National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: January 17, 2006

In reply refer to: A-06-01 through -03

Honorable Marion C. Blakey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

The National Transportation Safety Board is participating in two foreign investigations (one in Canada and the other in Russia) of recent fatal accidents involving Cessna 208 series airplanes[1] in icing conditions. Based on the preliminary findings from these investigations (which include new insight from flight recorder data obtained from one of the accident airplanes) and a previous assessment of Cessna 208 icing incidents and accidents,[2] the Safety Board is very concerned about deficiencies in the cold weather operational procedures used by Cessna 208 pilots and the performance of the airplane in icing conditions.[3] Investigators with the Interstate Aviation Commission of Russia and the Transportation Safety Board of Canada (TSB) also share these concerns. The Board believes that the urgent recommendations contained in this letter require immediate attention to mitigate the existing risk to the Cessna 208 fleet during the current icing season.

On October 6, 2005, about 0540 central daylight time, a Cessna 208B, Canadian registration C-FEXS, operated by Morning Star Air Express as cargo flight 8060, was destroyed when it impacted the ground about 5 minutes after takeoff from the Winnipeg International Airport (CYWG), Winnipeg, Manitoba, Canada. The certificated airline transport pilot was killed. Instrument meteorological conditions (IMC) prevailed and an instrument flight rules (IFR) flight plan had been filed for the flight destined for Thunder Bay, Ontario. According to

[1] Cessna 208 series airplanes (also referred to as Cessna Caravans) are high-wing, turbopropeller-driven, single-engine airplanes that can be configured for cargo, passenger, or mixed-use operations.

[2] In late 2003, the Safety Board initiated an assessment of 26 icing-related events in Cessna 208 airplanes. The Board's assessment focused on the certification of the Cessna 208 for in-flight icing conditions, the atmospheric conditions often encountered during cold weather ground and flight operations, airplane dispatch concerns, and Cessna 208 pilot experience and training information. As a result, the Safety Board issued Safety Recommendations A-04-64 through -67 to the Federal Aviation Administration (FAA) on December 15, 2004, addressing operational issues associated with Cessna 208 series airplanes in icing conditions. These recommendations are currently classified "Open—Acceptable Response."

[3] To operate in icing conditions, Cessna 208 series airplanes (and most types of turbopropeller-driven, single-engine airplanes) must have operational leading-edge deice boots on the wings and horizontal and vertical stabilizers, propeller anti-ice boots, a windshield anti-ice panel, heated pitot-static and stall warning systems, a standby electrical system, a wing ice detection light, and an engine inertial separator.

meteorological studies performed by the Safety Board and Environment Canada (the country's weather authority), meteorological data recorded at the time of the accident are consistent with light to moderate[4] icing conditions. The accident is currently under investigation by the TSB, with assistance from the Safety Board.

Witnesses indicated that before the flight,[5] the pilot[6] conducted a preflight inspection that included a tactile examination of the wings for ice and frost contamination.[7] About 2 minutes after takeoff, shortly after the pilot penetrated a broken cloud ceiling at 1,000 feet above ground level,[8] she informed air traffic control (ATC) that she needed to return to the airport because of icing conditions. Radar data indicate that the airplane climbed to about 2,200 feet above mean sea level (msl) before beginning a descent to 1,100 feet msl, at which time the airplane dropped below recorded radar coverage and impacted terrain about 4 miles southeast of the airport.[9] The entire accident flight lasted only about 5 minutes, and the Safety Board is concerned that the airplane, which was certified for flight into known icing, did not maintain flight in moderate icing conditions long enough to successfully land the airplane.

On November 19, 2005, about 1927 universal coordinated time, a Cessna 208B, Aruba registration P4-OIN, was destroyed when it impacted terrain while on approach to Domodedovo International Airport, Moscow, Russia. The two Russian certificated pilots and six passengers were killed. IMC prevailed and an IFR flight plan had been filed for the personal flight, which departed Voronezh Airport about 1810. The accident is currently under investigation by the Interstate Aviation Commission of Russia, with assistance from the Safety Board.

The accident airplane is one of the first Cessna 208B airplanes to be equipped with a cockpit voice recorder (CVR) and flight data recorder (FDR). The recorders were installed to

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[4] The FAA's Pilot/Controller Glossary provides the following definitions for icing intensities: "Trace—Ice becomes perceptible. Rate of accumulation is slightly greater than the rate of sublimation. Deicing/anti-icing equipment is not utilized unless encountered for an extended period of time (over 1 hour). Light—The rate of accumulation may create a problem if flight is prolonged in this environment (over 1 hour). Occasional use of deicing/anti-icing equipment removes/prevents accumulation. It does not present a problem if the deicing/anti-icing equipment is used. Moderate—The rate of accumulation is such that even short encounters become potentially hazardous and use of deicing/anti-icing equipment or flight diversion is necessary. Severe—The rate of accumulation is such that deicing/anti-icing equipment fails to reduce or control the hazard. Immediate flight diversion is necessary."

[5] The airplane had been kept in a heated hangar overnight and was pulled outside about 90 minutes before departure. According to recorded meteorological observations at CYWG, light snow was falling onto the airport at the time, and the temperature/dewpoint were slightly below freezing.

[6] Company records indicate that the pilot had accumulated a total of about 4,570 flight hours, including about 1,500 hours in the Cessna 208. This winter was the fourth icing season in which the pilot conducted operations in the Cessna 208. Company records also indicate that she received cold weather operations training within the past 12 months.

[7] As a result of an airworthiness directive (AD) issued in June 2005, the Cessna 208B airplane flight manual requires a tactile inspection of the wing during preflight inspection to ensure that the wings are not contaminated with ice in below-freezing conditions. The AD was prompted by discussions between the Safety Board and FAA that resulted from the Board's 2004 recommendations.

[8] The elevation at CYWG is 784 feet.

[9] Because the airplane was not equipped with flight recorders, precise information regarding airplane performance (including flightpath information below 1,100 feet msl) is not available.

comply with Russian certification requirements. Data from these recorders provided a significant amount of information that greatly aided investigators in determining the sequence of events in the accident and quantifying the effects of icing on the airplane's performance.

According to FDR data, the airplane climbed to a cruising altitude of 9,840 feet after takeoff. About 1906, an air traffic controller informed the flight crew that moderate icing in the clouds was forecasted. The pilots responded that they were above the clouds and were not experiencing any icing conditions. Review of the airplane's CVR revealed that about 5 minutes later, the pilots discussed amongst themselves that they were experiencing "severe icing" conditions. About 1914, ATC again asked the pilots about icing conditions and they responded that they were experiencing "light icing." About 1920, as the airplane neared the airport, ATC cleared the flight to descend to 5,900 feet then to 4,900 feet to begin the approach for landing. About 1925, the airplane leveled off at 4,920 feet at an airspeed of about 118 knots.

The CVR recorded the crew reading the descent checklist about the time that the FDR indicated that the airplane began to pitch up (from -0.1º to +7.3º) as the airspeed began to decrease.[10] About 1926, at an airspeed of about 102 knots, the airplane experienced a decrease in vertical acceleration and a slight decrease in airplane pitch angle consistent with significant flow separation over the wings and the initiation of an aerodynamic stall.[11] Shortly thereafter, the autopilot disengaged, and the airplane descended toward the ground with bank angle excursions of $\pm$ 40º and reached a maximum airspeed of about 226 knots just before ground impact. Preliminary calculations using FDR data indicate that the angle of attack (AOA)[12] was about 9º at the time of the initial upset. Additionally, the sound of the stall warning horn was not heard on the CVR until after the disconnect of the autopilot and onset of the roll excursion.[13]

Minimum Airspeeds for Flight in Icing Conditions

The Safety Board's 2003-2004 assessment of icing accidents and incidents involving Cessna 208 series airplanes focused on the airplane's certification for in-flight icing conditions, the atmospheric conditions often encountered during cold weather flight operations, and Cessna 208 pilot experience and training. Ten of the 15 in-flight icing accidents and incidents that were examined during the assessment occurred during the approach and landing phases of flight. The assessment also found that most of these icing-related, loss-of-control accidents

[10] The CVR recorded one of the pilots state "ice protection set" during the descent; however, it could not be determined if the ice protection system was activated.

[11] According to the Cessna 208 Pilot Operating Handbook (POH), the minimum airspeed in icing conditions is 105 knots. According to Cessna flight test data, with flaps up, a clean wing, and an AOA of about 15º, the stall speed is 78 knots.

[12] The accident airplane's AOA was derived from recorded pitch attitude and derived flightpath angle.

[13] Following the Safety Board's investigation of the January 9, 1997, accident involving an EMB-120 that crashed in Monroe, Michigan, the Board issued Safety Recommendation A-98-96, which asked the FAA to 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. This recommendation is currently classified "Open—Acceptable Response."

occurred during flight in icing conditions that were within the parameters of the FAA icing certification envelopes.[14]

The Safety Board learned during its 2003-2004 assessment that the Cessna 208 POH Known Icing Equipment Supplement recommends a minimum airspeed during flight in icing conditions (with flaps up) of 105 knots indicated airspeed (KIAS). The Board also learned that the 105 KIAS limitation was selected based on feedback from Cessna flight test personnel. Specifically, a Cessna flight test pilot stated to Safety Board investigators that he did not feel "comfortable" during some flights when the airspeed decreased below 105 knots. In addition, the supplement's normal procedures section recommends a climb airspeed of 120 KIAS when climbing out of icing conditions to reduce ice buildup on the areas aft of the deice boots, unless a climb at the slower Vy,[15] or best rate of climb, airspeed can get the airplane out of icing conditions.

Cessna's flight test personnel noted in the certification data that with heavy ice accumulations, a "mild buffet or nose bobbing (partial stalls)" could occur at speeds as high as 95 KIAS and the flaps retracted. During the Safety Board's 2003-2004 assessment of the certification information for Cessna 208 series airplanes, investigators noted that the airplanes were not subjected to flight-testing at the extreme edge of the FAA's envelope conditions and that, in fact, most of the flight tests were documented with an average mean volumetric diameter (MVD) drop size of 20 microns.[16] Cessna's certification data also noted that the equipment used to measure the icing environment during the Cessna 208B flight testing had failed and that accurate droplet size data was not obtained. Because of the inoperative equipment, flight test personnel estimated the droplet size to be around 15 microns and declared that to be a conservative measure. Additionally, flight test personnel noted significant performance degradations during some of the natural ice flight tests, but those degradations were not specified.

In March 2005, Cessna, in conjunction with the FAA, conducted three additional flight tests[17] in natural icing conditions. Tests were to be terminated when the airspeed decreased below 120 knots. In one of the flight tests, which encountered icing conditions of over 20 microns,[18] the flight test was terminated in accordance with Cessna flight test protocol when the airplane's airspeed decreased below 120 knots 9 minutes after the start of the icing encounter. During this icing encounter, the test airplane experienced a loss of 16 knots of airspeed in 8 minutes (from a 133-knot maximum speed to a low of 117 knots).

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[14] The icing certification envelopes, which define the parameters for safe operations in continuous maximum and intermittent maximum icing conditions, are found in 14 *Code of Federal Regulations* Part 25, Appendix C. The icing envelopes are based on a cloud's liquid water content (LWC), the mean effective diameter of the cloud droplets, the ambient air temperature, and the interrelationship of these three variables.

[15] Vy varies among the various Caravan models and pressure altitudes.

[16] These conditions were well within the appendix C icing envelopes, which utilize a maximum drop size of 40 microns for continuous flight in stratus-type clouds and 50 microns for intermittent operations in cumulus-type clouds. For reference, a human hair is about 100 microns in diameter.

[17] The March 2005 flight tests were conducted to evaluate deice boot operation and not minimum airspeed issues.

[18] The maximum LWC for a 20-micron drop size in stratus-type clouds is about 0.65 g/m^3 and 2.5 g/m^3 for cumulus-type clouds. The average LWC during this encounter was 0.275 g/m^3

In March 2005, the FAA issued AD 2005-07-01, requiring a revision to the POH icing supplement to include expanded guidance regarding the minimum icing airspeeds. The revision stated that pilots should exit icing conditions immediately if they are unable to maintain 120 knots and should sacrifice altitude to maintain a minimum of 105 knots. This, in effect, established 105 knots as the minimum operating airspeed in icing conditions. The supplement was also revised to instruct pilots to maintain 120 knots until on short final. In addition, as a result of the Board's assessment findings, the FAA questioned the adequacy of the stall warning system for the Cessna 208 series in icing conditions. Therefore, in April 2005, the FAA asked Cessna to conduct flight tests with ice shapes representing critical ice accretions[19] to determine whether the stall warning system provides an adequate alert to pilots before reaching the icing stall speed. Cessna is currently working with the FAA to develop these ice shapes.

Evidence thus far from the Winnipeg and Moscow accident investigations and the findings from the Board's icing assessment, indicate that the minimum operating airspeed in icing conditions of 105 KIAS does not provide an adequate margin of safety for pilots who encounter icing in flight.[20] The recent Cessna 208B accident in Moscow provides a clear example of this concern; the airplane departed controlled flight only 3 knots slower than the published minimum operating icing airspeed of 105 knots and no stall warning was provided to the pilots.

Although it is imperative that the FAA determine the airspeeds that will provide the performance, controllability, maneuverability, stability requirements, and adequate stall warning thresholds set forth in current icing certification requirements,[21] the immediate establishment of conservative airspeed margins is critical for the continued safe flight of the Cessna 208 in icing conditions. The Safety Board notes that the loss of control of the Russian Cessna 208 that occurred at 102 knots clearly shows that a safe margin would be at a speed substantially greater than the current published icing operating airspeed of 105 knots. The Safety Board further notes that Cessna flight test pilots used a minimum safe speed in icing of 120 knots and that they

[19] The FAA considers critical ice accretions as ice shapes that represent edge-of-the-envelope ice conditions, "runback" ice formations developed during relatively warm freezing conditions, intercycle ice, and ice adhering to the unprotected areas of the airframe.

[20] As a result of its investigation of the accident involving the EMB-120 that crashed in Monroe, Michigan, the Safety Board issued two recommendations related to in-flight icing (A-98-94 and A-98-95). Safety Recommendation A-98-94 asked that the FAA require "manufacturers of all turbine-engine-driven airplanes (including the EMB-120), to provide minimum maneuvering airspeed information for all 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." Safety Recommendation A-98-95 asked that this information be published in the POHs and made available to pilots with emphasis on maintaining minimum safe airspeeds while operating in icing conditions. Safety Recommendation A-98-94 is currently classified, "Open—Unacceptable Response" because the FAA's reported actions to date only address icing conditions. Safety Recommendation A-98-95 is classified, "Closed—Acceptable Alternate Action" as a result of the FAA's issuance of Notice N8400.39, "Minimum Maneuvering Airspeeds, and Flight in Icing Conditions," in January 2003.

[21] Current icing certification requirements include verification of flight performance under Subpart B of Part 23, to include climb performance, controllability, maneuverability, and stability requirements. These performance requirements became effective on May 10, 1993, and were not specified at the time of the Caravan series certification.

successfully exited the icing conditions when they could no longer maintain that speed. In the process of exiting, the flight test airplane further slowed to 117 knots. The Safety Board does not consider the minimum safe speed as simply the lowest speed at which control can be maintained; rather, the minimum safe speed is the speed that provides a substantial margin above the speed at which loss of control occurs. The minimum safe speed should also provide pilots adequate time to successfully exit icing conditions with consideration that airplane performance is likely to degrade further while the airplane is leaving icing conditions. Therefore, the Safety Board believes that the FAA should require all operators of Cessna 208 series airplanes to maintain a minimum operating airspeed of 120 knots during flight in icing conditions, even if a descent is required to do so.

Flight into Icing Conditions Beyond Light Icing

During the past 15 years, 12 in-flight icing-related fatal accidents in Cessna 208 airplanes have occurred, resulting in 33 fatalities. Nine non-fatal, in-flight icing-related accidents and incidents also occurred during the same period. This accident/incident history, along with the recent information from the Winnipeg and Moscow accidents, has prompted the Safety Board to investigate systemic problems with the airplane's design and operation in icing conditions.

Preliminary analyses of recorded radar data for the Winnipeg accident airplane and meteorological data from the flight recorder of an airplane that departed Winnipeg shortly before the accident flight, indicate that the accident airplane's performance was normal until about 2 minutes into the flight, when the pilot reported that she needed to return because of icing conditions. The flight lasted only about 3 more minutes. The Safety Board is concerned that the time available to escape less-than-severe icing conditions was extremely limited. The Board is also concerned that the airplane's failure to continue flight for more than 3 minutes in less-than-severe icing conditions calls into serious question the certification of the Cessna 208 for flight into known icing conditions.

As previously stated in this letter, during certification flight tests and recent in-flight icing testing, Cessna 208 series airplanes experienced significant performance degradations while in icing conditions that were within the icing certification envelopes. During the March 2005 Cessna tests, a flight experienced a loss of airspeed to below 120 knots within 9 minutes after entering icing conditions that were characterized as "moderate." The Safety Board notes that additional flights during the testing program in "light" icing conditions[22] were able to remain above 120 knots airspeed for considerably longer times and that the majority of Cessna 208 icing-related accidents and incidents (including the recent Winnipeg and Moscow accidents) occurred in icing conditions considered to be within the certification envelopes but not necessarily "severe." These facts indicate that although the Cessna 208 can be operated safely in "light" icing conditions, the airplane is at significant risk in icing conditions that are greater than "light." Therefore, the Safety Board believes that the FAA should prohibit all operators of Cessna 208 series airplanes from conducting flight into any icing conditions determined to be more than light icing.

[22] On-board instrumentation measured the MVD and LWC to be within appendix C icing conditions for all of the flight tests.

Use of Autopilot in Icing Conditions

Flight data from the Moscow accident indicate that the autopilot was used during the ascent and level-off portions of the flight preceding the upset but disengaged immediately following the decrease in vertical acceleration and pitch angle that occurred at an airspeed of 102 knots. The power lever was also increased at this moment. However, the cues associated with airplane performance degradation before the decrease in vertical acceleration were not adequate to prompt the pilots to take the direct and aggressive action that would have been necessary to avoid the upset. Specifically, the decrease in airspeed and increase in pitch attitude preceding the upset were gradual, and the changing control inputs required to maintain altitude were masked by the pilots' use of the autopilot.

It is difficult for pilots to effectively monitor control inputs made by an autopilot and detect changes in the magnitude and direction of these inputs as an airplane's performance degrades due to icing conditions. If the pilots involved in the Moscow accident had been flying the airplane manually (without the autopilot engaged), they likely would have noticed the increased control wheel force needed to maintain altitude, become aware of the airplane's altered performance characteristics, and increased their airspeed or otherwise altered their flight situation to avoid the loss of control. The Safety Board concludes that manually flying the Cessna 208 in icing conditions is necessary to enable pilots to sense the aerodynamic effects of icing and enhance their ability to retain control of the airplane.[23] Therefore, the Board believes that the FAA should require all operators of Cessna 208 series airplanes to disengage the autopilot and fly the airplane manually when operating in icing conditions.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Require all operators of Cessna 208 series airplanes to maintain a minimum operating airspeed of 120 knots during flight in icing conditions, even if a descent is required to do so. (A-06-01) Urgent
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> Prohibit all operators of Cessna 208 series airplanes from conducting flight into any icing conditions determined to be more than light icing. (A-06-02) Urgent
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> Require all operators of Cessna 208 series airplanes to disengage the autopilot and fly the airplane manually when operating in icing conditions. (A-06-03) Urgent

[23] The Safety Board previously addressed the use of autopilot in icing conditions when it issued Safety Recommendation A-98-97, which asked the FAA to 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. The FAA disagreed with the recommended action, and the safety recommendation was classified "Closed—Unacceptable Action" on January 12, 2001.

Acting Chairman ROSENKER and Members ENGLEMAN CONNERS, HERSMAN, and HIGGINS concurred with these recommendations.

[Original Signed]
By: Mark V. Rosenker
Acting Chairman