THIN *but* DEADLY

Another hard lesson that even a little ice can be dangerous.

BY MARK LACAGNINA

Noncompliance with procedures for the use of a Citation's deice boots led to an ice-induced stall.

On the morning of Feb. 16, 2005, two Cessna Model 560 Citation Vs operated by the same company and being flown only minutes apart encountered icing conditions on approach to Pueblo (Colorado, U.S.) Memorial Airport. One airplane crashed about 4 nm (7 km) from the runway, killing the two pilots and six passengers; the other airplane was landed safely.

The difference, according to the U.S. National Transportation Safety Board (NTSB), was that the flight crew of the accident airplane did not cycle their deice boots during the approach and did not increase their approach speed, as required in icing conditions. The result was an ice-induced stall and an upset from which the pilots were unable to recover. The crew of the other airplane cycled their deice boots several times and maintained a higher-than-normal approach speed.

In its final report, NTSB said that the probable cause of the accident was "the flight crew's failure to effectively monitor and maintain airspeed and comply with procedures for deice boot activation on the approach." The board said that a contributing factor was the failure of the U.S. Federal Aviation Administration (FAA) "to establish adequate certification requirements for flight into icing conditions, which led to the inadequate stall warning margin provided by the airplane's stall warning system."

Cross-Country Trip

The Citations were owned by Circuit City Stores and operated by Martinair. "Martinair has provided pilots and maintenance support for Circuit City Stores airplanes through a management services agreement since 1993," the report said. "At the time of the accident, Martinair managed 15 aircraft, operated 11 aircraft and had 33 full- and part-time pilots and eight aircraft mechanics. Martinair's chief pilot stated that, although Circuit City Stores flights fell under [the general operating and flight rules of U.S. Federal Aviation Regulations Part 91], company pilots generally adhered to Part 135 [on-demand] operating rules for these flights and used the same checklists and standard operating procedures used for Part 135 flights."

On the day of the accident, the Citations were scheduled to fly employees of Circuit City Stores from Richmond, Virginia, to Santa Ana, California, with en route fuel stops in Columbia, Missouri, and Pueblo.

The captain of the accident airplane, 53, had 8,577 flight hours, including 2,735 flight hours in type and 1,500 flight hours as a Citation pilot-in-command (PIC). He held type ratings for 500-series Citations, the Beech King Air 300 and 1900, and the Dassault Falcon 10. He was hired by Martinair in February 2002.

The first officer, 42, held a Citation 500 type rating and had 2,614 flight hours, including 1,397 flight hours in type and 322 flight hours as a Citation PIC. He was hired by Martinair in November 2004.

The accident airplane departed from Richmond at 0600 local time — 0400 Pueblo time — and arrived in Columbia about an hour and a half later. After about 30 minutes on the ground, the airplane continued the trip to Pueblo.

Before beginning the descent from cruise altitude at about 0840 Pueblo time, the crew received automatic terminal information system (ATIS) information indicating that weather conditions at the airport included surface winds from 060 degrees at 6 kt, 10 mi (16 km) visibility, an overcast ceiling at 1,400 ft and a

Supercooled large droplets typically splash and freeze relatively slowly on contact with an aircraft.

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When the surface-deice switch in the Citation V is selected to 'AUTO,' the boots cycle once; in 'MANUAL,' all the boots inflate and remain inflated until the switch is released.

surface temperature of minus 3 degrees C (27 degrees F).

The ATIS information indicated that Runway 08L was being used for landings. Accordingly, the crew briefed the instrument landing system (ILS) approach to that runway.

The airplane was descending in instrument meteorological conditions (IMC) at 0851 when the crew began discussing icing conditions. The captain said, "I'm going to heat them up." The report said that this statement likely referred to activation of the engine anti-ice system, which heats the engine inlets and the inboard wing leading edges. The captain also activated the windshield-heating system.

With deice boots of modern design on the airplane, pilots do not need to worry about the phenomenon of 'ice bridging.'

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The Citation V is certified for flight in icing conditions that are not severe. Engine bleed air is used to heat the engine inlets, inboard wing leading edges and the windshield. Deice boots are installed on the outboard wing leading edges and the horizontal stabilizer. Electric heating elements protect the pitot tubes, static ports and angle-of-attack (AOA) vanes.

'Real Thin Line'

The report said that analysis of cockpit voice recorder (CVR) data and meteorological data indicated that the airplane was in mixed icing conditions for about 5 1/2 minutes while descending from 21,000 ft to 14,000 ft.

At 0854, the captain asked the first officer if he saw any ice on the wing. "It's building a little bit right on the leading edge," the first officer said. "It's not the real white ice like we had yesterday. It's more … grayish. There's a real thin line back there."

The airplane was descending through 18,000 ft at 0858 when the captain said, "Doesn't look like we picked up any more [ice]."

The first officer said "nope" and suggested that the captain activate the deice boots. Noting that the surface temperature was minus 3 degrees C, he said, "It ain't going to melt much on the ground."

After the deice boots were cycled, both pilots commented about residual ice that remained on the boots. "Might have gotten rid of a little, but not much," the captain said. "Little sticky ice today," the first officer said. The flight crew did not activate the deice boots again during the descent and approach.

The report noted that the spring-loaded surface-deice switch in the Citation V has two positions: "MANUAL" and "AUTO." When the switch is held in the "MANUAL" position, all of the deice boots inflate simultaneously and remain inflated until the switch is released. Selection of "AUTO" initiates an 18-second cycle in which the various deice boots are inflated and deflated in a specific sequence. After the cycle is completed,

the boots remain deflated until the surface-deice switch is selected to "AUTO" again.

Ice Bridging Fallacy

During postaccident interviews, instructors at CAE SimuFlite, Martinair's training provider, told investigators that they teach pilots to activate deice boots after 1/4 to 1/2 in (6 to 13 mm) of ice has accumulated on them. The report said that the SimuFlite *Cessna Citation V Technical Manual* states, "Early activation of the boots may result in ice bridging on the wing, rendering the boots ineffective."

"Ice bridging is a phenomenon in which ice in the shape of an inflated deice boot forms after the boot is cycled," the report said. "Ice bridging had been known to occur on older deice boot designs that used larger tubes and lower pressures, resulting in slower inflation and deflation rates."

However, research has shown that ice bridging is not a risk for modern turbine airplanes equipped with segmented, high-pressure deice boots that inflate and deflate quickly, the report said.

In Advisory Circular 25.1419-1A, issued in May 2004, the FAA says that pilots should not wait for a specific amount of ice to accumulate before activating deice boots. "Although the ice may not shed completely with one cycle of the boots, this residual ice will usually be removed during subsequent boot cycles and does not act as a foundation for a bridge of ice to form," the FAA said.

The report said that concern about ice bridging is no reason for pilots of modern airplanes to delay activation of deice boots. "Activating the deice boots as soon as an airplane enters icing conditions provides the greatest safety measure," the report said.

Airspeed Factor Omitted

While conducting the "Approach" checklist at 0859, the first officer said that the landing reference speed, VREF, was 96 kt. An approach-airspeed adjustment required by company standard operating procedures (SOPs) had not been applied.

"In accordance with company guidance, if any amount of residual ice — that is, ice that remains on the deice surface after the deice boots have been cycled — is present, VREF should be increased by 8 kt, which would have resulted in a VREF of 104 kt instead of the 96 kt reported by the first officer," the report said.

At 0905, the approach controller told the crew to fly a heading of 240 degrees. The controller said that the heading was a vector to the final approach course for the ILS approach to Runway 26R.

The first officer, who had prepared for the ILS approach to Runway 08L, told the captain, "He did a change on us here." He then retuned the navigation receivers and set the instruments for the ILS approach to Runway 26R.

"During postaccident interviews, the controller stated that he was often asked by corporate

Cessna Citation V

Cessna Aircraft Co.

The Cessna Model 560 Citation V is a derivative of the Model S550 Citation S/II, with a fuselage stretched 2.0 ft (0.6 m) and higher-performance Pratt & Whitney JT15D-5A engines, each producing 2,900 lb (1,315 kg) thrust. Deliveries began in 1989.

The Citation V can accommodate two pilots and eight passengers. Maximum takeoff weight is 15,900 lb (7,212 kg). Maximum landing weight is 15,200 lb (6,895 kg). Maximum rates of climb are 3,650 fpm with both engines operating and 1,180 fpm with one engine operating. Maximum operating speeds are 292 kt below and 0.76 Mach above 29,000 ft. Maximum operating altitude is 45,000 ft.

The Citation V was replaced in 1994 by the Citation Ultra, which has increased performance, a higher payload, a digital autopilot and electronic flight instrument systems. The current version of the Model 560 is the Citation Encore, introduced in 2000 with more powerful engines, a longer wing with improved stall characteristics and other improvements.

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

pilots to use the runway opposite that being advertised on ATIS [i.e., reciprocal runway] and that, as a service, he would provide the closest runway as a matter of course as long as the winds allowed it," the report said.

SLD Conditions

At 0908, while discussing the location of a regional airplane that was holding at 9,000 ft to reduce its fuel load for landing, the first officer told the approach controller that the Citation had entered IMC at 9,400 ft. A few minutes later, the controller told the crew to fly a heading of 290 degrees to intercept the localizer at 7,000 ft and cleared them for the approach.

A study of meteorological data by the National Center for Atmospheric Research (NCAR) found that the airplane likely encountered supercooled large droplet (SLD) conditions while descending from 9,400 ft to 6,100 ft, where the upset occurred. An SLD is a water droplet that remains liquid at a temperature below freezing until it strikes or is struck by something solid; it then freezes relatively slowly.

"SLD conditions can cause [thin, rough] ice accretions that are more aerodynamically detrimental than those that were considered during the initial certification of many existing airplanes for flight in icing conditions," the report said.

The NCAR study found that, during the 4 1/2 minutes the Citation was in the SLD conditions, 1 to 4 mm (0.04 to 0.16 in) of additional ice likely accumulated along the wing leading edges.

At 0909, the first officer said, "You got a little different ice on there now. It's clear." The captain said, "Yeah, and open up those valves all the way." The report said that the captain likely was referring to the windshield anti-ice bleed air valves. The windshield bleed-air switch has two positions: "LOW" and "HIGH."

At 0910, the first officer said, "OK, ignition is on with the anti-ice, now it's on for sure. Glideslope is alive." He then conducted a partial briefing of the approach: "It's two hundred decision height and three-quarters of a mile."

Soon after the captain announced that he was extending the landing gear at 0911, the approach controller cleared the crew to land and told them to remain on his radio frequency.

Boots Neglected

At 0911, the captain said, "Speed brakes coming back out again." The first officer said, "OK, there's your glideslope intercept." The captain told the first officer to extend full flaps. The first officer replied, "Full selected and indicated … and you are plus twenty-five." The captain replied, "Slowing."

The crew did not activate the deice boots, as required by company SOPs and recommended by the SimuFlite technical manual. "When reconfiguring for approach and landing … with any ice accretion visible on the wing leading edge, regardless of thickness, activate the surface deice system," the manual says. "Continue to monitor the wing leading edge for any reaccumulation."

At 0912:08, the first officer said, "Slowing, sinking seven. Captured the localizer and the glideslope. I've got some ground, but stay on the gauges." He then briefed the missed approach procedure.

At 0912:37, three seconds before the upset occurred, the first officer suggested that the captain activate the deice boots and told him that airspeed was at VREF.

The report said that the airplane was descending through 6,100 ft, about 1,500 ft above ground level, at 0912:40 when the upset occurred — "a large roll to the left concurrent with a rapid decrease in pitch." The cockpit voice recorder recorded a tone consistent with activation of the autopilot-disconnect warning horn and a terrain awareness and warning system (TAWS) "BANK ANGLE" warning; the bank angle was about 50 degrees. The CVR stopped recording at 0912:55.

The Citation struck terrain at an elevation of about 4,600 ft. The airplane was destroyed by the impact and post-accident fire.

No Warning

The report said that the flight crew received no warning of the impending stall, which occurred well above the expected stall speed in icing conditions.

Based on input from the AOA system, the stick shaker in a Citation V activates when airspeed is about 7 percent above the speed at which the airplane, with uncontaminated wings, will stall. The report said that during flight tests of 560-series Citations in 1996, following three icing-related accidents, the FAA found that stall speeds increased 3–5 kt in icing conditions. In 1999, Cessna modified the stall warning system with an ice mode that causes the stick shaker to activate 5 kt above the clean-wing stall speed. The ice mode is armed when the engine anti-ice system is selected.

The accident airplane was equipped with the ice mode. The airplane flight manual (AFM) indicated that, at the airplane's landing weight and with full flaps, its stall speeds should have been 76 kt with uncontaminated wings and 81 kt with ice on the wings; stick shaker activation would occur at 86 kt.

Analysis of TAWS data indicated that airspeed was about 90 kt when the stall occurred. The report said that the flight crew should have been maintaining an airspeed of 114 kt at this point. In addition to the 8-kt adjustment of VREF for icing conditions, company SOPs and the AFM say that an additional 10 kt should

be maintained until the airplane is over the runway threshold.

Impact and fire damage to components of the AOA and stall warning systems precluded postaccident tests. The captain of the other Citation, which the report called the "sister ship," had flown the accident airplane the previous day and had found no problems with the systems. "Furthermore, no discrepancies were noted during the last scheduled maintenance inspection of the stall warning system," the report said.

Sister Ship

The sister ship was about 19 nm (35 km) behind the accident airplane on arrival at Pueblo. The flight crew of the sister ship told investigators that their airplane accumulated rime ice during descent.

"The first officer estimated that the ice was less than 1/2-in thick and stated that the deice boots effectively shed the ice," the report said. "He stated that there was no ice on the heated inboard wing leading edge or on the top of the wing. The captain stated that they kept the airspeed up on the approach because of the icing conditions."

The report said that performance calculations indicate that the sister ship's airspeed was more than 160 kt as it descended through 6,200 ft and that 120 kt was maintained until the airplane was about 200 ft above airport elevation, 4,726 ft.

"The sister ship landed on Runway 08L about 0926 without incident," the report said. "A review of the sister ship's CVR revealed that the pilots conducted several procedures to minimize any icing problems, including cycling the wing deice boots five times, turning the windshield heat to the 'HIGH' position, using only approach flaps until close to the ground, and keeping the engine power and speed as high as possible until clear of the clouds and landing was assured."

Slow Pace

In response to previous NTSB recommendations, the FAA formed the Ice Protection Harmonization Working Group in 1997 to review the icing-certification standards and operational guidance.

Among changes proposed by the group are a requirement that manufacturers demonstrate during transport airplane icing certification either that the airplane can be operated safely in SLD conditions or that a means is provided for the crew to detect and safely exit the conditions, and a requirement for guidance stating that deice systems should be activated as soon as icing conditions are encountered.

In the accident report, NTSB said that the working group is addressing some of the issues that were raised in previous recommendations. However, NTSB said that work is proceeding at "an unacceptably slow pace" and that "the FAA has taken no action to issue a final rule adopting the regulatory changes proposed by [the working group]."

Calls for Action

Based on the findings of the accident investigation, NTSB made the following new recommendations to the FAA:

- "Require that operational training in the Cessna 560 airplane emphasize the [AFM] requirements that pilots increase the airspeed and operate the deice boots during approaches when ice is present on the wings. (A-07-12);
- "Require that all pilot training programs be modified to contain modules that teach and emphasize monitoring skills and workload management, and include opportunities to practice and demonstrate proficiency in these areas. (A-07-13);
- "Require manufacturers and operators of pneumatic-deice-boot-equipped airplanes to revise the guidance contained in their manuals and training programs to emphasize that leading edge deice boots should be activated as soon as the airplane enters icing conditions. (A-07-14) … ;
- "Require that all pneumatic-deice-boot-equipped airplanes certified to fly in known icing conditions have a mode incorporated in the deice boot system that will automatically continue to cycle the deice boots once the system has been activated. (A-07-15);
- "When the revised icing certification standards (recommended in Safety Recommendations A-96-54 and A-98-92) and criteria are complete, review the icing certification of pneumatic-deice-boot-equipped airplanes that are currently certificated for operation in icing conditions and perform additional testing and take action as required to ensure that these airplanes fulfill the requirements of the revised icing certification standards. (A-07-16) … ; [and,]
- "Require modification of the Cessna 560 airplane's stall warning system to provide a stall warning margin that takes into account the size, type and distribution of ice, including thin, rough ice on or aft of the protected surfaces. (A-07-17)."

At press time, FAA responses to these recommendations had not been published. ●

This article is based on U.S. National Transportation Safety Board Accident Report NTSB/AAR-07/02, "Crash During Approach to Landing, Circuit City Stores, Inc., Cessna Citation 560, N500AT, Pueblo, Colorado, February 16, 2005." The 86-page report contains appendixes.