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U.S. Accident Report Blames Wing Ice And Airline Industry/FAA Failures In Fatal Fokker Crash

The U.S. National Transportation Safety Board (NTSB) said a takeoff delay in icing conditions that exceeded the effective holdover time of Type I deicing fluids and the captain's decision to use a lower rotation speed combined to doom the F28 airliner.

by
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"Strange as it may seem, a very light coating of snow or ice, light enough to be hardly visible, will have a tremendous effect on reducing the performance of a modern airplane. Although this was known in Canada for many years, only in the last three years has this danger been recognized here. It occurs only when the ship is on the ground, and makes take-off dangerous. To avoid this danger the airlines cover the wings with tarpaulins, or they make certain that all ice is off before the airplane is allowed to depart."

Jerome Lederer, President Emeritus, FSF
April 20, 1939

On March 22, 1992, about 2135 Eastern Standard Time, a Fokker 28-4000 (F28), operating as USAir flight 405, crashed during an attempted takeoff from runway 13 at LaGuardia Airport, Flushing, New York.

In February 1993, the U.S. National Transportation Safety Board (NTSB) named the entire "airline industry" and the U.S. Federal Aviation Administration (FAA) as probable causes of the crash.

As a contributing cause, the NTSB also cited inappropriate procedures used by the crew (and inadequate cockpit coordination) that, it said, led to a takeoff rotation at a lower than prescribed airspeed.

Instrument meteorological conditions prevailed at the time of the accident. Weather was reported to be indefinite ceiling 700 feet, sky obscured, visibility 3/4 mile, light snow and fog, temperature 32 degrees F (0° C), dew point 31 degrees F, wind 060 degrees at 13 knots, runway visual range 6,000 feet (1,818 meters) plus, surface visibility 7/8 mile, drifting snow, wet snow.

The crew members were on the third day of a four-day sequence.

At the time of the accident, the captain had logged a total of 9,820 flying hours, of which 2,200 were in the F28. He had a total of 1,400 hours as an F28 captain. The first officer had accumulated 4,507 flying hours, of which 29 hours were in the F28.

The airplane arrived from Jacksonville, Florida, and was parked at LaGuardia's Gate No. 1 at about 1949. The captain, age 44, left the cockpit without further comment or instructions, and the first officer prepared for the next leg to Cleveland, Ohio.

The first officer, 30, then went into the terminal for three to five minutes. The captain returned about 10 minutes after the first officer. Neither the pilot nor the first officer performed a walkaround inspection of the airplane, nor were they required to do so by USAir procedures, the NTSB said. The first officer described the snowfall as "not heavy, no large flakes." The NTSB said: "He stated that the windshield heat was on low, snow was sliding off the airplane and that the airplane's nose had a watery layer as far as his arm could reach out the window."

The NTSB said the first officer stated that they began rolling to the left "just like we lost lift."

USAir deicing records showed that the airplane was deiced with Type I fluid with a 50/50 water/glycol mixture at about 2026. After the deicing, one of the trucks had mechanical problems and was immobilized behind the airplane, resulting in a pushback delay of about 20 minutes. The captain then requested a second deicing and records show this was completed about 2100. At 2105:37, the first officer requested taxi clearance.

The before-takeoff checklist was completed during the taxi, and the first officer recalled that they selected engine anti-ice for both engines during taxi. The first officer stated that they had no visual or directional control problems, but said the captain announced that they would use USAir's contaminated runway procedures, which included the use of 18 degrees of flaps. He stated that the captain then announced that they would use a reduced V_1 speed of 110 knots.

The first officer said that he used the windshield wipers "a couple of times," that he used the wing inspection light to examine the right wing "maybe 10 times but at least three," checking the upper surface for contamination and the black strip on the leading edge for ice buildup. He stated that he did not see any contamination on the wing or on the black strip and, therefore, did not consider a third deicing necessary. He said that he did not consider the snowfall heavy and that as they approached the number one spot for takeoff, they looked back at the wings several times. Near the time of takeoff, the first officer recalled saying, "looks good to me, black strip is clear."

The cockpit voice recorder (CVR) revealed that the airplane was cleared for takeoff at 2134:51 (some 35 minutes after the second deicing), and at 2134:56.6, the CVR recorded a sound similar to the release of the parking brake, followed by an increase in engine noise. "At 2135:17.1, the captain and, immediately thereafter, the first officer made a callout of 80 knots and, at 2135:25.4, the first officer made a V_1 callout. At 2135:26.2, the first officer made a V_R callout."

The NTSB said the appropriate takeoff speeds for the F28 at 66,000 pounds gross weight and an 18-degree flap setting are 124 knots indicated airspeed for V_1/V_R and 129 knots indicated airspeed for V_2. At 2135:28.4, approximately 2.2 seconds after the V_R callout, the CVR recorded a sound similar to nose strut extension. Approximately 4.8 seconds after nose strut extension, the sound of stick shaker began and continued until the end of the CVR recording. At 2135:33.4, the first stall warning beep was recorded, followed by five stall warning beeps beginning 4.9 seconds later. At 2135:40.78, the sound of the first impact was recorded, followed by the sound of the second impact at 2135:41.58, and be the sound of the third impact at 2135:42.05. The recording ended at 2135:42.72.

The first officer recalled that the liftoff was normal and that he never called "positive rate." He was aware that the main landing gear came off the runway and "about at ground effect a pronounced buffet developed in the airframe."

The NTSB said the first officer stated that they began rolling to the left "just like we lost lift." He stated that as the captain leveled the wings, the aircraft headed toward the blackness over the water and that he joined the captain on the controls. The first officer said that they seemed to agree that the airplane was not going to fly and that their control inputs were in unison. He did not remember any aileron input, and there were no "heavy control inputs."

The first officer said that there was at least one cycle of pitch oscillation accompanying a buffet. He stated that he did not touch the power levers and that the last thing he remembered was an orange and white building that disappeared under the nose. "He recalled a flash, a jolt, a rumbling along the ground, and then a sudden stop," said the NTSB. The airplane came to rest partially inverted at the edge of Flushing Bay, with part of the fuselage and cockpit submerged in water.

The NTSB said the flight crew used right rudder to maneuver the airplane toward the ground and to avoid the water and continued to try to keep the nose up to impact in a flat attitude.

Scrape marks from the airplane's initial ground contact were approximately 4,250 feet (1,289 meters) from the threshold of runway 13 and about 36 feet (11 meters) left of the runway centerline, ranging from five- to 65-feet (1.5-20 meters) long. Aluminum particles and paint chips were found on these scrape marks. Plexiglas lens cover pieces were found that matched the plexiglas from the left wing tip about 200 feet (73 meters) from the impact scrape marks.

Of the 47 passengers, two flight crew members and two cabin crew members on board, the airplane captain, one of the cabin crew members and 25 passengers were fatally injured. Impact forces and the subsequent fire destroyed the airplane. During the accident sequence, the airplane struck and destroyed two of three outermost visual approach slope indicator (VASI) boxes, an instrument landing system (ILS) antenna and a water-pump house.

Following its investigation, the NTSB concluded that:

- Between 2100 and 2135, about 0.35 inch (8.89 millimeters of wet snow fell at LaGuardia. The snow contained a water equivalent of about 0.05 inch (1.27 millimeters).

- At the time of the accident, USAir did not require a specific exterior inspection for ice contamination of F28 aircraft during periods of freezing precipitation.

- During precipitation and freezing temperatures in the 35 minutes between the second deicing and takeoff, the airplane accumulated ice on its lifting surfaces.

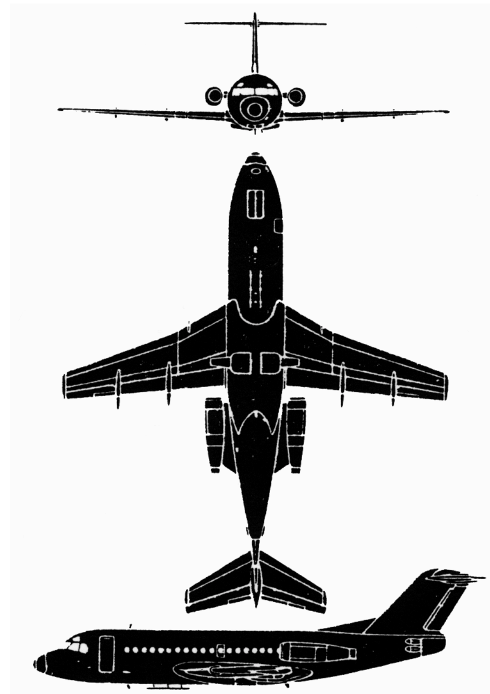
- The delay and taxi time of 35 minutes exceeded the Type I deicing fluid's published safe holdover time, which for the existing conditions was calculated to be about 11.37 minutes.

- The captain did not use a USAir-approved V_1 speed.

- The first officer called V_R (110 knots) early and the captain rotated about five knots early. The rotation rate was about 2.5 degrees per second.

- The airplane accelerated normally during the takeoff roll. After liftoff and before transitioning to the initial climb, the wing stalled before the stall warning system activated.

- Lateral instability was caused by an irregular stall progression across the wing that led to an abrupt left roll and wing-tip strike that further reduced the aircraft's ability to climb.



The twin-engine Fokker F28 Fellowship was designed for medium- to short-haul transport and first flew in 1967. When production ceased in 1987, 241 F28s had been built. The MK 4000 version can accommodate 85 passengers. The F28 has a maximum cruising speed at 23,000 feet (7,000 meters) of 455 knots (843 km/h or 523 mph). Economy cruising speed at 30,000 feet (9,150 meters) is 366 knots (678 km/h or 421 mph. The F28's maximum cruising altitude is 35,000 feet (10,675 meters).

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

- The airplane experienced a wing lift deficiency because of ice contamination.

- The initiation of rotation for takeoff at a speed about five knots below the prescribed speed resulted in a higher peak angle of attack (AOA) at liftoff and, with the wing contamination, eliminated an AOA stall margin that might have existed with a normal rotation.

- According to wind tunnel studies conducted by the manufacturer, F28 wing surfaces are sensitive to small amounts of contamination and significant lift loss can result.

- From the cockpit, the first officer visually checked the wing and stated that he looked for ice accumulation on the black strip on the leading edge. "The black strip, however, was intended to aid in detection of in-flight leading edge ice and, because of its location on the leading edge, is not effective for detecting upper surface ice," said the NTSB.

- At night, flight crews cannot visually detect minute amounts of ice on the wing from the cockpit, and they may not be able to detect such contamination from the cabin windows.

The NTSB determined that the probable cause of the accident was the failure of the "airline industry and the FAA to provide flight crews with procedures, requirements and criteria compatible with departure delays in conditions conducive to airframe icing" and the decision by the flight crew to "take off without positive assurance that the airplane's wings were free of ice accumulation after 35 minutes of exposure to precipitation following deicing." The ice contamination on the wings resulted in an aerodynamic stall and loss of control after liftoff, the NTSB said.

Contributing to the cause of the accident were inappropriate procedures used by (and inadequate coordination between) the flight crew that led to a takeoff rotation at a lower than prescribed airspeed, the report said.

"According to Fokker wind tunnel data, a wing upper surface roughness of only 1-2 mm diameter (0.4-0.8 inches) can cause lift losses on the F28 wing of about 22 and 33 percent, in ground effect and free air, respectively."

Aircraft headings and indicated airspeeds obtained from the on-board flight data recorder (FDR) were used to develop a history of the airplane's ground track from the beginning of the takeoff to impact. The acceleration during the takeoff, derived from the airspeed data, was compared with the expected acceleration, calculated by the airplane manufacturer. The comparison of accelerations showed that the takeoff ground roll was normal as would be expected with or without ice contamination on the wings.

The NTSB's evaluation of simulation data for the conditions of the accident takeoff, provided by Fokker, showed that the airplane without wing contamination would lift off about two seconds after the beginning of rotation, assuming an average three-degree-per-second rotation rate. During those two seconds, the airplane should accelerate about seven knots. Thus, with the beginning of the rotation at a pitch attitude of -1 degree and a proper speed of 124 knots, the airplane should lift off as it reached 131 knots when the AOA was about five degrees. The simulation data showed that the AOA would reach a peak of about nine degrees as the airplane transitioned to the initial climb. With a stall AOA of 12 degrees in ground effect, the airplane, without wing contamination, would have at least a three-degree AOA stall margin during the transition to climb. This margin would increase as the airplane accelerated and climbed out of ground effect.

The NTSB said, "Two distinctive sounds were recorded on the CVR shortly after the V_R call. The correlation with FDR data showed that the first sound occurred as the airplane passed 122 knots, and the second occurred 2.2 seconds later.

"A comparison of these sounds with sounds recorded during the normal takeoff of other F28 airplanes disclosed that the first sound was similar to the extension of a nose wheel strut and the second sound was similar to magnetic clicks that occur coincident with the extension of the main landing gear struts. The [NTSB] used the timing of these events to analyze the speed at which the captain started to rotate the airplane and the rate of rotation to the takeoff pitch attitude."

Fokker's simulation showed that during a normal rotation the nose strut extension occurs about 0.7 seconds after the captain initiates rotation through the control column. Thus, the NTSB concluded that the captain initiated a takeoff rotation when the airplane reached about 119 knots, about five knots lower than the proper rotation speed. The timing between the nose gear strut extension and the main gear strut extension indicated that the rotation rate was about 2.5 degrees per second, a rate that was in accordance with USAir procedures. The NTSB's analysis showed that, with the rotation at a speed five knots slower, 119 knots compared with 124 knots, the airplane would liftoff at about 128 knots with an AOA of about 5.5 degrees. Under these conditions, the AOA probably exceeded nine degrees as the airplane transitioned to a climb.

The NTSB said, "According to Fokker wind tunnel data, a wing upper surface roughness of only 1-2 mm diameter (0.4-0.8 inches) can cause lift losses on the F28 wing of about 22 and 33 percent, in ground effect and free air, respectively. When the aerodynamic characteristics of the wing were degraded during the simulations to a level consistent with the performance attained during previously conducted contaminated wing tests, the stall AOA in ground effect was reduced from 12 degrees to nine degrees. It is probable that during the transition to climb immediately after liftoff, the airplane reached an AOA beyond the stall AOA with significant loss of both lift and lateral control effectiveness.”

The abrupt roll that occurred during the takeoff of Flight 405 is consistent with this analysis. The replication of events in the F28 simulator confirmed that, with a contaminated wing, AOAs as high as 12 degrees (well into the stall regime) were reached even when the pilot initiated rotation at the proper speed to a target pitch attitude of 15 degrees at a rate of three degrees per second.

Fokker Report L-28-222, *Note on the Aircraft Characteristics as Affected by Frost, Ice or Freezing Rain Deposits on Wings*, had this to say about the effect of wing ice contamination on the F28 wing:

“With frost roughness present on the wing upper surface the characteristic of slow stall progression towards the wing tip is lost and uncontrollable roll may develop at angle of incidence (attack) as low as 10 degrees. The drag of the clean wing is such that the aircraft is capable of climbing away at the required climb angle at V_2 with one engine inoperative. In the case of a contaminated wing, the drag may, however, be doubled due to a wing stall which occurs at an angle of incidence (attack) only slightly greater than that for stick shaker operation. Consequently, acceleration is lost even with all engines operating at takeoff power.”

The NTSB cited a memorandum written by an Empire Airline captain in 1984 that was issued by the USAir F28 Flight Manager in November 1991. This memorandum stated:

“Contamination — Frost accumulations of as little as 1/16 of an inch, like medium to coarse grit sandpaper, on the wing leading edge can increase stall speeds by 30 percent (right in the vicinity of V_1, V_R). Uneven contamination across the leading edge will result in wing drop or roll off as the stall develops across the wing. Ice or frost accumulations can appear on leading edges during taxi out or takeoff roll. A deicing beforehand, even on a clean wing, may prevent such accretion.”

The NTSB said it was apparent from the evidence that after liftoff, the airplane could not transition to a positive climb angle. The maximum airspeed recorded by the FDR was 134 knots. The stick shaker activated at this time and airspeed then decreased and varied between 130 knots and 128 knots for the remainder of the flight.

According to the Fokker simulation data, the airplane at this speed should have been able to sustain a load factor of 1.5G at the stick shaker threshold AOA, which still would have provided about a three-degree AOA stall margin. The single “beep” of the aural stall warning immediately after stick shaker activation indicated that the airplane momentarily attained an even higher AOA, between 12.5 and 15 degrees. However, the signal was not continuous and for five seconds the airplane was apparently at an AOA less than that at which lift, with a clean wing, normally begins to decay and drag increases rapidly. That the airplane was unable to attain this normal flight performance was considered by NTSB to be conclusive evidence that the normal aerodynamic characteristics of the wing were significantly degraded by an accumulation frozen contaminant.

The NTSB found that the airplane had been properly cleared of ice and snow during the two deicing procedures at the gate but that 35 minutes had elapsed between the time the airplane was deiced and the initiation of takeoff.

The NTSB found that the airplane had been properly cleared of ice and snow during the two deicing procedures at the gate but that 35 minutes had elapsed between the time the airplane was deiced and the initiation of takeoff. During this time the airplane was exposed to continuing precipitation in below-freezing temperatures.

The report conceded that determination of the amount of ice that could have been formed on the airplane surfaces after deicing required analysis of numerous variables and assumptions. The length of time that the deicing fluid was effective had to be estimated. In spite of extensive research, the calculation of effective holdover time is complicated by more than 30 variables that may influence the effectiveness of the deicing solution.

The NTSB believed that, given the numerous variables and complexity of the problem, “the specific amount of ice that accumulated on the aerodynamic surfaces of the airplane during the taxi phase was indeterminable. However, the NTSB also believed that contamination of a small amount did occur in the 35 minutes following the second deicing and that this accumulation led to the control difficulty shortly after rotation.” In its conclusions, the NTSB calculated that the Type I deicing fluid’s published safe holdover time for the existing conditions was 11.37 minutes.

The report noted that neither pilot performed a walkaround inspection or took any special actions to check the condition of the wing leading edge and upper surface. Following the two deicings, the flight crew was apparently satisfied that the airplane was free of adhering contamination.

The flight crew was not aware of the exact delay it would encounter before takeoff and the decision to leave the gate was reasonable, the NTSB said. After taxiing, when it became evident that the aircraft would be delayed for a prolonged period, conversations between the captain and the first officer showed that they were aware of, and probably concerned about, the risk of reaccumulating frozen contamination on the wing. The NTSB stated that their awareness should have been heightened by the need to use the windshield wipers intermittently in combination with the freezing outside air temperature.

When it became apparent that the delay would exceed 20 minutes, the NTSB believed there should have been a careful examination of the airplane's surfaces in accordance with USAir guidelines.

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The wing inspection light had been used by the first officer to look at the wing on several occasions, but the only related comment recorded on the CVR was nearly 30 minutes after departing the gate and about five minutes before takeoff. The first officer said, "looks pretty good to me from what I can see," and that observation was made through a window probably wet from precipitation.

The NTSB did not believe that this constituted a careful examination. But it recognized the dilemma facing flight crews in having to return to the gate for more deicing, which might result in delays or cancellation of the flight.

Once the decision to proceed with the takeoff was made, the NTSB said the flight crew should have made certain that their takeoff procedures afforded maximum safety margins. "Guidance disseminated to USAir F28 flight crews in November 1991 specified the particular sensitivity of the nonslatted F28 wing to the aerodynamic effects of wing contamination and discussed the use of conservative takeoff speeds and takeoff rotation rates."

While preparing for takeoff, the captain said that he would use 110 knots as the V_1 decision speed. For this flight, the specified V_1 speed would have been 124 knots. USAir procedures prescribed that the nonflying pilot call out V_1 five knots below the specified speed so that an engine failure at V_1 would result in a "go" decision. The NTSB said this procedure was appropriate. However, the use of a further reduced V_1 of 110 knots was not authorized for this airplane, it said.

There was no discussion between the captain and first officer (who had 29 hours in the F28, his only piloting experience in transport-category turbojet aircraft) about the reduced V_1 selection. The first officer could not explain why the captain chose 110 knots. The NTSB assumed that the captain was concerned about the airplane's stopping ability on the runway since he made a reference to the difficulty of stopping on a "short runway going that fast."

The NTSB said that because V_1 speed is only significant in the context of a rejected takeoff or the continuation of a takeoff following the failure of an engine, the captain's selection of a reduced V_1 of 110 knots was not in itself a factor in the accident. However, the selection of a low V_1 speed led the first officer to call V_R prematurely. The first officer stated that, because V_1 and V_R are normally the same speed, he inadvertently followed his normal procedure of calling V_R immediately after V_1.

The correlation of CVR and FDR data showed that the V_R call occurred at about 113 knots, approximately 11 knots below the correct rotation speed of 124 knots. The first officer noted that despite the premature V_R call, the captain did not rotate the airplane for liftoff until the appropriate speed.

However, the analysis of the sounds associated with nose gear strut extension disclosed that the captain began takeoff rotation five knots below the proper V_1 speed. The NTSB could not determine the reason for the captain's action. Because the airspeed indicator bug was set properly for a V_R of 124 knots, the NTSB believed that the captain may have been reacting, in a somewhat delayed manner, to the first officer's early V_R callout without cross-checking his own airspeed indicator.

Because of the early rotation, the airplane lifted off prematurely and at an AOA about 0.5 degrees higher than it would have otherwise, the NTSB said. This would have been insignificant during a normal takeoff with an uncontaminated wing. However, with the performance of the wing degraded by contamination, this increment in AOA may have been the difference between a successful transition to climb and an immediate stall resulting in the accident, the NTSB said.

"Following the stick shaker and control problems, the flight crew did not try to increase engine thrust and did not lower the nose slightly to regain flying speed. The first officer stated that both he and the captain knew that the airplane was not going to fly and that the focus of their efforts was to stay over land and remain upright. Other than initially applying rudder, there were no other appropriate corrective actions taken by the flight crew. They used the yoke to hold on to the aircraft, but did not accomplish any of the actions that would have minimized the effects of the crash," the report said.

The NTSB briefly discussed the differences between Type I deicing fluids and Type II anti-icing fluids and stated that, at the time of the accident, LaGuardia Airport prohibited the use of Type II fluids. Type II fluids may increase holdover times, but the use of this fluid has not been widespread in the United States even though Type II has been in use in Europe for some time. Each air carrier must decide whether to upgrade equipment and whether to use Type II fluid, which may be relatively expensive.

The NTSB did not find that the restrictions placed on the use of Type II deicing fluid played any part in the causal factors of this accident. Nevertheless, had Type II fluid been used in this case, the increased holdover time might have provided an improved margin of safety, it said.

The report criticized as inadequate a belief by F28 pilots surveyed that "they could detect any significant contamination from the cockpit."

The NTSB wants the FAA to require airports to establish (and submit for FAA approval) a deicing plan that includes, at a minimum, the membership of the airport deicing working group; the equipment and procedures to be used for gate and offgate deicing; description(s) of gatehold parameters and procedures; and delineation of responsibilities for the deicing of airplanes at the gate or offgate, as applicable. One consideration would be moving the deicing equipment and procedures away from the gates to an area closer to the takeoff point. The obvious advantage would be deicing immediately prior to takeoff.

U.S. Federal Aviation Regulations (FAR) place the responsibility on the pilot-in-command to ensure that the airplane is airworthy. The NTSB was not satisfied that looking through a wet window at night using a wing inspection light to check the wing for ice contamination constituted a careful inspection. The NTSB recommended that when there is doubt about ice contamination "a careful examination of the wing should involve some type of exterior inspection allowing for a close examination and tactile inspection of the wings."

The report criticized as inadequate a belief by F28 pilots surveyed that "they could detect any significant contamination from the cockpit." It added: "Because of this apparent universal overconfidence, the [NTSB] is concerned that flight crews did not attach enough significance to the company's directive about conducting a careful examination of the wings after 20 minutes in weather conditions conducive to accumulation of ice."

Given the difficulty of doing a tactile inspection and the subsequent delays that might be incurred, the pilot-in-command not only has to be assertive but also needs the support and cooperation of the air carrier in accepting delays, inconveniences and additional costs in the interest of safety.

The NTSB has expressed alarm over a disproportionate number of air carrier takeoff accidents where upper-wing ice contamination was cited as the probable cause or the sole contributing factor in the accidents.

The NTSB's strident criticism of the airline industry and the FAA stems from the fact that during a period of years it has issued 39 safety recommendations that address ice accumulation, engine ice accumulation, ground icing and deicing, and the detection of weather conducive to icing conditions.

It said 20 of these recommendations were prompted by five airplane accidents: DC-9-15, Sioux City Airport, Sioux City, Iowa, Dec. 27, 1968; DC-9-10, Newark International Airport, Newark, New Jersey, Nov. 27, 1978; DC-9-15, Philadelphia International Airport, Philadelphia, Pennsylvania, Feb. 5, 1985; DC-9-15, Stapleton International Airport, Denver, Colorado, Nov. 15, 1987; and DC-9-15, Cleveland-Hopkins Airport, Cleveland, Ohio, Feb. 17, 1991.

The NTSB recommendations addressed topics that include informing operators about the characteristics of deicing/anti-icing fluids; informing flight crews about the potential for ice formation after deicing; reviewing information that air carrier operators provide to flight crews on runway contamination and engine anti-ice procedures during ground operations; requiring flight crew inspections before takeoff if takeoff is delayed after deicing; emphasizing to air carrier maintenance departments the importance of maintaining ground support equipment; and requiring air carrier training programs to cover the effect of wing leading-edge contamination on aerodynamic performance. Despite these recommendations, and actions taken by government agencies and air carriers, similar accidents continued to occur.

Following the accident investigation of an Air Florida Boeing 737-222 that crashed after takeoff on Jan. 13, 1982, near Washington National Airport, Washington, D.C., the FAA published Advisory Circular (AC) 20-117, *Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing*. This AC emphasizes the "clean aircraft concept," stressing that even very small amounts of frost, ice or snow on particular aircraft surfaces can cause degradation of aircraft performance in aircraft flight characteristics.

The NTSB noted that "since that AC was originally published, 10 icing-related accidents have occurred and that prior to Jan. 1, 1992, the FAA had not mandated any specific regulations on airframe icing detection, prevention and deicing."

The FAA has established (by way of an Interim Final Rule, which became effective Nov. 1, 1992) a requirement for FAR Part 121 certificate holders to develop an FAA-approved aircraft ground deicing and anti-icing program and to comply with that established program anytime conditions are such that frost, ice or snow could adhere to an aircraft's wings, control surfaces, propellers, engine inlets and other critical surfaces.

The FAA rule is designed to provide an added level of safety to flight operations in adverse weather conditions and to provide enhanced procedures for safe takeoffs in such conditions.

The NTSB said the measures did not go far enough.

[Editor's note: The following FAR are in effect for aircraft operation in icing conditions: FAR Part 91.3, *Responsibility and Authority of the Pilot In Command*; FAR Part 121.629, *Operation in Icing Conditions*; FAR Part 91.527, *Operating in Icing Conditions* and FAR Part 135.227, *Icing Conditions: Operation in Icing Conditions.*

In addition, the Flight Safety Foundation's *Flight Safety Digest*, Vol. 11, No. 12, December 1992, contains a discussion of deicing and anti-icing procedures, and the April 1992, *Accident Prevention* Bulletin, Vol. 49, No. 4, "How Much is Too Much Wing Ice," contains a review of the February 1991, DC-9-15 accident at Cleveland, Ohio].♦

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