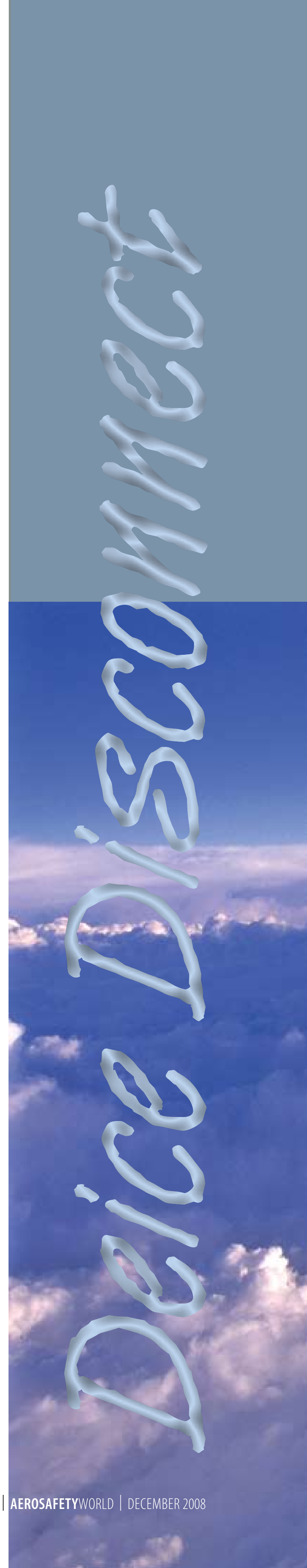
Deice Disconnect



The U.S. National Transportation Safety Board (NTSB) is pointing to a recent ice-related accident involving a Cessna Citation as yet another product of what NTSB Chairman Mark Rosenker calls "the ongoing disconnect" between traditional guidance about cycling pneumatic deice boots and research that has shown the guidance to be baseless and dangerous. The board has campaigned for more than 10 years to change both the outdated guidance and the habits it has fostered. The apparent problem for NTSB and others seeking change is that a substantial number of people in the aviation industry have not been convinced that change is necessary.

Generations of pilots have been taught to wait until a specific amount of ice accumulates on the wing leading edges before cycling pneumatic deice boots. Traditional training warns pilots that premature activation of the boots could make them prey to a hazardous phenomenon called *ice bridging*, which renders the boots useless beneath a bridge, or sheath, of ice.

The report on the March 17, 2007, Citation 500 accident, published in August, is brief, a product of what NTSB calls a "limited" investigation, but highlights the board's decade-long effort to change the way deice boots are operated.

'No Buffet, No Warning'

The Citation pilots were conducting an air ambulance flight from their base in Punta Gorda, Florida, to Beverly, Massachusetts, with a paramedic, an emergency medical technician, a patient and the patient's husband aboard.

The pilot, 45, had 4,950 flight hours, including 3,200 hours in type. The copilot, 60, held a Boeing 737 type rating and had 25,982 flight hours, including 25 hours in the Citation. The airplane was built in 1974 and had accumulated more than 22,000 hours of operation. It was not equipped with an ice-detection system or a stall-warning device such as a stick shaker. Stall warning is provided aerodynamically with inboard wing leading edge strips that cause buffeting 5 kt above stall speed in the landing configuration. This assumes an uncontaminated airframe; stall speed increases as ice accumulates.

Beverly Municipal Airport was reporting surface winds from 310 degrees at 8 kt, 1 mi (1,600 m) visibility in mist and a 500-ft overcast. A circling approach to Runway 34 was in use, but the pilots told air traffic control that their operations manual prohibited circling approaches when the ceiling is lower than 1,500 ft. They requested and received clearance to conduct the global positioning system approach straight in to Runway 16.

The pilots activated the anti-ice systems when the airplane entered clouds at 3,500 ft (Figure 1). "Moments later, the copilot noticed that they were picking up a trace amount of rime ice on the windscreen," the report said. "However, since neither pilot saw any ice on the wings, the deice boots were never activated."

The pilots acquired visual contact with the airport as the airplane neared the minimum descent altitude, 600 ft, and continued the descent at 107 kt — 10 kt above the reference landing speed.

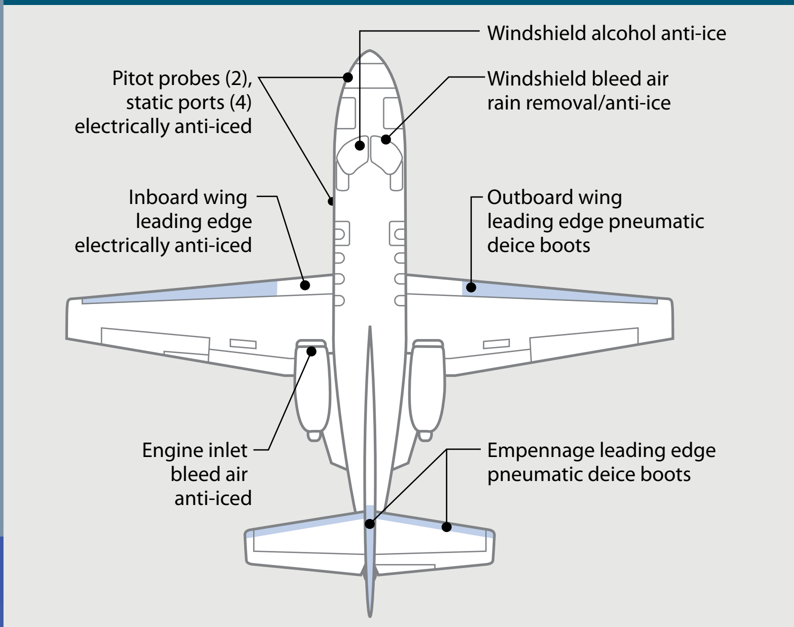
The pilot told investigators that shortly after crossing a treeline, the right wing suddenly dropped. "There was no buffet and no warning, just a sudden loss of lift," he said. "I attempted to roll the wings level and added power to arrest the sink but was unable to before the right wing struck the runway." He said that the airplane then "tracked straight down the runway and was taxied to the ramp without further incident." None of the people aboard was hurt.

'Hollowed-Out Area'

Both pilots believed that the upset had been caused by wind shear. However, no turbulence had been reported, and the flight crew of a Canadair Challenger that was landed on Runway 16 shortly after the Citation said that they had not encountered wind shear on approach.

"After taxiing to the ramp, the [Citation] flight crew conducted a post-flight inspection of the airplane," the report said. "They noted that the right wing was bent upward about 10 degrees and light rime ice was present on the leading edges of the wings [and] horizontal stabilizer." The pilots said that the ice was less than

Citation Ice Protection Systems



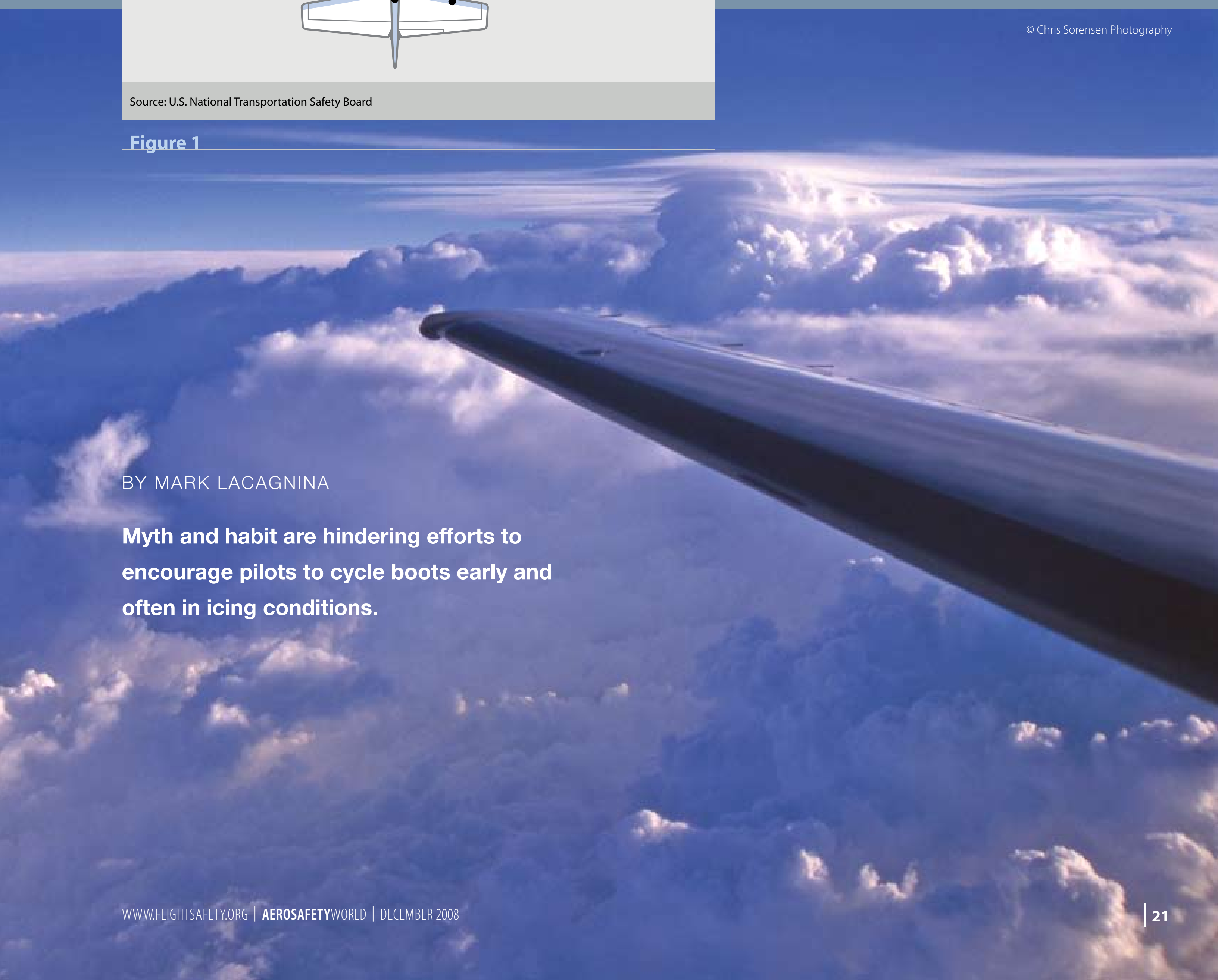
Source: U.S. National Transportation Safety Board

Figure 1

1/4 in (6 mm) thick. A customer service agent on the ramp estimated that the strip of rime ice on the wing leading edges was 1/16 to 1/8 in (2 to 3 mm) thick and 2 in (5 cm) wide.

An examination of the airplane by a U.S. Federal Aviation Administration (FAA) inspector revealed substantial damage. "The upper wing skin on the right wing/fuel tank had been breached, exposing the main spar," the report said. "The spar was broken, and the outboard portion of the right wing and aileron had been bent in an upward direction."

Investigators found that the pilots had operated the Citation's ice-protection systems as required by the airplane flight manual (AFM). The



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BY MARK LACAGNINA

Myth and habit are hindering efforts to encourage pilots to cycle boots early and often in icing conditions.

manual says that the anti-ice equipment should be activated when operating in visible moisture with an indicated outside air temperature between 4 degrees C and minus 30 degrees C (40 degrees F and minus 22 degrees F). The pilots had done so before entering the clouds on descent.

The AFM also says, "Surface deice [the boots] should be used when ice buildup is estimated between 1/4 and 1/2 in [13 mm] thickness. Early activation of the boots may result in ice bridging on the wing." Both pilots said that

Residual ice remains on a Mitsubishi MU-2 deice boot after the first cycle during flight tests conducted behind a tanker airplane dispensing colored water.

they had visually checked the wings after entering the clouds and saw no ice; therefore, they did not cycle the boots.

The pilot told investigators he had been taught that if you "blow [the boots] too soon, you can get a hollowed-out area." The copilot said that he had little experience with boot-equipped airplanes but had learned that "boots have some adverse features" and should not be activated "unless you have 1/4 to 1/2 in of ice."

Ice Bridging

Finding little to fault in the pilots' performance, NTSB laid the blame for the Citation accident squarely at the feet of the FAA and Cessna Aircraft Co. The report said that the probable causes of the accident were "the inadequate guidance and procedures provided by the airplane manufacturer regarding operation of the pneumatic deice boots. Also causal [were] the FAA's inadequate directives, which failed to require manufacturers to direct flight crews to immediately operate pneumatic deice boots upon entering icing conditions."

The report noted that many other AFMs direct pilots to delay operation of their deice boots until 1/4 to 1 in [25 mm] of ice has accumulated. "This guidance was included to prevent the occurrence of ice bridging, though the FAA and manufacturers have been unable to substantiate its existence," it said.

In theory, ice bridging begins with a thin, malleable layer of ice that deforms, rather than shatters, when a deicing boot is inflated. The layer is molded into the shape of the inflated boot, then hardens, accretes more ice and creates a shell (bridge) that is impervious to further inflation and deflation of the boot.

Concern about this phenomenon was found to have been involved in the Jan. 9, 1997, crash of Comair Flight 3272 in Monroe, Michigan. The crew of the Embraer 120 Brasilia was being vectored for an approach to Detroit Metropolitan Wayne County Airport when the autopilot disconnected during a turn at 4,000 ft. The twin-turboprop airplane rolled nearly inverted and descended rapidly to the ground, killing all 29 people aboard.

The cause of the accident, according to NTSB, was a small amount of rough ice that accumulated and triggered a stall as the airplane was slowed for the approach. Following company guidance, the pilots had not cycled the deice boots.

The investigation revealed that about a year before the accident, Embraer had revised the AFM to advise pilots to activate the boots at the first sign of ice accumulation. NTSB found, however, that because of concern about ice bridging, Comair and six of the nine other operators of Brasilias in the United States had not incorporated the revision into their procedural guidance. Comair's flight standards manual (FSM) said that pilots should not activate the boots until 1/4 to 1/2 in of ice accumulates because premature activation could "result in the ice forming the shape of an inflated deice boot, making further attempts to deice in flight impossible."

The investigation of the Comair accident generated several recommendations, including a call for an industrywide effort "to educate manufacturers, operators and pilots of [turboprop airplanes] regarding the hazards of thin, possibly imperceptible, rough ice accumulations, the importance of activating the leading edge deice boots as soon as the airplane enters icing conditions … and the importance of maintaining minimum airspeeds in icing conditions." Subsequent ice-related accidents prompted NTSB to include operators of boot-equipped jets in similar recommendations.

Mass Revisions

In July 1999, the FAA cited the Comair accident and several other ice-related accidents in proposing rule making to revise the AFMs of 43 airplanes to "include requirements for activation of the airframe pneumatic deice boots … at the first sign of ice accumulation [anywhere on the airplane or upon annunciation by an ice-detection system] to prevent reduced controllability due to adverse aerodynamic effects of ice adhering to the airplane prior to the first deice cycle." Among the proposed requirements was continued operation of the boots until the airplane exits the icing conditions.

In the proposal, the FAA discussed a workshop that was held in Cleveland in November 1997 to explore the phenomenon of ice bridging. The workshop was attended by 67 representatives of aircraft and deice boot manufacturers, the airlines, pilot groups, the National Aeronautics and Space Administration, NTSB, and civil aviation authorities. The participants shared and discussed the results of icing wind tunnel and flight tests.

The boot manufacturers, for example, said that they had been unable to reproduce ice bridging under any wind tunnel or laboratory conditions and that reports of ice bridging they had investigated turned out to actually have involved residual or intercycle ice — ice that remains on the boot after an inflation/deflation cycle and ice that accumulates between cycles.

"The general consensus of the workshop participants was that ice bridging is not a problem for modern pneumatic deice boot designs," the FAA said.

Deice boots essentially are fabric-reinforced rubber sheets cemented to the leading edges of the wing and tail. A pressure source is used to inflate tubes within the boots and to create a vacuum that deflates the boots and holds them flat against the leading edges.

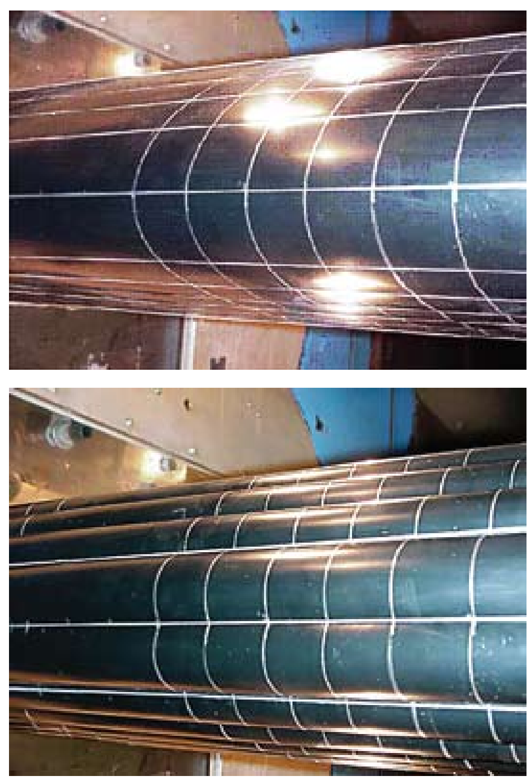
Modern boots have short, segmented, small-diameter tubes that are operated by relatively high-pressure engine bleed air. Older boot designs, which date back to the 1930s, have long, unsegmented, large diameter tubes typically operated by engine-driven pneumatic pumps at pressures that are relatively low and vary according to engine speed. "This low pressure, coupled with long and large-diameter tubes caused early deice systems to have very lengthy inflation and deflation cycles and dwell times [i.e., the period in which the boot remains completely inflated]," the FAA said.

The results of extensive icing wind tunnel tests in 2006 supported activation of deice boots at the first sign of ice.

Doubting Thomases

Several people who commented on the rule-making proposal pointed to airplanes on the list that have no history of ice-related accidents. One said that the FAA merely was speculating that the proposed AFM revisions will improve safety and challenged the agency to test the proposed procedure on each of the airplanes. The FAA rejected these comments, saying that "the potential still exists for reduced

U.S. Federal Aviation Administration



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Old-design deice boots, like those on the Gulfstream I, have longer and larger tubes that cycle much more slowly than those in modern boots.

controllability of all airplanes equipped with pneumatic deice boots due to the adverse aerodynamic effects of ice adhering to the airplane."

Other comments reflected the reasons, beyond concern about ice bridging, that many operators prefer to wait until some ice accumulates before cycling the boots. Chief among them is the perception that boots work best, shedding ice more cleanly, if cycling is delayed. The FAA acknowledged that residual ice and intercycle ice can cause adverse aerodynamic effects but pointed out that persistent ice accretions result even when boots are cycled after 1/4 to 1/2 in of ice builds up. It said that the proposed procedure, which calls for continuous cycling of the boots while flying in icing conditions, "will minimize the residual and intercycle ice accretions." The FAA pointed out that "the residual and intercycle ice accretion thickness resulting from this procedure is less than the ice accretion thickness typically recommended prior to operation of the pneumatic deice boots."

Among other objections were that cycling boots early and often increases pilot workload and maintenance costs associated with wearing out the boots. The FAA rejected these comments, also.

Citations Withdrawn

NTSB's conclusion that the FAA's "inadequate directives" were a causal factor in the Citation air ambulance accident referred, in part, to the withdrawal of Citation 500-series airplanes — about 1,400 total — from the proposed rule making.

The FAA's decision not to pursue Citation AFM revisions was based on flight tests conducted by the manufacturer. Cessna fitted artificial ice shapes simulating 1/2 in of clear and rime ice to a Citation 550, which has a similar wing and tail as the original 500 and 501 models, and a Citation 560. Evaluation of the airplanes' stall characteristics was performed in level flight and steep turns. The FAA said that the flight tests demonstrated "acceptable stall protection and maneuver margins at operational speeds" and showed that the airplanes "can safely operate with ice accretions associated with the AFM normal operations procedures of the deice boots."

The Jetstream 41 also was withdrawn based on original ice-certification flight test data provided by British Aerospace. The Douglas DC-3 and the Gulfstream I were among other airplanes withdrawn from the proposed rule making because they have old-design boots and may be prone to ice bridging.

'Accidents Could Still Occur'

The FAA and several other civil aviation authorities have published guidance based on what has been learned about icing from research and recent accident investigations. For example, in Advisory Circular (AC) 91-74A, the FAA says that "even a thin layer of ice at the leading edge of a wing, especially if it is rough, can have a significant effect in increasing stall speeds" and recommends that deice systems be activated at the first indication of icing.

The agency currently is considering whether to make this recommendation a requirement for newly manufactured transport category airplanes. NTSB has called on the FAA to expand the proposed requirement to all airplanes with deice boots. Noting that Cessna removed the reference to ice bridging from the Citation AFM in February but retained the recommendation to wait until 1/4 to 1/2 in of ice builds before activating the boots, the board said that many AFMs contain similar guidance.

NTSB said that since 1982, it has investigated 43 ice-related turbine-airplane accidents that have resulted in 201 fatalities and 16 serious injuries. "If pilots continue to adhere to guidance about delaying deice boot activation, similar accidents could still occur," the board said.