones similar to that of the altitude alerter]

portions of the wreckage … . There was no indication that any fire existed before the airplane impacted the ground.

"The accident was not survivable because the impact forces exceeded human tolerances and aircraft design strength; no occupiable space remained intact."

Investigators found no evidence of a pre-existing malfunction or failure of the airplane or its systems.

Investigators examined the possibility that wake turbulence was involved in the accident, because the A320 (Cactus 50) descended through 5,500 feet at the same location where, two minutes later, the EMB-120 entered the uncommanded roll at 4,000 feet. Nevertheless, the report said that the A320's wake vortices could not have descended below 4,500 feet.

"Although the radar ground tracks of Cactus 50 and Comair Flight 3272 converged near the accident site, … Cactus 50's wake vortices would have been above and northeast of Comair Flight 3272's flight path near the upset location," said the report. "Thus, Comair Flight 3272 was separated from the vortices vertically and horizontally, and, therefore, wake turbulence was not a factor in the accident."

FDR data showing a decrease in lift and an increase in drag during the descent from 7,000 feet to 4,000 feet indicated that a thin, rough layer of ice accumulated on the airplane's leading edges and that ice ridges might have built up on the upper surface of the wing leading edges.

The subsequent airplane upset might have involved several factors, including asymmetric lift caused by the ice accumulation and by uneven ice self-shedding; operation at a relatively low airspeed without flaps; aerodynamic effects created during the left turn and during asymmetric power application; and the autopilot disengagement.

The EMB-120 had no ice adhering to its surfaces when the crew began the descent from cruise altitude. "Although Comair Flight 3272 was operating in winter weather conditions throughout its flight from the Cincinnati area to Detroit, CVR and weather information indicated that the airplane was operating above the cloud tops at its cruise altitude of 21,000 feet … ," said the report. "Further, the temperatures and the altitudes flown during the en route phase of the flight were too cold to be conducive to airframe ice accretion … .

"Meteorological information and pilot reports indicated that the airplane was probably intermittently in clouds as it descended between about 11,000 feet … and 8,200 feet … ; below 8,200 feet … , the airplane was probably operating predominantly in the clouds."

Before departing from Covington, the crew received weather information that included forecasts and reports of icing conditions. An AIRMET (airman's meteorological information) said that there might be occasional light-to-moderate rime icing in clouds below 18,000 feet. A pilot report (PIREP) said that a Falcon 20 crew encountered light-to-moderate rime icing while descending from 14,000 feet to 4,000 feet 17 nautical miles (32 kilometers) east of Detroit Metropolitan Airport.

Several air-carrier flight crews reported icing in the Detroit area on the afternoon of the accident. The reports included the following:

- The crew of Northwest Flight 208, a McDonnell Douglas DC-9 that was approximately 10 minutes ahead of the EMB-120 on the approach to Runway 3R, reported light rime icing;

- The crew of Cactus 50, the Airbus A320, reported moderate rime icing; and,

- The crew of Northwest Flight 272, a DC-9 approximately two minutes behind the EMB-120, reported moderate-to-severe rime icing.

The report said, "The captain of Northwest Flight 272 … stated [during a postaccident interview] that the icing conditions they encountered during the approach to Detroit were the 'heaviest I've seen this season … [there was] some splash back [to side windows, which] does not happen too often on [a] DC-9; only heavy ice will do this.'

"The captain … stated that the cloud tops were near 7,000 [feet] or 8,000 feet … and that the airplane started to accumulate ice rapidly when the airplane leveled off at 4,000 feet. … The first officer [said] that 'this encounter was as bad as I have ever seen it.'"

The icing PIREPs were not disseminated by air traffic controllers or by the ATIS. "Although … the absence of these additional PIREPs [likely did not affect] the accident flight crew's actions (because they were provided with adequate preflight, en route and arrival weather information to conduct the flight safely; they should have been aware that they would be operating in potential icing conditions), it is possible that the PIREP information would have greatly benefited other pilots," said the report.

The crew of one air-carrier airplane reported that they encountered no icing during their approach to Detroit. "The crew of Northwest Flight 483, which was approximately five minutes ahead of the EMB-120 on the approach, reported observing no icing," said the report.

The accident-airplane flight crew's activation of the ice-protection systems for the windshield and propellers indicated that they were aware that the airplane was operating in icing conditions. Nevertheless, the crew did not activate the deicing boots. The report said that the crew either did not see ice building

1551:00	**INT-1**	six.
1551:00	**INT-2**	six thousand.
1551:14	**DTW**	comair thirty-two seventy-two fly heading one four zero.
1551:17	**RDO-1**	one four zero comair thirty-two seventy-two.
1551:20	**INT-2**	wonder what plane he's looking at?
1551:25	**INT-1**	ah the one ah that's not going one four zero.
1551:27	**OPS**	thirty-two seventy-two you calling detroit?
1551:30	**RDO-1**	yes sir we're in range ... ah positive fuel ... we'll be at the gate in approximately nine minutes and forty-eight seconds.
1551:38	**OPS**	approximately, huh?
1551:39	**RDO-1**	approx—, of course.
1551:41	**OPS**	do you guys know if you have any special assistance coming in?
1551:44	**RDO-1**	I can't recall anyone coming out so I thi— I think we're all good there ... all all we'll need is just fuel.
1551:51	**OPS**	roger that ah bravo * three.
1551:53	**CAM**	[sound of three tones similar to that of the altitude alerter]
1551:54	**RDO-1**	roger that ... and how many do we have going back so I know how many seats to give you?
1551:58	**OPS**	ah, you're booked to twenty-eight right now.
1552:01	**RDO-1**	okay, that'll be our load then ... we can take them all ... thanks.
1552:07	**INT-1**	took 'em a while but they came back to me.
1552:13	**INT-2**	that's good news ... no changes while you were away.
1552:13	**DTW**	comair thirty-two seventy-two descend and maintain four thousand.
1552:16	**RDO-1**	four thousand comair thirty-two seventy-two.
1552:20	**INT-1**	four's in the altitude alert.
1552:23	**INT-2**	four thousand verified.
1553:03	**DTW**	cactus fifty zero six zero to intercept three right.
1553:05	**CACT50**	zero six zero okay ... you got any windshear reports on the final?
1553:09	**DTW**	ah no ... I haven't had anything ah ... just ah slick runways and ah low visibilities.
1553:15	**CACT50**	okay ... yeah it's two thirty-seven at thirty-two up here.
1553:18	**DTW**	ah you'll pick up a head wind once you get down ah probably oh two thousand feet or so.

1553:25	**DTW**	comair thirty-two seventy-two turn right heading one eight zero ... reduce speed to one five zero.
1553:29	**RDO-1**	heading one eight zero ... speed one five zero comair thirty-two seventy-two.
1553:42	**CAM**	[sound of three tones similar to that of the altitude alerter]
1553:42	**DTW**	comair thirty-two seventy-two reduce speed to one five zero.
1553:45	**RDO-1**	speed one five zero comair thirty-two seventy-two.
1553:52	**INT-2**	this guys got —
1553:53	**INT-1**	they gotta always tell us twice.
1553:55	**INT-2**	he's got short term memory disorder I think.
1553:57	**INT-1**	is that what that is?
1553:58	**INT-2**	yeah, he's got alzheimer's ... that's what it is.
1553:59	**DTW**	comair thirty-two seventy-two now turn left heading zero nine zero ... plan a vector across the localizer.
1554:04	**RDO-1**	heading zero niner zero comair thirty-two seventy-two.
1554:10.9	**CAM**	[sound of click]
1554:13.2	**CAM**	[sound of faint click]
1554:14.4	**CAM**	[sound of several unidentified thumps fade in and out]
1554:15.9	**CAM**	[sound of several "whirring" noises, similar to that of the elevator trim servo]
1554:16.0	**CAM**	[sound of increase in discrete high frequency noise similar to that of power increase]
1554:17.1	**CAM**	[significant reduction in background ambient noise]
1554:20.8	**INT-1**	looks like your low speed indicator.
1554:20.9	**INT-2**	* *.
1554:23.6	**INT-1**	power.
1554:23.9	**CAM**	[sound similar to that of stickshaker starts]
1554:24.1	**INT-2**	thanks.
1554:24.1	**CAM**	[sound of three chimes and "autopilot" aural warning]
1554:25.9	**CAM**	[sound similar to that of stickshaker stops]
1554:26.1	**INT-2**	oh.
1554:26.1	**INT-1**	oh #.
1554:26.8	**CAM**	[sound of increase in background noise similar to that of power increase]
1554:29.0	**CAM**	[sound of GPWS "bank angle" aural warning]

on the airplane's leading edges or determined that the ice buildup was not sufficient to warrant activation of the deicing boots.

"At the time of the accident, Comair's pilots were trained to activate deicing boots when they observed between one-quarter [inch] and one-half inch [six millimeters and 13 millimeters] of ice accumulation," said the report.

Comair's flight standards manual (FSM) provided the following guidance to pilots: "Allow ice accumulation to build approximately one-half inch prior to inflating the wing … deice boots. … Premature activation of the deice boots could result in ice forming the shape of an inflated deice boot [a process called ice bridging], making further attempts to deice in flight impossible."

Embraer in April 1996 issued an operational bulletin (OB 120-002/96) providing information on the results of EMB-120 icing-controllability tests and a related airplane flight manual (AFM) revision (Revision 43) recommending activation of deicing boots at the first indication of icing.

Comair inserted Revision 43 in the AFM carried aboard the accident airplane, but did not insert the revision in the EMB-120 FSM or give copies of the revision to pilots.

The FSM is an aircraft-type-specific company flight manual required by FAA. The FSM incorporates much of the information in the AFM, as well as FAA-approved company procedures that differ from those in the AFM. The report said that Comair pilots used the company's FSM and operations manual, rather than the AFM, as their primary sources of procedural guidance.

The report said, "According to Comair's EMB-120 program manager, the proposed procedural changes contained in AFM Revision 43 were contrary to Comair's training procedures and practices; he stated that for years the company had trained pilots to be aware of ice bridging … . He further stated that Comair personnel believed that enacting the changes would result in potentially unsafe operations because of ice bridging."

AFM Revision 43 was approved by CTA and FAA. The FAA principal operations inspector (POI) assigned to Comair did not require the airline to incorporate the revision in its FSM and training procedures. "During postaccident interviews, the POI stated that he was not aware that [OB 120-002/96] existed until after the accident and thus was not aware of the rationale behind [the AFM] revision," said the report.

At the time of the accident, Comair was one of seven EMB-120 operators in the United States; only two of the seven operators incorporated AFM Revision 43 in their procedures.

The report said that concerns about ice bridging persist among flight crews and operators despite findings that ice bridging does not occur on turboprop airplanes with serviceable deicing-boot systems. The findings include the following:

- A September 1995 U.K. Civil Aviation Authority report, *Ice Detection for Turboprop Aircraft* (paper 95007) [reprinted in *Flight Safety Digest* Volume 14, November 1995], said, "Although [surveyed pilots] frequently observed residual ice on the boots [after activating the boots at the first sign of icing], the only reported ice-bridging incident happened to a light twin piston-engined aircraft. Piston-engined aircraft have a pneumatic system which operates from an engine-driven pump, rather than engine bleed air. This means that … the system pressures are lower and the boot inflation times are longer"; and,

- The consensus of the November 1997 Airplane Deicing Boot Ice Bridging Workshop, cosponsored by FAA and the U.S. National Aeronautics and Space Administration (NASA), was that there is not factual evidence that ice bridging is a problem for modern turbine-powered airplanes.

The NTSB report said, "Despite the lack of evidence that ice bridging is a problem in modern turbopropeller-driven aircraft, … many pilots and operators have deeply ingrained beliefs that they should delay deicing-boot activation to avoid ice bridging."

The report said that another factor that might cause pilots to delay activation of deicing boots is the FAA's description of trace icing as nonhazardous. FAA publications, including the *Aeronautical Information Manual* (which provides information for pilots) and *Flight Services* (FAA Order 7110.10M, which provides information for flight-service specialists), describe trace icing as follows:

"Ice becomes perceptible. Rate of accumulation is slightly greater than the rate of sublimation. It is not hazardous even though deicing/anti-icing equipment is not utilized unless encountered for an extended period of time (over one hour)."

Nevertheless, delaying deicing-boot activation can cause decreased airplane performance and departure from controlled flight. Postaccident wind-tunnel tests by NASA and FAA showed that thin, rough ice accumulations significantly increase drag and decrease lift, thus reducing stall margins and adversely affecting handling characteristics.

"The suggestion in current [FAA] publications that 'trace' icing is 'not hazardous' can mislead pilots and operators about the adverse effects of thin, rough ice accretions," said the report.

U.S. Federal Aviation Regulations (FARs) Part 25 icing certification standards do not account for delayed activation of deicing boots, malfunction of deicing boots, residual ice (ice remaining after boot activation) and intercycle ice (ice accumulation on boots between cycles). FAA is developing new Part 25 standards that will account for these factors.

"However, FAA personnel indicated that the new icing standards [would be] applied to new airplanes for which icing certification is sought; they would not automatically retroactively apply to airplanes that are currently certificated for flight in icing conditions," said the report.

The crew probably did not perceive the hazard posed by the icing conditions in which they were operating the accident airplane. "There was no … discussion of flap usage, stall speeds, recommended minimum airspeeds for icing conditions, ice accumulation (potential or observed) and its effects on the airplane's performance at any time during the descent from cruise altitude," said the report.

The report said that the crew's acceptance of the 150-knot airspeed restriction "without hesitation, comment or reconfiguration" was further evidence that they did not

1554:29.1	**CAM**	[sound of three chimes and "auto-pilot" aural warning]
1554:31.0	**CAM**	[sound similar to that of stickshaker starts and continues to the end of tape]
1554:33.3	**INT-?**	[sound of single human breath]
1554:34.3	**CAM**	[sound of three chimes and "auto-pilot" aural warning]
1554:35.3	**CAM**	[sound of GPWS "bank angle" aural warning]
1554:37.1	**INT-1**	[nonpertinent exclamation]
1554:38.2	**CAM**	[sound of three chimes and "auto-pilot" aural warning]
1554:39.1	**INT-1**	[nonpertinent exclamation]
1554:40.1	**CAM**	[end of tape]

CAM	=	Cockpit area microphone
HOT	=	Crewmember hot microphone
RDO	=	Radio transmission from accident aircraft
-1	=	Voice (or position) identified as captain
-2	=	Voice (or position) identified as first officer
-?	=	Unidentifiable voice
COM	=	Miscellaneous radio communications or aircraft aural warnings heard on crewmember cockpit voice recorder channels
ZOB	=	Cleveland Air Route Traffic Control Center
DTW	=	Detroit Metro Air Traffic Control Tower
OPS	=	Airline operations
CACT50	=	America West Airlines Flight 50
*	=	Unintelligible word
#	=	Expletive deleted
...	=	Pause
( )	=	Questionable text
[ ]	=	Editorial insertion
—	=	Break in continuity
GPWS	=	Ground-proximity warning system
ILS	=	Instrument landing system
RVR	=	Runway visual range

Source: U.S. National Transportation Safety Board believe a hazardous icing situation existed. "Whether the pilots perceived ice accumulating on the airplane or not, they should have recognized that operating in icing conditions at the ATC-assigned airspeed of 150 knots with flaps retracted could result in an unsafe flight situation," said the report.

Nevertheless, Comair's guidance regarding airspeeds in icing conditions was "ambiguous and unclear."

In December 1995, Comair distributed to its EMB-120 pilots a memorandum that said that the pilots should not operate the EMB-120 at less than 160 knots in icing conditions and that they should operate the airplane at 170 knots when holding with possible residual (intercycle) ice on the airframe. The memorandum said, "Monitor airspeed closely when in icing conditions, especially in turns."

In October 1996, the airline issued a flight standards bulletin that said that EMB-120 pilots should maintain a minimum airspeed of 170 knots when climbing on autopilot or holding in icing conditions. The report said, "[There was] no mention of a minimum airspeed for nonclimbing/nonholding icing operations."

Embraer's EMB-120 AFM Revision 43, which recommended a minimum airspeed of 160 knots in icing conditions with flaps retracted and landing gear retracted, was not incorporated in Comair's EMB-120 FSM. The report said, "At the time of the accident, the only icing-related airspeed specified in … Comair's EMB-120 FSM was [a] minimum airspeed for holding in icing conditions (160 knots)."

The flight crew probably did not notice a change in the airplane's handling characteristics because they were operating the airplane on autopilot. "Because the pilots … were operating the airplane with the autopilot engaged during a series of descents, right and left turns, power adjustments, and airspeed reductions, they might not have perceived the airplane's gradually deteriorating performance," the report said.

Furthermore, during the left turn begun several seconds before the upset occurred, the crew probably did not notice that the autopilot was working against the airplane's deviation from the desired airplane attitude; the airplane was banking left because of lift asymmetry caused by ice accumulation, ice-ridge formation and uneven ice self-shedding.

"The deviations from the desired airplane attitude were becoming noticeable about the time that the pilots were increasing engine power to maintain 150 knots … ," said the report. "It is likely that the subtle visual cues that were available were not adequate to prompt the pilots to take the direct and aggressive action that would have been necessary to avoid the upset. …

"The pilots could not have identified the buildup in control-wheel forces … unless the autopilot had been disengaged and they were flying the airplane manually."

The crew received no warning of the impending stall. "The stall-warning system installed in the accident airplane did not provide an adequate warning to the pilots because ice contamination was present on the airplane's airfoils and the system was not designed to account for aerodynamic degradation or [to] adjust its warning to compensate for the reduced stall-warning margin caused by the ice," said the report.

Indicated airspeed was 146 knots when power was increased. Left-engine torque increased momentarily to 108 percent, and right-engine torque increased momentarily to 138 percent. The reason for the torque split was not determined, but could have involved uneven throttle movement by the pilots, ice ingestion by the left engine or improper engine trim.

"Postaccident simulations indicated that this torque split had a significant yaw-producing effect at a critical time in the upset event, exacerbating the airplane's excessive left roll tendency," said the report.

The crew received no warning of the impending autopilot disengagement. "There is no cockpit warning generated when the airplane's roll angle exceeds the maximum angle that the autopilot can command, until the roll angle exceeds 45 degrees and the autopilot disengages," said the report.

The report said, "The sudden disengagement of the autopilot greatly accelerated the left-rolling moment that had been developing, suddenly putting the airplane in an unusual attitude."

The airplane rolled left, into a nearly inverted attitude, almost immediately after the autopilot disengaged. "Although the FDR data indicated that the pilots responded to the upset within one second of the autopilot disengagement and [that] the airplane responded somewhat to the control-wheel inputs, the airplane did not respond normally or promptly," said the report. "The airplane entered an extreme nose-down pitch attitude from which it did not recover."

The report said that this accident — and several previous accidents involving turboprop airplanes operating in icing conditions — show that FAA's icing-certification process is inadequate. Although Embraer exceeded Part 25 standards during EMB-120 icing-certification tests, the manufacturer did not, and was not required by FAA to, demonstrate the airplane's performance with a thin, rough ice accumulation and a small ice ridge on the wing leading edges.

"Postaccident icing and wind-tunnel information indicated that with a small ice ridge along that thin rough surface, the aerodynamic effect on handling and stall margin/stall warning (reduced stall AOA and rapid decrease in lift) can be worse than [the effects with] any of the ice shapes that the FAA required for icing certification," said the report.

Based on these findings, NTSB made the following recommendations to FAA:

- “Amend the definition of trace ice contained in [FAA] Order 7110.10[M], *Flight Services,* (and in other FAA documents as applicable) so that it does not indicate that trace icing is not hazardous;

- “Require [POIs] to discuss the information contained in [AFM] revisions and/or manufacturers’ operational bulletins with affected air carrier operators and, if the POI determines that the information contained in those publications is important information for flight operations, to encourage the affected air carrier operators to share that information with the pilots who are operating those airplanes;

- “With [NASA] and other interested aviation organizations, organize and implement an industry-wide training effort to educate manufacturers, operators and pilots of air carrier and general aviation turbopropeller-driven airplanes regarding the hazards of thin, possibly imperceptible, rough ice accumulations, the importance of activating the leading-edge deicing boots as soon as the airplane enters icing conditions (for those airplanes in which ice bridging is not a concern), and the importance of maintaining minimum airspeeds in icing conditions;

- “Require manufacturers and operators of modern turbopropeller-driven airplanes in which ice bridging is not a concern to review and revise the guidance contained in their manuals and training programs to include updated icing information and to emphasize that leading-edge deicing boots should be activated as soon as the airplane enters icing conditions;

- “With [NASA] and other interested aviation organizations, conduct additional research to identify realistic ice accumulations, to include intercycle and residual ice accumulations and ice accumulations on unprotected surfaces aft of the deicing boots, and to determine the effects and criticality of such ice accumulations; further, the information developed through such research should be incorporated into aircraft-certification requirements and pilot-training programs at all levels;

- “Actively pursue research with airframe manufacturers and other industry personnel to develop effective ice detection/protection systems that will keep critical airplane surfaces free of ice; then require their installation on newly manufactured and in-service airplanes certificated for flight in icing conditions;

- “Require manufacturers of all turbine-engine-driven airplanes (including the EMB-120) to provide minimum-maneuvering-airspeed information for all airplane configurations, phases and conditions of flight (icing and nonicing conditions); minimum airspeeds also should take into consideration the effects of various types, amounts and locations of ice accumulation, including thin amounts of very rough ice, ice accumulated in supercooled large-droplet icing conditions and tailplane icing;

- “Require the operators of all turbine-engine-driven airplanes (including the EMB-120) to incorporate the manufacturer’s maneuvering airspeeds for various airplane configurations and phases and conditions of flight in their operating manuals and pilot training programs in a clear and concise manner, with emphasis on maintaining minimum safe airspeeds while operating in icing conditions;

- “Require the manufacturers and operators of all airplanes that are certificated to operate in icing conditions to install stall warning/protection systems that provide a cockpit warning (aural warning and/or stick shaker) before the onset of stall when the airplane is operating in icing conditions;

- “Require all operators of turbopropeller-driven air carrier airplanes to require pilots to disengage the autopilot and fly the airplane manually when they activate the anti-ice systems;

- “Require all manufacturers of transport-category airplanes to incorporate logic into all new and existing transport-category airplanes that have autopilots installed to provide a cockpit aural warning to alert pilots when the airplane’s bank and/or pitch exceeds the autopilot’s maximum bank and/or pitch command limits;

- “Expedite the research, development and implementation of revisions to the icing-certification-testing regulations to ensure that airplanes are adequately tested for the conditions in which they are certificated to operate; the research should include identification (and incorporation into icing-certification requirements) of realistic ice shapes and their effects and criticality;

- “When the revised icing-certification standards and criteria are complete, review the icing certification of all turbopropeller-driven airplanes that are currently certificated for operation in icing conditions and perform additional testing and take action as required to ensure that these airplanes fulfill the requirements of the revised icing-certification standards;

- “Review turbopropeller-driven airplane manufacturers’ [AFMs] and air carrier flight-crew operating manuals (where applicable) to ensure that these manuals provide operational procedures for flight in icing conditions, including the activation of leading-edge deicing boots, the use of increased airspeeds and disengagement of autopilot systems before entering icing conditions (that is, when other anti-icing systems have traditionally been activated);

- “Require air carriers to adopt the operating procedures contained in the manufacturer’s [AFM] and subsequent approved revisions or provide written justification that an equivalent safety level results from an alternative procedure;

- “Ensure that flight-standards personnel at all levels (from aircraft-evaluation groups to certificate-management offices) are informed about all manufacturer operational bulletins and [AFM] revisions, including the background and justification for the revision;

- “Revise [FAA’s] current EMB-120 [FDR-]system inspection procedure to include an FDR readout and evaluation of parameter values from normal operations to ensure a more accurate assessment of the operating status of the flight-control-position sensors on board the airplane;

- “Reemphasize to pilots, on a periodic basis, their responsibility to report meteorological conditions that may adversely affect the safety of other flights, such as in-flight icing and turbulence, to the appropriate facility as soon as practicable; [and]

- “Amend [FAA] Order 7110.65, *Air Traffic Control*, to require that [ATIS] broadcasts include information regarding the existence of pilot reports of icing conditions in that airport terminal’s environment (and adjacent airport-terminal environments as meteorologically pertinent and operationally feasible) as soon as practicable after receipt of the pilot report.”

NTSB reiterated to FAA the following recommendations, which were based on findings from the investigation of the Oct. 31, 1994, accident involving a Simmons Airlines Avions de Transport Regional ATR-72 in Roselawn, Indiana, U.S.:

- “Revise the icing criteria published in [FARs] Parts 23 and 25, in light of both recent research into aircraft ice accretion under varying conditions of liquid-water content, drop-size distribution and temperature, and recent development in both the design and use of aircraft. Also, expand the Part 25 appendix C icing-certification envelope to include freezing drizzle/freezing rain and mixed water/ice crystal conditions as necessary; [and,]

- “Revise the icing-certification-testing regulation to ensure that airplanes are properly tested for all conditions in which they are authorized to operate, or are otherwise shown to be capable of safe flight into such conditions. If safe operations cannot be demonstrated by the manufacturer, operational limitations should be imposed to prohibit flight in such conditions, and flight crews should be provided with the means to positively determine when they are in icing conditions that exceed the limits for aircraft certification.”♦

This article, except where specifically noted, was based entirely on U.S. National Transportation Safety Board *Aircraft Accident Report: In-flight Icing Encounter and Uncontrolled Collision with Terrain; Comair Flight 3272; Embraer EMB-120RT, N265CA; Monroe, Michigan; January 9, 1997* (NTSB/AAR-98/04, adopted Nov. 4, 1998). The 348-page report contains figures and appendixes.

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