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Airframe Icing, Low Airspeed Cause Stall During Nonprecision Approach

The Saab 340B's autopilot was in the altitude-hold mode and the engines were producing near-flight-idle power during a circling approach. The stall-warning system did not activate before the aircraft stalled. The flight crew recovered control of the aircraft 112 feet above the ground.

FSF Editorial Staff

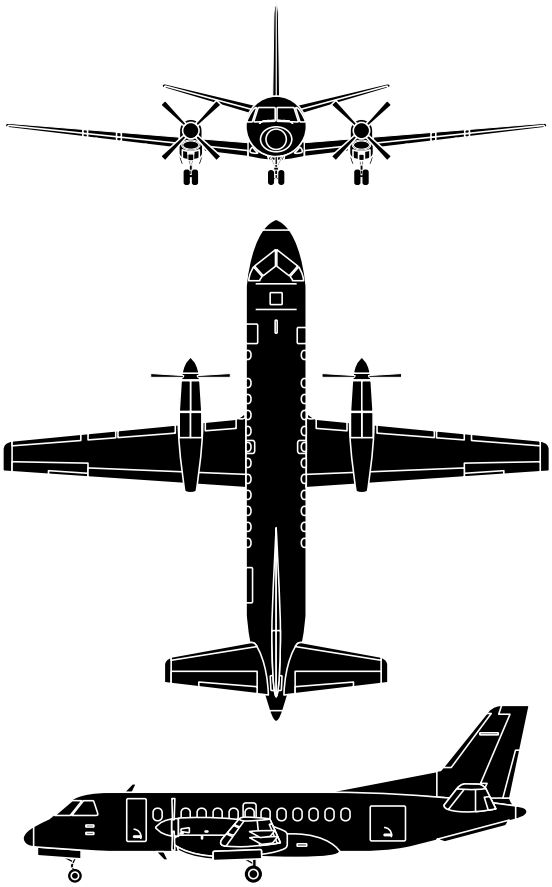
At 1800 local time June 28, 2002, a Saab 340B that was being operated on a regular public transport flight from Sydney to Bathurst — both in New South Wales, Australia — stalled while the flight crew was conducting a circle-to-land maneuver at the Bathurst airport following a nighttime nonprecision instrument approach in intermittent icing conditions. The crew regained control of the aircraft 112 feet above ground level (AGL), conducted a missed approach and landed the aircraft without further incident. The two pilots, flight attendant and 29 passengers were not injured, and the aircraft was not damaged.

The Australian Transport Safety Bureau (ATSB) said, in its final report, that the following were significant factors in the serious incident:[1]

- "Although provided with visual cues ([ice on the] windshield wiper), the flight crew did not detect airframe [ice] or wing ice during the descent and therefore did not take measures to remove the ice;
- "The flight crew left the power setting unchanged at 17 percent [torque] after leveling out when 50 percent to 60 percent would have been appropriate given the aircraft configuration and environmental conditions;
- "The flight crew allowed the aircraft's speed to slow below a safe speed;
- "The stall-warning system did not activate prior to the stall;
- "The aircraft was not fitted with the Canadian stall-warning-system modification.[2] If this had been fitted and activated, it would have alerted the flight crew and provided them with between [three seconds to four seconds of] warning of the impending stall;
- "The SOP [the aircraft operator's *Operations Manual — Standard Operating Procedures*] did not require activation of the deice boots in known icing conditions as per the manufacturer documentation; [and,]
- "The SOP allowed for the use of the autopilot during icing conditions, which masked tactile cues regarding the increasing nose-up [pitch] attitude."

The report included the following comments by the Australian Civil Aviation Safety Authority (CASA):

- "The crew failed to recognize the sudden loss of height and significant roll as a stall event. Consequently, the crew did not report the incident in a timely manner nor inform the operator of the seriousness of the incident;
- "This resulted in the aircraft continuing normal scheduled operations when a thorough inspection of the aircraft



Saab 340B

Saab-Scania (now Saab Aircraft) and Fairchild Aircraft began the development of a twin-turboprop regional airplane in 1980. The prototype SF-340 first flew in 1983, and the airplane entered production as the SF-340A in 1984. Saab assumed control of development and production of the airplane in 1985; Fairchild continued as a subcontractor until 1987, and "SF" was eliminated from the model designation. Saab ceased production of the 340 in 1999.

The SF-340A has 1,294-kilowatt (1,735-shaft-horsepower) General Electric (GE) CT7-5A2 engines and four-blade Dowty Rotol propellers. The 340B, a "hot and high" version that entered production in 1989, has GE CT7-9B engines rated at 1,305 kilowatts (1,750 shaft horsepower) for takeoff and 1,394 kilowatts (1,870 shaft horsepower) with automatic power reserve. The B model also has a larger tail, higher operating weights and increased performance.

The airplane has accommodations for two pilots, a flight attendant and up to 37 passengers. Maximum takeoff weight is 12,927 kilograms (28,500 pounds). Maximum landing weight is 12,700 kilograms (28,000 pounds).

Maximum rate of climb at sea level is 2,050 feet per minute. Maximum single-engine rate of climb at sea level is 525 feet per minute. Maximum cruising speed is 282 knots at 15,000 feet. Service ceilings are 25,000 feet, standard, and 31,000 feet, optional. Single-engine service ceiling is 11,300 feet. Stall speeds are 106 knots with flaps retracted and 88 knots with flaps fully extended.♦

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

should have been conducted before further flight; [and,]

- "The operator should ensure that crews are aware of their obligation to report any incident and provide sufficient detailed information for a considered evaluation of appropriate actions to be taken."

The report did not identify the aircraft operator.

"At the time of the serious incident, the operator, along with some of its Australian code-share partners, was in the hands of an administrator and on the verge of being sold," the report said. "The investigation found nothing to indicate that the financial health of the parent operator or the impending sale of the operator had any influence on the circumstances leading to this incident."

The pilot-in-command (PIC) had an air transport pilot license (ATPL) and 9,530 flight hours, including 1,939 flight hours in type. He was employed by the operator as a Swearingen Metro 23 copilot in 1994. He flew as a Saab 340 copilot and Metro 23 commander before receiving his Saab 340 command endorsement in 2000.

On the day of the incident, he arose at 0630 and reported for duty at 1100.

"He commented that he had been up a few times during the night with his young children but said that he was feeling well at the time," the report said.

The copilot had an ATPL and 6,620 flight hours, including 1,451 flight hours in type. She was employed by the operator in 1995 and flew as a Metro 23 copilot for five years before becoming a Saab 340 copilot.

The copilot reported for duty at 1100. The pilots conducted six flights before departing from Sydney for the flight to Bathurst. The PIC told investigators that it had been "a long day" and that the copilot and he "had the occasional yawn, but no more than usual."

The report said, "The copilot said that with six sectors already flown and three to go, it had been a big day with a heavy workload. … She said that she had not had a meal that day except a sandwich … at about 1330."

Fatigue was not cited as a factor in the incident.

"Although the flight crew had been on duty for some time, there was insufficient evidence to suggest that they were suffering from the effects of fatigue," the report said. "There was no evidence that personal, psychological or physiological factors affected the performance of the flight crew."

The aircraft was about 77 kilograms (170 pounds) over its maximum takeoff weight when it departed from Sydney.

"Although the aircraft may have taken off slightly overweight, based on the fuel burn for the Sydney–Bathurst sector, the aircraft was probably at less than maximum weight at the time of the serious incident and therefore within normal operating parameters," the report said.

Flying time from Sydney to Bathurst [which is about 86 nautical miles (159 kilometers) northwest] was about 35 minutes. The area forecast for the route of flight indicated that the freezing level was at 4,000 feet and that moderate icing conditions could be expected in clouds above the freezing level. The forecast for Bathurst included snow showers, a surface temperature of 2 degrees Celsius (36 degrees Fahrenheit), a broken ceiling at 800 feet and southwesterly winds gusting to 28 knots.

The PIC told investigators that the aircraft entered clouds several times during descent from cruise altitude (12,000 feet), to the initial approach altitude (5,700 feet) and then to the minimum descent altitude (MDA; 3,810 feet) for the global positioning system (GPS) approach. Airport elevation was 2,435 feet.

The report said that icing conditions conducive to the accumulation of clear ice on the aircraft likely were encountered during the descent.

The copilot said that the engine anti-ice system was on during the descent, but the propeller deice system was off, and the deice boots on the wing leading edges and tail leading edges were not activated. The flight crew observed ice accumulating on the windshield wiper but not on the wing leading edges.

"The ice accretion on the wings was likely to have been a clear ice deposit, which may have been difficult for the flight crew to recognize at night," the report said.

The PIC was flying the aircraft on autopilot. During the descent to the MDA, with the flaps extended 20 degrees and the landing gear extended, the PIC reduced power to about 17 percent torque. He did not increase power when the autopilot leveled the aircraft at the MDA.

The company's chief pilot told investigators that a steep descent, with the engines at flight idle, would have been required for the arrival and GPS approach but that power should have been increased to 50 percent to 60 percent with the aircraft in level flight.

"The PIC commented that in hindsight, perhaps he should have increased power, but when he checked, the speed was still decreasing towards the circling-approach speed [130 knots]," the report said. "He said that maybe he was looking at something else just before the incident or perhaps he was distracted while attaining visual conditions and thinking about the turn to downwind."

The autopilot's altitude-hold mode was engaged, and the autopilot increased nose-up pitch trim to maintain the selected altitude as airspeed decreased. At the time, the aircraft was on a westerly heading. The flight crew intended to circle to land to the south — on Runway 17.

Flight data recorder (FDR) data indicated that airspeed was 133 knots when the PIC began a right turn, using the autopilot, to establish the aircraft on the downwind leg for Runway 17.

"The PIC, who had been looking out at the [airport], commanded the autopilot to roll the aircraft to the right to begin tracking downwind for Runway 17," the report said. "At about this time, the copilot, who had also been looking at the runway, glanced inside and observed that the airspeed was decreasing towards 120 knots and called 'speed.'"

The PIC increased power and began rolling the aircraft out of the right turn, which had reached 28 degrees of bank. About the same time, the left wing stalled and the airplane rolled left and pitched nose-down.

Airspeed was about 113 knots and angle-of-attack was 9.5 degrees when the stall occurred.

Airspeed was about 113 knots and angle-of-attack was 9.5 degrees when the stall occurred. The report said that the stall-warning system did not activate because the ice that had accumulated on the wings during the descent caused the aircraft to stall at a lower-than-normal angle-of-attack.

The stall-warning system in the incident aircraft comprised two angle-of-attack sensors, two computers, stick-shaker actuators on both control columns and a stick-pusher actuator mounted on the PIC's control column and connected mechanically to the copilot's control column.

With the flaps retracted, the stick shaker is activated and the autopilot is disconnected when either sensor measures 12.5 degrees angle-of-attack. The stick pusher is activated when one sensor measures 19 degrees angle-of-attack and the other sensor measures an angle-of-attack of 12.5 degrees or more. The stick pusher applies 36.3 kilograms (80.0 pounds) of force on the control columns, which results in a four-degree reduction in pitch attitude.

With the flaps extended, the angle-of-attack at which the stick shaker and stick pusher are activated varies up to one degree. The report said that with flaps extended 20 degrees, the stick shaker would be activated at 13.1 degrees angle-of-attack.

Analysis of FDR data by Saab Aircraft indicated that 0.5 inch (12.7 millimeters) of ice was on the wing leading edges when the left wing stalled. The pilot began rolling the aircraft out of the resulting steep left bank, applied nose-up pitch control

and increased power to 51 percent. At the time, the aircraft was descending through about 960 feet AGL with a pitch attitude of 27 degrees nose-down.

"The PIC overpowered the autopilot, rolling the aircraft back from 109 degrees left bank to a bank angle of approximately 35 degrees when — due to high angle-of-attack, ice accumulation on the wing leading edges and the continuing roll rate to the right — the right wing stalled, rolling the aircraft to about 56 degrees [right bank]," the report said. "During this second stall, the stick-shaker/stall-warning system was most probably activated and, consequently, the autopilot disengaged."

The aircraft was descending through about 688 feet AGL at 146 knots when the autopilot disengaged. Angle-of-attack had increased to 16.22 degrees, and the aircraft's pitch attitude was 19 degrees nose-down.

The aircraft descended 576 feet during the next eight seconds. The PIC rolled the airplane to a wings-level attitude, increased power to 100 percent and continued applying nose-up pitch control. The FDR recorded an airspeed of 165 knots and a vertical acceleration of 2.56 g (2.56 times standard gravitational acceleration) when the aircraft stopped descending and began to climb.

The flight crew retracted the landing gear and the flaps, and conducted the missed approach procedure. The crew then conducted a nondirectional beacon (NDB) approach and landed the aircraft.

The aircraft descended 576 feet during the next eight seconds.

The flight crew believed that the aircraft had been upset by turbulence. The copilot said that she observed no ice on the aircraft during a postlanding inspection.

"The aircraft and flight crew completed their assigned duties that evening, which included a sector to Parkes [New South Wales] and return to Sydney via Bathurst," the report said. "The next day, the PIC reported to the operator's fleet manager that the aircraft 'dropped a wing' at Bathurst but that they had recovered the aircraft and landed, and there was no evidence of airframe ice.

"The fleet manager advised him to submit a report. The PIC submitted an incident report to the operator four days later — on Tuesday, 2 July 2003."

On July 1, 2003, ATSB received a confidential report by a passenger on the incident flight.

"The ATSB quarantined the flight recorder and, after retrieval and examination of the data, commenced an investigation," the report said. "The ATSB subsequently notified the operator about the seriousness of the incident. The operator immediately grounded the aircraft to conduct an airworthiness examination. During the intervening time, the aircraft had been operating on its scheduled routes and had flown 27 hours spread across 35 flights."

Examination of the aircraft by ATSB and by the operator revealed no damage.

Investigators found inconsistencies in information published in the SOP, the airplane flight manual (AFM) and the aircraft operating manual (AOM) on the use of the deice boots and the autopilot in icing conditions.

The SOP said that the deice boots should be activated when about 10.0 millimeters (0.4 inch) of ice has accumulated on the wing leading edges.

"However, the AOM advised flight crew to operate the boot deice system when ice has accumulated to about 6.0 millimeters [0.2 inch] thickness on the leading edges," the report said. "Volume 2 of the AOM instructed flight crew to operate the boot deice system at the first sign of ice formation anywhere on the aircraft."

The report said, "Had the wing deice boots been used during the descent, the accretion of ice on the wings should have been minimized, allowing the aircraft's stall-warning system to operate as designed. This would have given the flight crew sufficient warning of the impending stall due to the decreasing airspeed and increasing angle-of-attack."

The SOP recommended "maximum use" of the autopilot during takeoff, climb, cruise, descent and instrument approaches. The SOP also said that the autopilot should be in full-bank mode during all approaches. Maximum bank angle in the full-bank mode is 27 degrees.

The AFM, however, recommended that the autopilot be operated in half-bank mode — which limits bank angle to 13.5 degrees — during flight in icing conditions.

The PIC of the incident aircraft was operating the autopilot in full-bank mode.

"The use of half-bank mode by the crew during the incident would have increased the safety margin between the aircraft speed and the stall speed and allowed for the triggering of the stall-warning system prior to the [initial] stall," the report said.

The SOP, AFM and AOM included a recommendation for autopilot-mode selection during climb in icing conditions. The manuals said that the IAS (indicated-airspeed-hold) mode is the only vertical mode that should be used during climb when airframe icing is observed or is possible.

The report said that the manuals contained no other instructions for the use of the autopilot in icing conditions.

"Had the autopilot been turned off, the PIC, with the continuing need to trim the aircraft, would have realized that something was amiss," the report said.

The report said that the flight crew was not aware that the autopilot had increased significantly the aircraft's nose-up pitch attitude to maintain altitude as airspeed decreased.

"A common trim-tab-position indicator is located on the lower right corner of the center instrument panel," the report said. "It provides the only indication to the flight crew of the position of the various trim tabs and is not in the flight crew's primary field of view. … The elevator-trim systems do not provide any aural indication [clacker] to alert the flight crew whenever they are operated."

The report cited four other incidents in which Saab 340s stalled with little warning or no warning to the flight crew:

- On Sept. 23, 1991, a 340 stalled during a climb in icing conditions in Europe. "The flight crew regained control and descended the aircraft approximately 4,000 feet," the report said. "The flight crew reported that only a moderate amount of ice was present on the wings and that they had operated the [deice] boots at least once during the climb." As a result of the incident, the manufacturer issued an AOM bulletin stating that stall speed would increase in icing conditions. "This increase was quoted as being '10 percent for flight with 0.5 inch (12 millimeters) of simulated ice and 18 percent with 3.0 inches (75 millimeters) of simulated ice' (clean, flaps-up configuration)," the report said. "[The bulletin] also included information that stall warning in the form of buffeting may be experienced at speeds up to 25 percent above the clean (ice-free) stall speed."

- On March 23, 1994, during a climb in icing conditions in the United Kingdom, the rate of ice accumulation did not appear heavy to the 340 flight crew, and they did not activate the deice boots. Nevertheless, aircraft performance deteriorated, and a severe vibration was perceived by the crew to be the result of ice on the left propeller. The autopilot disconnected, and the aircraft rolled rapidly into a 60-degree right bank. The report said that a factor in the incident was the crew's use of an "inappropriate autopilot mode" during the climb.

- On June 12, 1994, a 340 was being flown in New Zealand with the engine-deice system and propeller-deice system engaged. The flight crew activated the deice boots to remove a small buildup of ice just before entering a holding pattern at 11,000 feet. Indicated airspeed decreased from 180 knots to 140 knots, and a severe vibration began. The crew disengaged the autopilot and applied nose-down pitch control to regain airspeed. At the same time, roll oscillations began with up to 30 degrees of bank, and there was little response by the aircraft to flight-control inputs by the crew. The roll oscillations continued until airspeed increased to 180 knots.

- In February 1998, the flight crew of a 340 encountered icing conditions while flying the airplane to a cruise altitude of 16,000 feet in the United States. Soon after the crew established level flight, the stall-warning system activated, and the aircraft rolled left. "The aircraft continued to react sluggishly to aileron [control] and elevator control until the flight crew had descended the aircraft to 11,000 feet," the report said. The PIC said that a small amount of mixed ice had accumulated on the airframe during the climb but he did not activate the deice boots because he was concerned that "ice bridging" might occur. The report said that this concern was unfounded. "Classic ice bridging [typically had] occurred when ice accreted around the inflated tube [deice boot] and remained after the tube deflated," the report said. "The resulting cavity beneath the ice allowed the tube to inflate and deflate beneath the 'ice bridge,' resulting in no ice removal from the wing. Providing that the deice systems (which include the boots) are maintained correctly, there is no documented evidence to date of [deice] boot ice bridging in modern turbopropeller aircraft."

- On Nov. 11, 1998, a 340A accumulated ice during a scheduled public transport service flight in Australia. Soon after the flight crew conducted a turn to enter a holding pattern over Eildon Weir, Victoria, the aircraft stalled, rolled about 126 degrees left and pitched about 35 degrees nose-down. The crew regained control of the aircraft after it descended 2,300 feet in 10 seconds. The crew told air traffic control that they had encountered turbulence. [The flight attendant received minor injuries; the two pilots and 28 passengers were not injured. Among the significant factors listed by ATSB in its final report on the incident were that the crew allowed airspeed to slow below the published holding speed and that the stall-warning system did not activate before the aircraft stalled.[3]]

The Bathurst-incident report said, "Crews depend on the artificial stall-warning system to alert them to an impending stall. However, the [incidents] have shown that it is possible for the aircraft to stall in icing conditions with little to no warning to crews."

Based on the findings of the incident investigation, ATSB recommended that three Australian aircraft operators — Hazelton Airlines, Macair and Regional Express — "note the circumstances [in which] Saab 340 aircraft can stall without warning in icing conditions and alert their flight crew accordingly."

AAIB recommended that CASA "examine the circumstances surrounding this incident where Saab 340 aircraft can stall

without warning in icing conditions and take appropriate action to ensure the safety of the Saab 340 fleet within Australia."

AAIB recommended that Saab Aircraft "modify the stall-warning system of the worldwide fleet of Saab 340 aircraft to give sufficient warning of an impending stall to crews during flight in icing conditions."

The report said that the operator of the incident aircraft took the following actions:

- A draft of a new section for the SOP titled "Cold Weather Operations," containing expanded information on operations in icing conditions and recovery from a roll upset, was reviewed to incorporate issues arising from the incident investigation;
- The SOP was revised to correct inconsistencies between the AFM, AOM and SOP; and,
- Training in stall recovery, unusual-attitude recovery, operations in icing conditions and minimum maneuvering speeds during circling approaches was incorporated in flight-simulator training.♦

[FSF editorial note: This article, except where specifically noted, is based on Australian Transport Safety Bureau Air Safety Investigation Report 200203074: *Inflight Loss of Control due to Airframe Icing, Saab 340B, VH-OLM, 28 June 2002*. The 36-page report contains illustrations.]

Notes

1. International Civil Aviation Organization Annex 13, *Aircraft Accident and Incident Investigation*, defines a serious incident as "an incident involving circumstances indicating that an accident nearly occurred."

2. The report said that the stall-warning system modification required by Transport Canada for Saab 340 aircraft registered in Canada includes an "ICE SPEED" switch that, when selected by the flight crew, causes stall warnings to be generated at lower angles-of-attack. With the "ICE SPEED" switch selected, the stick shaker, aural stall warning and visual stall warning are generated at angles-of-attack from 5.9 degrees with flaps retracted to 2.1 degrees with flaps fully extended; the stick pusher is activated at 11 degrees angle-of-attack, regardless of flap position. The report said that if the incident aircraft had been equipped with the Canadian modification, the stall-warning system would have activated when angle-of-attack reached about 3.7 degrees, at an airspeed of about 120 knots.

3. Australian Transport Safety Bureau. Air Safety Investigation Report 1998025068: *Saab SF340A, VH-LPI, Eildon Weir, Victoria, 11 November 1998*. See also: FSF Editorial Staff. "Icing, Inadequate Airspeed Trigger Loss of Control of Saab 340." *Accident Prevention* Volume 58 (October 2001).

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