FLIGHT SAFETY FOUNDATION
Accident Prevention
Vol. 58 No. 10 *For Everyone Concerned With the Safety of Flight* October 2001

Icing, Inadequate Airspeed Trigger Loss of Control of Saab 340

The flight crew was conducting a turn to enter a holding pattern at 15,000 feet when the airspeed decreased below the published holding speed. The airplane, which had accumulated ice, stalled and descended for 10 seconds before the crew regained control.

FSF Editorial Staff

About 1738 local time on Nov. 11, 1998, the flight crew of a Saab 340A began a left turn to enter a holding pattern at 15,000 feet over Eildon Weir, Australia. The airplane was being operated in instrument meteorological conditions and had accumulated ice. During the turn, a pre-stall buffet occurred. The crew believed that the vibration was caused by an icing-induced propeller imbalance. The autopilot disconnected, and the airplane rolled left, pitched nose-down and descended 2,300 feet before control was regained by the crew. The flight attendant received minor injuries; the two pilots and 28 passengers were not injured. The airplane was not damaged.

The Australian Transport Safety Bureau (ATSB) said, in its final report, that the following significant factors were involved in the incident:

- "The stall-warning system did not activate prior to the stall;
- "The crew allowed the aircraft's speed to slow below the published holding speed;
- "The crew interpreted the ice deposit as being less than that specified in the aircraft flight manual [AFM] for activation of the wing-deice system;
- "The crew misinterpreted the pre-stall buffet as propeller ice vibration;
- "The Saab 340 aircraft is capable of accreting ice deposits without visual clues being provided to the flight crew; [and,]
- "The aircraft was not fitted with the Canadian stall-warning system [which activates at lower angles-of-attack than the standard stall-warning system]. If this had been fitted and activated, it would have … provided the crew with between 10 [seconds] to 18 seconds warning of the impending stall."

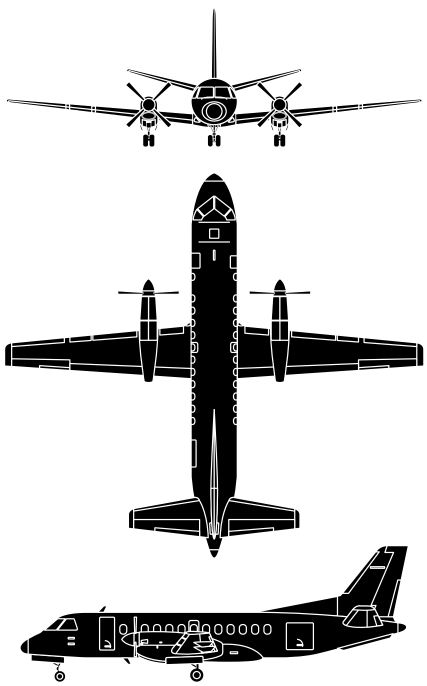
The airplane was being operated on a scheduled flight from Albury to Melbourne. [The report did not identify the company that operated the airplane.]

"The crew had earlier flown the aircraft from Melbourne to Albury and described the departure from Albury and [the] following climb to cruising level as normal," the report said.

The captain had an air transport pilot (ATP) certificate and 13,486 flight hours, including 3,109 flight hours in type. He was hired by the company in 1991 and served as a first officer in [Swearingen/Fairchild] Metros and Saab 340s, and as a Metro captain before becoming a Saab 340 captain in October 1995.

The first officer had an ATP certificate and 5,460 flight hours, including 365 flight hours in type. He was a flight instructor before being hired by the company as a Saab 340 first officer in 1998.

During their Saab 340 transition training, both pilots received flight training to recognize and recover from stalls, and to recover from unusual airplane attitudes. At the time, the company did not have use of a flight simulator, and flight training maneuvers were limited. For example, to prevent fluids from spilling from the onboard toilet, pitch was limited to between 10 degrees and 20 degrees, and bank was limited to 60 degrees. After the company later obtained use of a flight simulator, the flight-training maneuvering limits also were used during simulator training.



Saab 340A

Saab-Scania (now Saab Aircraft) and Fairchild Aircraft began development of a twin-turboprop transport aircraft designated as the SF-340A in 1980. The airplane made its first flight in 1983. Saab assumed control of development and production of the airplane in 1985. The airplane was designated as the 340A in 1987.

The airplane has accommodations for two pilots on the flight deck and up to 35 passengers in the cabin. Maximum takeoff weight is 12,700 kilograms (28,000 pounds). Maximum landing weight is 12,020 kilograms (26,500 pounds).

Each of the General Electric CT7-5A2 turboprop engines is rated at 1,294 kilowatts (1,735 shaft horsepower) and drives a four-blade Dowty Rotol propeller.

Maximum rate of climb at sea level is 1,800 feet per minute (fpm). Maximum single-engine rate of climb at sea level is 550 fpm. Best-range cruising speed at the service ceiling, 25,000 feet, is 250 knots. Maximum cruise speed at 15,000 feet and 11,793 kilograms (26,000 pounds) is 272 knots. Stall speed with flaps retracted is 104 knots. Stall speed with flaps in landing configuration is 82 knots.

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

The company's simulator-training program included stall-recognition-and-recovery training but not unusual-attitude-recovery training. Nevertheless, training captains were allowed to use time remaining at the completion of scheduled simulator training sessions to conduct exercises requested by pilots. The captain of the incident airplane had practiced unusual-attitude recovery in the simulator; both pilots had practiced stall-recovery in the simulator.

"The operator's crews were not exposed to the presentation of the electronic attitude director indicator [EADI] at extreme attitudes during training and were, therefore, not familiar with the display presented to them at extreme attitudes," the report said.

The airplane operating manual (AOM) and the AFM did not contain information on recovering from unusual attitudes. The report said that the operator's policy-and-procedures manual and operations manual contained minimal information on flight in icing conditions and on crew duties in holding patterns.

"The operator's operations manuals did not prohibit the use of the autopilot in icing conditions," the report said.

After departing from Albury, the crew was told by air traffic control (ATC) to fly to the Eildon Weir VOR (very-high-frequency omnidirectional radio) at Flight Level (FL) 150 (15,000 feet). Cloud bases were at 10,000 feet, and cloud tops were at 20,000 feet. The outside air temperature at 15,000 feet was −6 degrees Celsius (C; 21 degrees Fahrenheit [F]). The crew activated the engine anti-ice system and the propeller deice system; the crew did not activate the wing deice boots.

"They reported [that] the only visible ice on the aircraft was a light rime deposit on the leading edge of the wings and a small buildup of ice on the [windshield] wiper arms," the report said. "The crew's interpretation of this ice deposit was that it did not meet the requirements in the [AFM] for the activation of deice boots and, consequently, they were not activated."

At the time of the accident, the AFM recommended activation of the deice boots when ice accumulated to about 0.5 inch (12 millimeters) on the wing leading edges. (Saab Aircraft in October 1999 revised the AFM and AOM with a requirement to operate the deice boots in the continuous mode at the first sign of ice accumulation.)

"[At the time of the accident], the information contained in the [AOM] and [AFM] on activation of the deice boots supported the 'myth' of ice bridging [in modern turboprop aircraft]," the report said.

Ice bridging occurs when ice accumulates on an inflated deice boot and then remains in place after the boot deflates. A cavity is created between the ice accumulation and the deflated boot, and subsequent boot activation has no effect on the ice.

"Ice bridging is a phenomenon that has existed in folklore since the early days of aircraft operation, when deicing boots were first introduced to aircraft design," the report said. "These early boots were characterized by long, uninterrupted spanwise, large-diameter tubes, which were inflated by low-pressure engine-driven pneumatic pumps.

"This combination of low-pressure pump and long-and-large-diameter tube for the deice boot resulted in a long inflation time. The subsequent deflation time was also lengthy, resulting in a long 'dwell time.' Dwell time is that time that the boot remains inflated between inflation and deflation. …

"Modern [turboprop] aircraft are equipped with a different form of deice boots [consisting of] short lengths of inflatable tubes that are segmented across the span and are of a much smaller diameter. They are inflated at much higher pressures by engine bleed air.

"This combination of high-pressure air and shorter tube length and diameter results in very short dwell times, often less than two seconds in some configurations. This … results in a very effective system for ice removal.

"Providing that the deice system [is] maintained correctly, there is no documented evidence to date of deicing boot ice bridging in modern [turboprop] aircraft."

The Saab 340 certification test report said that at temperatures from –5 degrees C to –10 degrees C (23 degrees F to 14 degrees F), ice deposits normally were shed during the first activation of the deice boots and that very little residual ice remained; below –20 degrees C (–4 degrees F), several activations of the deicing boots were required to shed ice deposits and a significant amount of residual ice remained between boot activations.

"The [incident] aircraft was operating in icing conditions; however, it was not in the temperature band … where residual ice remains after activation of the boots," the incident report said. "Although this information on differing shedding rates at differing temperatures was discovered in the flight testing for the certification of the aircraft, [the information] was not included in any of the operating manuals for the aircraft."

The flight crew said that flight conditions were smooth, with only light turbulence. The crew had turned off the seat-belt signs, and the flight attendant had completed normal cabin service.

When the airplane was near Melbourne, ATC told the crew to enter the published holding pattern at the Eildon Weir VOR and to hold until 1750.

Before the airplane arrived over the VOR, the first officer (the pilot flying) reduced engine power from a torque setting of 63 percent to a torque setting of 47 percent to reduce airspeed from 170 knots to the published holding speed of 154 knots. (The Saab 340 AOM recommends holding torque settings of 30 percent to 40 percent.) About one minute later, the captain observed that the indicated airspeed was 149 knots and told the first officer to check the airspeed. The first officer increased power to 62 percent torque. Airspeed stabilized at 144 knots. The first officer increased power to 73 percent torque.

"The resultant torque setting of 73 percent was greater than that required during cruise," the report said. "Neither crewmember appears to have been concerned at this apparent anomaly. It appears likely that they both lacked situational awareness about what was causing the adverse effect on the aircraft performance."

The autopilot was engaged in full-bank mode, which limited bank angle to 28 degrees. The AFM recommended operation of the autopilot in half-bank mode in icing conditions; half-bank mode limited bank angle to 13.5 degrees.

"The manufacturer advised [that half-bank mode] would provide extra margins above the stall [and should be used] whenever possible, particularly in icing conditions," the report said. "The operator had previously used half-bank mode in all operations to provide a better ride for all passengers. However, following a routine surveillance inspection, the [Australian] Civil Aviation Safety Authority (CASA) had directed the company to use full-bank mode in holding patterns, thereby reducing the radius of turn to keep the aircraft within the protected airspace of the holding pattern."

The airplane arrived over the VOR at 1738. The first officer selected the autopilot "HDG/ALT" (heading/altitude) mode and the outbound heading for the holding pattern. Airspeed was 149 knots when the airplane began a 28-degree-banked left turn.

"During the next 21 seconds as the turn progressed, the airspeed gradually decreased, and the aircraft began to buffet at 141 [knots]," the report said. "The crew assessed this buffet as a propeller ice imbalance."

Airflow separation occurred over the inboard section of the right wing. As the lift produced by the right wing decreased, the airplane began to roll right.

"The autopilot commanded an increase in aileron deflection to the left to attempt to return the aircraft to the predetermined setting of 28 degrees," the report said. "As the speed decreased further, the airflow separation increased and the autopilot again tended to increase the aileron output to compensate for the loss of lift."

Airspeed was about 136 knots, angle of bank was 27 degrees and angle-of-attack was 12.7 degrees when the autopilot disconnected. One second later, the airplane stalled. It rapidly rolled left to a bank angle of 127 degrees and pitched 36 degrees nose-down. The pilots told investigators that neither the stick shaker nor the stall-warning clacker [i.e., aural warning] activated before the upset occurred.

“The [first officer] initially started recovery action; however, the [captain] took control of the aircraft and recovered it to normal flight after a height loss of 2,300 feet,” the report said.

During the upset, the flight attendant received back bruises.

After regaining control of the airplane, the crew told ATC that they had encountered turbulence and icing conditions, and requested clearance to maintain FL 130. ATC told the crew to hold at FL 130.

“The crew reported that following the loss of control, they observed a thin white line of rime ice on the leading edges,” the report said. “However, following activation of the wing deice boots, the ice broke away from the leading edges.”

After landing in Melbourne, the crew told the company that they had encountered turbulence. Maintenance engineers performed a heavy-turbulence inspection of the airplane and found no damage.

Data recorded during the incident were recovered from the airplane’s digital flight data recorder (DFDR). The report said that Saab Aircraft analyzed the data and concluded that the airplane stalled because “a significant amount of ice had been allowed to accumulate on the leading edges of the wing.”

“The manufacturer’s analysis concluded [that] there was nothing in the data suggesting a fault with the autopilot or … any system fault within the aircraft that may have contributed to the occurrence,” the report said.

Before the incident, the U.S. Federal Aviation Administration (FAA) issued airworthiness directives (ADs) affecting operations in icing conditions of the Saab 340 and several other turboprop aircraft as a result of the Avions de Transport Regional (ATR) 72 accident at Roselawn, Indiana, U.S.

[The flight crew lost control of the ATR 72 on Oct. 31, 1994, while conducting a descent in a holding pattern. The 68 occupants were killed when the airplane struck terrain. The U.S. National Transportation Safety Board (NTSB) said, in its final report, that the probable causes of the accident were “the loss of control, attributed to a sudden and unexpected aileron hinge moment reversal that occurred after a ridge of ice accreted beyond the deice boots because: 1) ATR failed to completely disclose to operators — and incorporate in the ATR 72 AFM, flight crew operating manual and flight crew training programs — adequate information concerning previously known effects of freezing precipitation on the stability and control characteristics, autopilot and related operational procedures when the ATR 72 was operated in such conditions; 2) the French Directorate General for Civil Aviation’s inadequate oversight of the ATR 42 and 72, and its failure to take the necessary corrective action to ensure continued airworthiness in icing conditions; and 3) the French Directorate General for Civil Aviation’s failure to provide the (FAA) with timely airworthiness information developed from previous ATR incidents and accidents in icing conditions.”[1]]

[FAA AD 96-09-21 affected the Saab 340A, 340B and 2000. Among the AD requirements was a revision of model 340 flight manuals to prohibit use of the autopilot when the flight crew observed an “accumulation of ice on the upper surface of the wing aft of the protected area” or an “accumulation of ice on the propeller spinner farther aft than normally observed.” The AD also required revision of the model 340 flight manuals to prohibit use of the autopilot “when unusual lateral trim requirements or autopilot trim warnings are encountered while the airplane is in icing conditions.”[2]]

The report said that the AD was not incorporated in Saab 340 AOMs by the Swedish airworthiness authority (Luftfartsverket [LFV]), by Saab Aircraft or by CASA.

“[LFV] did not consider that these issues applied to the Saab 340; and, therefore, they did not issue a corresponding [AD] for the type,” the report said. “As the [AD] dealt with operations in severe icing conditions, LFV did agree, however, to insert certain sections of the [AD] into the Saab 340 [AOM].”

For example, LFV inserted instructions on the use of the autopilot in freezing rain/drizzle in the Saab 340 AOM.

“The manufacturer [Saab Aircraft] indicated that the [AD] was not incorporated into the Saab 340 manuals due to disagreements concerning the applicability of the information to the Saab 340,” the report said. “They also indicated [that the AD] was applicable to U.S. operators only.

“CASA did not impose the requirements of [AD] 96-09-21 to flight manuals of the Saab 340 because the state of manufacture [Sweden] did not issue it. CASA stated that this was in accordance with the standards and recommended practices of ICAO [International Civil Aviation Organization] Annex 8, *Airworthiness of Aircraft*. The investigation team found, however, that the [AD] had been implemented in the flight manuals of other turboprop aircraft, either by a manufacturer’s amendment or a flight manual amendment issued by CASA.”

The incident pilots told investigators that the EADI was “of little use” during the recovery.

“Both crewmembers described the [EADI display] as ‘a mess of blue and brown,’” the report said. “The [captain] reported that he had used the standby attitude indicator to aid in the recovery of the aircraft to straight-and-level flight.”

At the time of the incident, the Saab 340 AOM said that some information is removed from the EADI at extreme airplane attitudes — that is, when the airplane pitches more than 30 degrees nose-up or more than 20 degrees nose-down, or rolls more than 65 degrees. The AOM said that information remaining on the EADI includes an attitude-warning flag, an attitude display and flight-director command bars.

The report said, however, that information remaining on the EADI differed from the AOM description when the incident was replicated during the investigation in the operator's flight simulator.

Saab Aircraft on Oct. 25, 1999, amended the AOM with information on what the EADI would show at extreme airplane attitudes.

"[The information] coincided with the pictorial displays observed in the operator's Saab 340 flight simulator during the replication of the occurrence sequence," the report said.

The AOM amendments incorporated by Saab Aircraft on Oct. 25, 1999, included information on recovering from unusual attitudes, responding to stick-shaker activation (stall warning) and recovering from a stall.

Transport Canada required modification of the Saab 340 stall-warning system before the airplane began service in Canada in November 1994.

"The stall-warning systems fitted to Canadian-registered Saab 340s are essentially the same as those fitted to Australian and other Saab 340 aircraft operated worldwide," the report said. "However, to meet Transport Canada's requirements, an added input has been provided to the stall-warning computers. This input is designated as 'ice speed' and is controlled by the activation of an 'ICE SPEED' switch."

When the "ICE SPEED" switch is selected, the stall-warning system (stick shaker) and the stall-identification system (stick pusher) activate at lower angles-of-attack than when the "ICE SPEED" switch is not selected.

During the incident investigation, ATSB (then called the Bureau of Air Safety Investigation) recommended that Kendall Airlines, Hazelton Airlines and Macair "note the circumstances of [the incident] and alert their aircrew accordingly."

On Jan. 7, 1999, Kendall Airlines told ATSB that it had issued an operational memorandum to its crewmembers. The memorandum included an increase of the minimum holding speed in icing conditions to 170 knots and a prohibition on the use of the autopilot when holding in icing conditions.

During the investigation, ATSB recommended that LFV "review the certification aspects of the [Saab 340's] stall-warning system, particularly in icing conditions."

On Sept. 16, 1999, LFV told ATSB that "any retroactive requirements that would significantly increase safety for all types of aircraft in icing conditions should … be coordinated worldwide and not just be applied to one type."

LFV said that FAA had issued a notice of proposed rule making to require pilots to activate deicing boots at the first sign of ice accumulation. "A change implementing the FAA proposal … will be introduced in all LFV [AFMs] and in the manufacturers' [AOMs] shortly," LFV said.

During the investigation, ATSB recommended that CASA "examine the circumstances surrounding [the incident] and take whatever steps it considers necessary to ensure the safety of the Saab 340 fleet operating within Australia."

On Aug. 13, 1999, CASA told ATSB that it "does not believe at this time that there is an airworthiness problem with this aircraft type that requires immediate mandatory action."

CASA said, "Pending the outcome of the FAA proposal [to require activation of deice boots at the first sign of ice accumulation], CASA will write to Australian operators of this aircraft type to inform them of the [ATSB incident] investigation and recommend [that] they review their training and operating procedures, and write to the manufacturer and associated regulatory authorities to seek their views and to elicit comments on appropriate action."

FAA on Dec. 27, 1999, issued AD 99-19-14, requiring flight crews of Saab 340s and Saab 2000s equipped with pneumatic deicing boots to activate the boots "at the first sign of ice formation anywhere on the aircraft or upon annunciation from an ice-detector system."

During the investigation, ATSB made the following recommendations to Saab Aircraft:

- "Amend the Saab 340 [AOM] to more appropriately alert pilots that the stall-warning system may not activate when the aircraft is operating in icing conditions;
- "Note the circumstances of [the incident] and alert [Saab] 340 operators accordingly; [and,]
- "Modify the stall-warning system of the worldwide fleet of Saab 340 aircraft to include the ice-speed modification, as a matter of priority."

On Feb. 18, 1999, Saab Aircraft told ATSB that it was distributing to Saab 340 operators AOM Operations Bulletin No. 56, *Artificial Stall Warning in Icing Conditions*. The bulletin said that "with Mod. No. 2650 (ice-speed system) installed and selected, the stall-warning triggering level is changed to give stall warning at a higher speed. … The artificial stall-warning system does not always provide a stall [warning] before stall is encountered if there is ice on the wing."

On Aug. 6, 1999, Saab Aircraft told ATSB that its analysis of data from the incident airplane's DFDR showed that there were several natural warnings of the impending stall.

"The stall buffet started slightly more than six seconds prior to the stall and five KIAS [knots indicated airspeed] above the aerodynamic stalling speed," Saab Aircraft said. "There was also a significant increase in pitch attitude prior to the stall, while the aircraft was still in level flight. … Finally, the speed was decreasing to values well below the minimum recommended speeds for holding."

Saab Aircraft said that it did not agree with the recommendation to incorporate the ice-speed modification on all Saab 340s because the modification was based on "the most adverse ice accretion defined by Transport Canada."

"For takeoff, the lower angle-of-attack triggering levels are inhibited [for] six minutes from liftoff when the [ice-speed system] is selected … to prevent the crew from [experiencing] an undesired [stick-]pusher activation. … In landing when the [ice-speed system] is selected on, the resulting reference speeds are about 20 [KIAS] to 25 KIAS higher than for the clean aircraft, which sometimes creates difficulties when landings are made with a less-critical ice accretion, which is the most common case. Also, the required landing distances are significantly longer."

After completing the incident investigation, ATSB reiterated the recommendation that the stall-warning systems in all Saab 340s be modified with the ice-speed modification. ATSB also made the following recommendations to Saab Aircraft:

- "Include information in both the [AFM] and the [AOM] advising of the differing shedding capabilities of the wing deice boots at different temperatures; [and,]

- "Advise operators that use of autopilot modes that do not include IAS [indicated airspeed] mode will not afford protection against penetration of the required stall margins."♦

[FSF editorial note: This article, except where specifically noted, is based on Australian Transport Safety Bureau Air Safety Investigation 199805068, *Saab — SF340A, VH-LPI, Eildon Weir, Victoria, 11 November 1998*. The 62-page report contains diagrams.]

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1. U.S. National Transportation Safety Board. *Aircraft Accident Report: In-flight Icing Encounter and Loss of Control, Simmons Airlines, d.b.a American Eagle Flight 4184, Avions de Transport Regional (ATR) 72-212, N401AM, Roselawn, Indiana, October 31, 1994*. Volume 1: Safety Board Report. NTSB/AAR-96/01.

2. U.S. Federal Aviation Administration. Airworthiness Directive 96-09-21: *Icing Conditions*. June 11, 1996.

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