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Log 2331

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: November 19, 1991

In reply refer to: A-91-87 through -90 and A-91-122

Honorable James B. Busey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On December 26, 1989, United Express,[1] flight 2415 (Sundance 415), a British Aerospace BA-3101 Jetstream, N410UE, crashed approximately 400 feet short of runway 21R at Tri-Cities Airport, Pasco, Washington.[2] The airplane crashed while executing an instrument landing system (ILS) approach to the runway at approximately 2230 pacific standard time. Visual meteorological conditions prevailed beneath the cloud bases, which were approximately 1,000 feet above ground level at the time of the accident. The airplane was destroyed, and the two pilots and all four passengers received fatal injuries.

Recorded air traffic control radar data revealed that the flight did not intercept the final approach course until it was about 1.5 miles inside the outer marker, at an altitude about 1,000 feet above the glideslope, on the ILS approach to runway 21R. Further examination of the radar data and weather information indicated that the airplane was in the clouds in icing conditions for almost 9 and 1/2 minutes. As the approach was initiated, the flightcrew called the Seattle Air Route Traffic Control Center for a missed approach because of "a couple of flags on our instruments" but then elected to continue the approach.

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[1] The airplane was operated by NPA Inc., (NPA is the name of the airline and is not an abbreviation) as United Express flight 2415. NPA and United Express will be used synonymously throughout the report.

[2] For more detailed information, read Aviation Accident Report--"Unstabilized Approach and Loss of Control, NPA, Inc. dba United Express, Flight 2415, a British Aerospace BA-3101, Jetstream, N410UE, Tri-Cities Airport, Pasco, Washington, December 26, 1989" (NTSB/AAR-91/06)

The local controller at the Pasco air traffic control tower observed the airplane at an altitude higher than normal descending with its wings level. He stated that the rate of descent was faster than other airplanes he had observed. He said that he later saw the airplane nose over and crash short of runway 21R.

The following surface observations were taken at the Tri-Cities Airport, Pasco, Washington, about the time of the accident:

> Time--2145; type--surface observation; ceiling--estimated 1,000 feet overcast; visibility--7 miles; temperature--32^{o} F; dewpoint--30^{o} F; wind--calm; altimeter--30.27 inches of mercury.

> Time--2250; type--local observation; ceiling--estimated 1,000 feet overcast; visibility--7 miles; temperature--32^{o} F; dewpoint--30^{o} F; wind--calm; altimeter--30.26 inches.

The 1900 and 2200 surface weather maps, prepared by the National Weather Service, showed a large high-pressure area centered over extreme southeastern Idaho with an elongated axis oriented south-southeast, north-northwest from southeastern New Mexico through central British Columbia. Conditions in the Columbia River Basin were overcast skies with areas of fog, light drizzle and light snow. Winds varied from very light from the southwest through the northwest to calm.

The following pilot reports (PIREPs) are descriptive of conditions in the Columbia River Basin:

> Location: over Walla Walla, time--1920, altitude--3,500 feet, type airplane--PA-34, icing--moderate mixed below 3,500 feet.

> Location: over Spokane, time--1928, altitude--unknown, type airplane--Cessna 172, sky--overcast tops 3,700 feet.

> Location: over Pasco, time--1920, altitude--4,000 feet, type airplane--BA-31, icing--moderate mixed surface to 4,000 feet.

The National Transportation Safety Board determined that the probable cause of this accident was the flightcrew's decision to continue an unstabilized ILS approach that led to a stall, most likely of the horizontal stabilizer, and loss of control at low altitude. Contributing to the accident was the air traffic controller's improper vectors that positioned the airplane inside the outer marker while it was still well above the glideslope. Contributing to the stall and loss of control was the accumulation of airframe ice that degraded the aerodynamic performance of the airplane.

The investigation revealed deficiencies regarding rules for airplane icing certification which the Federal Aviation Administration (FAA) should take action to correct.

The British Aerospace Jetstream 3101 was certified under provisions of type certificate A21EU, Federal Aviation Regulations (FAR) 21-29 and FAR 23, effective February 1, 1965, including Amendments 23-1 through 23-3 and special FAR 41, effective October 17, 1979, including Amendments 41-A and 41-C. The airplane was equipped and certified for flight into icing conditions with compliance demonstrated for the requirements of 14 Code of Federal Regulations (CFR) Section 25.1419: Ice Protection.

Safety Board investigators used a BA-3100 simulator to evaluate the aircraft handling characteristics with and without ice accumulation on the aerodynamic surfaces. The Pasco Runway 21R ILS was simulated and approaches were flown from an initial position approximately 1.5 miles inside the outer marker at an altitude of 3,000 feet.

The simulator was programmed for the weight and balance of the accident flight and aerodynamic performance penalties approximating those expected from ice accumulation were used. The approaches were started at 160 knots with 20° flaps. The airplane was slowed to 140-145 knots, and a 2,000 feet per minute (fpm) rate of descent was established with 20 to 30 percent torque. This resulted in the airplane descending in a 10° to 12° nose-down attitude. Similarly, to achieve "near maximum" descent performance, the airplane was flown at 145 knots with 50° flaps and idle power. In this case, a descent rate of 2,800 to 3,000 fpm was achieved in an 18° to 20° nose-down attitude. In all cases, the pilots were able to successfully land on the runway during the simulation.

On January 20, 1991, at Beckley, West Virginia, a CC Air[3] BA-3101 airplane crashed during an approach and landing attempt. Although the Safety Board has not determined the probable cause of that accident, the evidence indicates that the airplane was flown on an ILS approach in icing conditions, with the deicing system inoperative. When the airplane was on short final approach, as the flaps were lowered to the 50° landing flaps setting, the airplane pitched down and crashed on the runway. The evidence indicates that about 1 inch of ice accumulation was present on the leading edges of the airplane's wings and empennage surfaces.

As a result of that accident, the manufacturer conducted flight tests that involved ice accretions at flap configurations different than during previous certification testing,[4] and an amount of ice greater than would be expected with normal operation of the leading edge deicing systems. British Aerospace provided the Safety Board with the following excerpts from a summary review of the icing tests:

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[3] Carolina Commuter, Inc.

[4] Reference CFR 14 Part 25.1419 Ice Protection; and FAA Advisory Circular 20.73.

There were two fundamental differences from the (flight test) work carried out previously and reported in FTR 177/JM.[5] First, the flight through the icing clouds was carried out in 20^0 flap, gear up, configuration at 120 knots simulating icing conditions during the initial approach. This decision was based on the circumstances surrounding the Beckley accident and is different from the initial icing certification trials in that, for those flights, the aircraft was flown at 140 knots in a clean configuration (holding) through the cloud. The ice accretions on the leading edges were possibly different in shape due to different angles of attack at the wing and the tail. The second difference from the previous icing work was accretion of 1 inch of ice, or more. Previous work investigated only 1/2 inch of residual ice on the boots, which is the accretion at which normal procedures require the boots to be operated. The aircraft was also loaded to the maximum weight and the most forward CG [center of gravity] (appropriate to weight) in order to ensure that the tailplane was developing the highest download (in the 50^0 flap configuration).

The results of initial testing showed that with 1 inch of ice on the leading edges, the 20^0 to 50^0 flap extension can be performed normally with no unexpected behaviour or response.

Tests conducted with 50^0 flaps at 135 knots with 1 inch of ice disclosed the onset of longitudinal stability changes during a push over maneuver. There was a perceptible reduction in stick force when a load factor of 0.5 g[6] was reached. The reduction in stick force was much more pronounced when the test was conducted at 150 knots, to the extent that the stick showed a tendency to move forward, if unrestrained. [Similar testing for 20^0 flap showed no stick force reduction]. Also noted from the results and observed by the pilots was that higher speeds gave more adverse characteristics in that the reduction in stick forces were more pronounced. This is as expected, resulting from the more negative tailplane angle of attack at the higher airspeed.

Throughout these tests the aircraft was fully controllable and responded normally to the recovery control inputs. The load factor during recovery was normally around 1.5 'g' with no evidence of wing stall or buffet.

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[5] Jetstream 31 - G-JSSD, Effect of Ice on Aircraft Handling Characteristics (1984 Trials). This report investigated the effect of 1 to 1.5 inches of ice on all airframe surfaces, 2 to 2.5 inches of ice on unprotected parts, and 1/8 to 1/4 inch of ice on protected parts of the airframe leading edges.

[6] A unit of acceleration equal to the acceleration of gravity that is used to measure the force on a body undergoing acceleration and expressed as a multiple of the body's weight.

Following these tests, and in order to reduce the likelihood of encountering partial tail stall with excessive ice accretion, two actions have been taken by British Aerospace and the regulatory authorities. The first action reduces the V_{FE} (maximum speed with flaps extended) of 50° flaps from 153 knots to 130 knots. Secondly, appropriate wording is placed in the flight manual to ensure that the landing flaps are limited to 20° when there is any visible ice accretion on any part of the aircraft.

As part of the investigation of the accident at Pasco, the deice distribution valve, timer, ejector, and tail boot pressure switch were removed from the wreckage for testing under the supervision of the Safety Board. Connections to the proper valve port were verified before the removal of the deice distribution valve. The distribution valve did not appear to be burned and did not experience excessive heat damage. All deice boot supply lines were examined, and no defects were detected. All hose clamps were in place, and all boots were found securely attached to their respective surfaces. All boots were examined, and none of them exhibited evidence of any preimpact failure, tear, or puncture.

The automatic inflation cycle deice system timer and the distribution valve were tested at the B. F. Goodrich facilities in Akron, Ohio, on March 14, 1990. There were no anomalies found that would have affected the operation of the timer; however, the distribution valve failed to allow air to flow through port B (wing deice boot port). All other functions of the valve were found to perform satisfactorily. The valve was examined further at the valve manufacturer's facilities (Lucas Aerospace - formerly Bendix) and at the Safety Board's Materials Labratory. These examinations confirmed that the valve failed to allow air to flow through port B. Disassembly of the distribution valve body revealed the presence of deposits on the port B side of the interior. Analysis of these deposits showed that they were rich in aluminum and chlorine. A 28-volt DC power supply was attached to the solenoid for port B. The solenoid operated normally when energized by the power supply. However, the control valve operated by the port B solenoid could not be moved easily and was subsequently removed from its cylinder using pliers. The cylinder was also removed from the body of the distribution valve and sectioned in order to view the cylinder interior. White powdery deposits were noted on the spring end (opposite from the solenoid) of both the control valve and interior of the cylinder. In addition, bands of dark deposits were noted on the remainder of the control valve and cylinder interior.

The Safety Board believes that Sundance 415 accumulated at least 1/2 and possibly as much as 1 inch of mixed rime and clear ice during the flight. A layer of mixed ice of this depth has a tendency to collect in a "mushroom" or "ram's horn" shape. Such a layer of ice, both because of its depth and shape, would be detrimental to the airflow over the wing and empennage airfoil surfaces, affecting the stall characteristics of the airplane.[7]

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[7] "Effect of Ice on Aircraft Handling Characteristics (1984 Trials)," Jetstream 31--G-JSSD, British Aerospace Flight Test Report FTR.177/JM, dated May 13, 1985.

Based on the original BA-3100 certification tests, the airplane's pneumatic boot deicing system should have effectively removed an accumulation of rime ice of this magnitude. However, according to the manufacturer, the contamination found in the deice distribution valve had been in a position blocking the poppet valve at the wing deicing post for a protracted period of time. Although a flightcrew that had flown the airplane on a previous flight reported that the wing deicing system was operating, the Safety Board could not determine with certainty that it was operating properly. The Safety Board notes that it might have been difficult for either the previous crew or the accident crew to ascertain that the system was functioning properly during a preflight check.

If the flightcrew was relying on the illumination of the wing deice light on the instrument panel skirt as an indication that the boots were operating properly, they could have been misled. The investigation disclosed that the light illuminates with only 10 pounds per square inch (psi) pressure, but 15 psi is required to inflate the boots properly. Thus, even if the poppet was not stuck but only restricted in movement, there could have been sufficient air pressure to give the appearance of normal operation based on the light, without actually inflating the boots sufficiently to remove ice. The Safety Board believes that the presence of ice adhering to the wings after landing at Yakima may have been the result of an ineffective deicing system. If this was the case, the problem should have become apparent to the accident flightcrew on the flight to Yakima. Without a cockpit voice recorder, the Safety Board had no knowledge of the crew's actions and could not determine whether they were aware of a deicing system problem or whether they attempted to use the system during the approach to Pasco. However, because there were no other factors to explain the flightpath of the airplane to the position of ground impact, the Safety Board concludes that the airplane did accumulate a buildup of leading edge ice during the descent.

The Safety Board was unable to determine the flightcrew's use of deicing equipment during the final approach segment. The Safety Board believes it is possible that the captain failed to actuate the deicing equipment on final approach, either due to the high workload of an unstablilized approach or because he may not have understood the importance of removing ice from the leading edge prior to entering the low speed regime of final approach and landing. The NPA chief pilot for the BA-3100 fleet at the time of the accident stated that NPA's procedures for the icing conditions experienced on the accident flight required deice boots to be actuated prior to selecting the final landing configuration. This is consistent with the company's written "cold weather operations" procedures, which stated, "Wing icing....is most serious on landing; therefore, pilots should attempt to remove ice before beginning the approach."

The specific requirement to actuate deice boots prior to establishing the final landing configuration was not included in NPA's written standard operating procedures. Also, the written standard operating procedures did not inform flightcrews that the 1/2 inch minimum criterion for deice boot operation applied only to enroute flight and not to the final approach segment. The Safety Board notes evidence of an incomplete transfer of this information to NPA flightcrews because the BA-3100 captain, who arrived at Pasco between 2130 and 2215, landed with an estimated 1/4 inch of airframe ice. According to his understanding of NPA procedures, "he did not accumulate enough to use the boots." The Safety Board believes that NPA's written standard operating procedures should provide more specific guidance to flightcrews on deice boot operation during the final approach segment.

The Safety Board concludes that the deice indicating system did not meet the certification requirements of 14 CFR 23.1416 or 25.1416 because the indicating light would illuminate at a lower pressure (10 psi) than the pressure required to fully inflate the boots (15 psi). Nevertheless, this deficiency is not considered to be a factor in this accident because the flightcrew was probably aware that the wing deice system was not fully operational if this were the case from earlier observations.

The actions taken by British Aerospace, and the airworthiness actions taken by the Civil Aviation Authority and the FAA to limit the 50^{o} flap speed to 130 knots, should prevent tail stall and pitch down with a reasonable ice accumulation. Nevertheless, the Safety Board is concerned that the susceptibility of the BA-3100 to reduced longitudinal stability upon selection of 50^{o} flaps was not detected during the airplane's original icing certification tests. A review of the testing protocol disclosed that ice was accumulated only when the airplane was in the "clean" (gear and flaps retracted) configuration. The airplane was then flown in the various flap configurations without evidence of adverse flying qualities. Subsequently, it was determined that ice accumulated in a different position on the stabilizer leading edge when the airplane was flown through the icing condition in the 20^{o} flap configuration. This difference in ice accretion was shown to be more critical in degrading the aerodynamic characteristics of the stabilizer at the higher angle of attack associated with 50^{o} flaps.

Original certification tests investigated only 1/2 inch of ice, whereas the reduction in longitudinal stability during subsequent flight tests did not occur until 1 inch of ice was accumulated on the airframe leading edges. Procedures require that the deicing boots be operated when 1/2 inch of ice has accumulated, which should preclude a reduction in longitudinal stability. Nonetheless, the Safety Board believes that the certification requirements should be amended to require flight tests to evaluate the accumulation of ice in all configurations where extensive exposure to icing conditions can be expected.

As a result of its investigation of this accident, the National Transportation Safety Board makes the following recommendations to the Federal Aviation Administration:

> Amend the icing certification rules to require flight tests wherein ice is accumulated in those cruise and approach flap configurations in which extensive exposure to icing conditions can be expected, and require subsequent changes in configuration, to include landing flaps. (Class II, Priority Action) (A-91-87)

Review the airframe icing certification data for existing Part 23 and Part 25 airplanes to verify that the flight profiles examined included ice accumulated at those cruise and approach flap configurations in which extensive exposure to icing conditions can be expected, with subsequent changes in configuration, to include landing flaps. Require additional flight tests as necessary. (Class II, Priority Action) (A-91-88)

Require manufacturers to review the pneumatic deice boot system designs for aircraft used in 14 CFR Parts 121 and 135, to ensure that the pneumatic pressure threshold at which each deice boot indication light is designed to illuminate is sufficient pressure for effective pneumatic deice boot operation, and issue Airworthiness Directives to modify systems found to be deficient in this regard. (Class II, Priority Action) (A-91-89)

Revise Advisory Circular (AC) 20-73, "Aircraft Ice Protection," and AC 23.1419-1, "Certification of Small Airplanes for Flight in Icing Conditions," to include guidance for the fulfillment of 14 CFR Parts 23.1416(c) and 25.1416(c) by ensuring that the pneumatic pressure threshold at which each deice boot indication light is designed to illuminate is sufficient pressure for effective pneumatic deice boot operation. (Class II, Priority Action) (A-91-90)

Issue an Operations Bulletin to the Principal Operations Inspectors of 14 CFR 121 and Part 135 air carriers to verify that air carriers have established procedures for flightcrews to take appropriate actions when they have encountered icing conditions during a flight, to check for the presence of, and to rid airplanes of accumulated airframe ice prior to initiating final approach, in accordance with airplane manufacturers' recommendations on the use of deice systems. (Class II, Priority Action) (A-91-122)

KOLSTAD, Chairman, COUGHLIN, Vice Chairman, LAUBER, HART and HAMMERSCHMIDT, Members, concurred in these recommendations.

James L. Kolstad

By: James L. Kolstad
Chairman