# 01/13/82 Air Florida, Inc.

# Official Accident Report Index Page

| | |
|---|---|
| **Report Number** | NTSB-AAR-82-8 |
| **Access Number** | PB82-910408 |
| **Report Title** | Air Florida, Inc., Boeing 737-222, N62AF, Collision with 14th Street Bridge, Near Washington National Airport, Washington, D.C., January 13, 1982. |
| **Report Date** | August 10, 1982 |
| **Organization Name** | National Transportation Safety Board Bureau of Accident Investigation Washington, D.C. 20594 |
| **WUN** | 3453-B |
| **Sponsor Name** | NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20594 |
| **Report Type** | Aircraft Accident Report January 13, 1982 |
| **Distribution Status** | This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161 |
| **Report Class** | UNCLASSIFIED |
| **Pg Class** | UNCLASSIFIED |
| **Pages** | 141 |
| **Keywords** | Deicing/anti-icing; engine anti-ice system; takeoff with snow/ice; engine instruments; blocked $Pt_2$; B-737 pitchup/rollover; winter operations; gate-hold procedures; ATC separation criteria; airport certification; crash/fire/rescue; water rescue; flightcrew performance. |

**Abstract**

On January 13, 1982, Air Florida Flight 90, a Boeing 737-222 (N62AF), was a scheduled flight to Fort Lauderdale, Florida, from Washington National Airport, Washington, D.C. There were 74 passengers, including 3 infants, and 5 crewmembers on board. The flight's scheduled departure time was delayed about 1 hour 45 minutes due to a moderate to heavy snowfall which necessitated the temporary closing of the airport.

Following takeoff from runway 36, which was made with snow and/or ice adhering to the aircraft, the aircraft at 1601 e.s.t. crashed into the barrier wall of the northbound span of the 14th Street Bridge, which connects the District of Columbia with Arlington County, Virginia, and plunged into the ice-covered Potomac River. It came to rest on the west side of the bridge 0.75 nmi from the departure end of runway 36. Four passengers and one crewmember survived the crash.

When the aircraft hit the bridge, it struck seven occupied vehicles and then tore away a section of the bridge barrier wall and bridge railing. Four persons in the vehicles were killed; four were injured.

The National Transportation Safety Board determines that

the probable cause of this accident was the flightcrew's failure to use engine anti-ice during ground operation and takeoff, their decision to take off with snow/ice on the airfoil surfaces of the aircraft, and the captain's failure to reject the takeoff during the early stage when his attention was called to anomalous engine instrument readings. Contributing to the accident were the prolonged ground delay between deicing and the receipt of ATC takeoff clearance during which the airplane was exposed to continual precipitation, the known inherent pitchup characteristics of the B-737 aircraft when the leading edge is contaminated with even small amounts of snow or ice, and the limited experience of the flightcrew in jet transport winter operations.

# Facts of the Accident

| | |
|---|---|
| **Accident NTSB ID** | 82-08 |
| **Airline** | Air Florida, Inc. |
| **Model aircraft** | 737-222, N62AF, serial number 19556 |
| **Aircraft manufacturer** | Boeing |
| **Engine type** | JT8D-9A |
| **Engine manuafacturer** | Pratt & Whitney |
| **Date** | 01/13/82 |
| **Time** | 1601 |
| **Location** | 14th Street Bridge near Washington National Airport, Washington, DC |
| **Country** | USA |
| **IFR or VFR?** | IFR |
| **Fatalities** | 74 in airplane plus 4 persons in vehicles on bridge |
| **Injuries** | 5 in airplane plus 4 persons in vehicles on bridge |
| **Fire during flight?** | N |
| **Fire on the ground?** | N |
| **Probable cause** | The flightcrew's failure to use engine anti-ice during ground operation and takeoff, their decision to take off with snow/ice on the airfoil surfaces of the aircraft, and the captain's failure to reject the takeoff during the early stage when his attention was called to anomalous engine instrument readings. |
| **Contributing causes** | The prolonged ground delay between deicing and the receipt of ATC takeoff clearance during which the airplane was exposed to continual precipitation, the known inherent pitchup characteristics of the B-737 aircraft when the leading edge is contaminated with even small amounts of snow or ice, and the limited experience of the flightcrew in jet transport winter operations. |
| **Weather conditions** | Moderate to heavy snowfall, visibility 1/4 to 5/8 mile |
| **Total crew size** | 5 |
| **Cockpit crew size** | 2 |
| **Cabin crew size** | 3 |
| **Passengers** | 74 |
| **Report ID** | NTSB/AAR-82-8 |
| **Pages** | 141 |
| **Day or night?** | Day |
| **Flight number** | 90 |
| **Flight origin** | Washington, DC |

| | |
|---|---|
| **Flight destination** | Fort Lauderdale, FL |
| **Description** | The Wahington, DC to Ft. Lauderdale, FL flight's scheduled departure time was delayed about 1 hour 45 minutes due to a moderate to heavy snowfall. Following takeoff, the aircraft crashed into the barrier wall of the northbound span of the 14th Street Bridge and plunged into the ice-covered Potomac River. |

# Synopsis

On January 13, 1982, Air Florida Flight 90, a Boeing 737-222 (N62AF) was a scheduled flight to Fort Lauderdale, Florida, from Washington National Airport, Washington, D.C. There were 74 passengers, including 3 infants, and 5 crewmembers on board. The flight's scheduled departure time was delayed about 1 hour 45 minutes due to a moderate to heavy snowfall which necessitated the temporary closing of the airport.

Following takeoff from runway 36, which was made with snow and/or ice adhering to the aircraft, the aircraft crashed at 1601 e.s.t. into the barrier wall of the northbound span of the 14th Street Bridge, which connects the District of Columbia with Arlington County, Virginia, and plunged into the ice-covered Potomac River. It came to rest on the west side of the bridge 0.75 nmi from the departure end of runway 36. Four passengers and one crewmember survived the crash.

When the aircraft hit the bridge, it struck seven occupied vehicles and then tore away a section of the bridge wall and bridge railing. Four persons in the vehicles were killed; four were injured.

The National Transportation Safety Board determines that the probable cause of this accident was the flightcrew's failure to use engine anti-ice during ground operation and takeoff, their decision to take off with snow/ice on the airfoil surfaces of the aircraft, and the captain's failure to reject the takeoff during the early stage when his attention was called to anomalous engine instrument readings. Contributing to the accident were the prolonged ground delay between deicing and the receipt of ATC takeoff clearance during which the airplane was exposed to continual precipitation, the known inherent pitchup characteristics of the B-737 aircraft when the leading edge is contaminated with even small amounts of snow or ice, and the limited experience of the flightcrew in jet transport winter operations.

# 1. Factual Information

## 1.1 History of the Flight

On January 13, 1982, Air Florida, Inc., Flight 90, a Boeing 737-222 (N62AF), was a scheduled passenger flight from Washington National Airport, Washington, D.C., to the Fort Lauderdale International Airport, Fort Lauderdale, Florida, with an intermediate stop at the Tampa International Airport, Tampa, Florida. Flight 90 was scheduled to depart Washington National Airport at 1415 e.s.t. 1 The Boeing-737 had arrived at gate 12, Washington National Airport, as Flight 95 from Miami, Florida, at 1329. Snow was falling in Washington, D.C., in the morning and in various intensities when Flight 95 landed and continued to fall throughout the early afternoon.

Because of the snowfall, Washington National Airport was closed for snow removal from 1338 to 1453 and Flight 90's scheduled departure was delayed. At 1359:21, Flight 90 requested and received an instrument flight rules (IFR) clearance from clearance delivery.

Seventy-one passengers and 3 infants were boarded on the aircraft between 1400 and 1430; there were five crewmembers — captain, first officer, and three flight attendants. About 1420, American Airlines 2 maintenance personnel began deicing the left side of the fuselage using a model D40D Trump vehicle (No. 5058) containing Union Carbide Aircraft Deicing Fluid II PM 5178. The deicing truck operator stated that the captain told him that he would like to start deicing just before the airport was scheduled to reopen at 1430 so that he could get in line for departure. American maintenance personnel stated that they observed about one-half inch of wet snow on the aircraft before the deicing fluid was applied. Fluid had been applied to an area of about 10 feet when the captain terminated the operation because the airport was not going to reopen at 1430. At that time, the flightcrew also informed the Air Florida maintenance representative that 11 other aircraft had departure priority and that there were 5 or 6 aircraft which had departure priority before Flight 90 could push back from the gate.

Between 1445 and 1450, the captain requested that the deicing operation be resumed. The left side of the aircraft was deiced first. According to the operator of the deicing vehicle, the wing, the fuselage, the tail section, the top part of the engine pylon, and the cowling were deiced with a heated solution consisting of 30 to 40 percent glycol and 60 to 70 percent water. No final overspray was applied. The operator based the proportions of the solution on guidance material from the American Airlines maintenance manual and his knowledge that the ambient temperature was 24°F, which he had obtained from current weather data received at the American Airlines line maintenance room. The operator also stated that he started spraying at the front section of the aircraft and progressed toward the tail using caution in the areas of the hinge points and control surfaces to assure that no ice or snow remained at these critical points. He also stated that it was snowing heavily as the deicing/anti-icing substance was applied to the left side of the aircraft.

Between 1445 and 1500, the operator of the deicing vehicle was relieved from his deicing task, and he told his relief operator, a mechanic, that the left side of the aircraft had been deiced.

The relief operator proceeded to deice the right side of the aircraft with heated water followed by a finish anti-ice coat of 20 to 30 percent glycol and 70 to 80 percent water, also heated. He based these proportions on information that the ambient temperature was 28°F. (The actual temperature was 24°F.) The operator stated that he deiced/anti-iced the right side of the aircraft in the following sequence: the rudder, the stabilizer and elevator, the aft fuselage section, the upper forward fuselage, the wing section (leading edge to trailing edge), the top of the engine, the wingtip, and the nose. Afterwards, he inspected both engine intakes and the landing gear for snow and/or ice accumulation; he stated that none was found. The deicing/anti-icing of Flight 90 was completed at 1510. At this time about 2 or 3 inches of wet snow was on the ground around the aircraft. Maintenance personnel involved in deicing/anti-icing the aircraft stated that they believed that the aircraft's trailing and leading edge devices were retracted. American Airlines personnel stated that no covers or plugs were installed over the engines or airframe openings during deicing operations.

At 1515, the aircraft was closed up and the jetway was retracted. Just before the jetway was retracted, the captain, who was sitting in the left cockpit seat, asked the Air Florida station manager, who was standing near the main cabin door, how much snow was on the aircraft. The station manager responded that there was a light dusting of snow on the left wing from the engine to the wingtip and that the area from the engine to the fuselage was clean. Snow continued to fall heavily.

A tug was standing by to push Flight 90 back from gate 12. The operator of the tug stated that a flight crewmember told him that the tower would call and advise them when pushback could start. At 1516:45, Flight 90 transmitted, "Ground Palm Ninety 3 Like to get in sequence, we're ready." Ground control replied, "Are you ready to push?" Flight 90 replied, "Affirmative," at 1516:37. At 1517:01, Ground control transmitted, "Okay, push approved for Palm Ninety--better still, just hold it right where you are Palm *[sic]*, I'll call you back." At 1523:37, Ground control transmitted, "Okay Palm Ninety, push approved."

At 1525, the tug attempted to push Flight 90 back. However, a combination of ice, snow, and glycol on the ramp and a slight incline prevented the tug, which was not equipped with chains, from moving the aircraft. When a flight crewmember suggested to the tug operator that the aircraft's engine reverse thrust be used to push the aircraft back, the operator advised the crewmember that this was contrary to the policy of American Airlines. According to the tug operator, the aircraft's engines were started and both reversers were deployed. He then advised the flightcrew to use only "idle power."

Witnesses estimated that both engines were operated in reverse thrust for a period of 30 to 90 seconds. During this time, several Air Florida and American Airlines personnel observed snow and/or slush being blown toward the front of the aircraft. One witness stated that he saw water swirling at the base of the left (No. 1) engine inlet. Several Air Florida personnel stated that they saw an area of snow on the ground melted around the left engine for a radius ranging from 6 to 15 feet. No one observed a similar melted area under the right (No. 2) engine.

When the use of reverse thrust proved unsuccessful in moving the sircraft back, the engines were shut down with the reversers deployed. The same American Airlines mechanic that had inspected both engine intakes upon completion of the deicing/anti-icing operation performed another general examination of both engines. He stated that he saw no ice or snow at that time. Air Florida and American Airlines personnel standing near the aircraft after the aircraft's engines were shut down stated that they did not see any water, slush, snow, or ice on the wings.

At 1533, while the first tug was being disconnected from the towbar and a second tug was being brought into position, an assistant station manager for Air Florida who was inside the passenger terminal between gates 11 and 12 stated that he could see the upper fuselage and about 75 percent of the left wing inboard of the tip from his vantage point, which was about 25 feet from the aircraft. Although he observed snow on top of the fuselage, he said it did not appear to be heavy or thick. He saw snow on the liase and radome up to the bottom of the windshield and a light dusting of snow on the left wing.

At 1535, Flight 90 was pushed back without further difficulty. After the tug was disconnected both engines were restarted and the thrust reversers were stowed. The aircraft was ready to taxi away from the gate at 1538.

At 1538:16 while accomplishing after-start checklist items, the captain responed "off" to the first officer's callout of checklist item "anti-ice." At 1538:22 the ground controller said: "Okay and the American that's towing there...let's...six twenty four can you...get...around that...Palm on a pushback?" Flight 90 replied, "Ground Palm Ninety, we're ready to taxi out of his way." Ground control then transmitted, "Okay Palm Ninety, Roger, just pull up over behind that...TWA and hold right there. You'll be falling in *[sic]* behind a...Apple 4 ...DC Nine." Flight 90 acknowledged this transmission a 1538:47. Flight 90 then fell in behind the New York Air DC-9. Nine air carrier aircralt and seven general aviation aircraft were awaiting departure when Flight 90 pushed back.

At 1540:15, the cockpit voice recorder (CVR) recorded a comment by the captain, "...go over to the hangar and get deiced," to which the first officer replied "yeah, definitely." The captain then made some additional comment which was not clear but contained the word "deiced," to which the first officer again replied "yeah--that's about it." At 1540:42, the first officer continued to say, "it's been a while since we've been deiced." At 1546:21, the captain said, "Tell you what, my windshield will be deiced, don't know about my wings." The first officer then commented, "well--all we need is the inside of the wings anyway, the wingtips are gonna speed up on eighty anyway, they'll shuck all that other stuff." At 1547:32, the captain commented, "(Gonna) get your wing now." Five seconds later, the first officer asked, "D'they get yours? Did they get your wingtip over 'er?" The captain replied, "I got a little on mine." The first officer then said, "A little, this one's got about a quarter to half an inch on it all the way."

At 1548:59, the first officer asked, "See this difference in that left engine and right one?" The captain replied, "Yeah." The first officer then commented, "I don't know why that's different — less it's hot air going into that right one, that must be it -- from his exhaust — it was doing that at the chocks 5 awhile ago....ah." At 1551:54, the captain said, "Don't do that — Apple, I need to get the other wing done."

At 1553:21, the first officer said, "Boy...this is a losing battle here on trying to deice those things, it (gives) you a false feeling of security that's all that does." Conversation between the captain and the first officer regarding the general topic of deicing continued until 1554:04.

At 1557:42, after the New York Air aircraft was cleared for takeoff, the captain and first officer proceeded to accomplish the pretakeoff checklist, including verification of the takeoff engine pressure ratio (EPR) setting of 2.04 and indicated airspeed bug settings of 138 kns ($V_1$) 6; 140 kns ($V_R$) 7 and 144 kns ($V_2$) 8 Between1558:26 and 1558:37, the first officer asked, "Slush (sic) runway, do you want me to do anything special for this or just go for it." (The first officer was the pilot flying the aircraft.) The captain responded, "unless you got anything special you'd like to do." The first officer replied, "Unless just take off the nosewheel early like a soft field takeoff or something; I'll take the nosewheel off and then we'll let it fly off."

At 1558:55, Flight 90 was cleared by local control to "taxi into position and hold" on runway 36 and to "be ready for an immediate [takeoff]." Before Flight 90 started to taxi, the flightcrew replied, "...position and hold," at 1558:58. As the aircraft was taxied, the tower transmitted the takeoff clearance and the pilot acknowledged, "Palm 90 cleared for takeoff." Also, at 1559:28, Flight 90 was told not to delay the departure since landing traffic was 2 1/2 miles out for runway 36; the last radio transmission from Flight 90 was the reply, "Okay" at 1559:46.

The CVR indicated that the pretakeoff checklist was completed at 1559:22. At 1559:45, as the aircraft was turning to the runway heading, the captain said, "Your throttles." At 1559:46, the sound of engine spoolup was recorded, and the captain stated, "Holler if you need the wipers...." At 1559:56, the captain commented, "Real cold, real cold," and at 1559:58, the first officer remarked, "God, look at that thing, that don't seem right, does it?"

Between 1600:05 and 1600:10, the first officer stated, "...that's not right...," to which the captain responded, "Yes it is, there's eighty." The first officer reiterated, "Naw, I don't think that's right." About 9 seconds later the first officer, added, "... maybe it is," but then 2 seconds later, after the captain called, "hundred and twenty," the first officer said, "I don't know."

Eight seconds after the captain called "Vee one" and 2 seconds after he called "Vee two," the sound of the stickshaker 9 was recorded. At 1600:45, the captain said, "Forward, forward," and at 1600:48, "We only want five hundred." At 1600:50, the captain continued, "Come on, forward, forward, just barely climb." At 1601:00, the first officer said, "Larry, we're going down, Larry," to which the captain responded, "I know it."

About 1601, the aircraft struck the heavily congested northbound span of the 14th Street Bridge, which connects the District of Columbia with Arlington County, Virginia, and plunged into the ice-covered Potomac River. It came to rest on the west end of the bridge 0.75 nmi from the departure end of runway 36. Heavy snow continued to fall and visibility at the airport was varying between 1/4 mile and 5/8 mile.

When the aircraft struck the bridge, it struck six occupied automooiles and a boom truck before tearing away a 41-foot section of the bridge wall and 97 feet of the bridge railings. As a result of the crash, 70 passengers, including 3 infants, and 4 crewmembers were killed. Four passengers and one crewmember were injured seriously. Four persons in vehicles on the bridge were killed; four were injured, one seriously.

At 1603, the duty officer at the airport fire station ratified crash/fire/rescue (CFR) equipment based on his monitoring of a radio transmission between Washington National Tower and the operations officer that an aircraft was possibly off the end of runway 36.

Safety Board investigators interviewed more than 200 witnesses to establish the sequence of events from the start of the takeoff until impact, and more than 100 written statements were obtained. (See figure 1 for witness locations and flightpath. Numbers correlate to the locations of 10 of the witnesses interviewed.)

Ground witnesses generally agreed that the aircraft was flying at an unusually low altitude with the wings level and attained a nose-high attitude of 30° to 40° before it hit the bridge. (See figure 2.) Four persons in a car on the bridge within several hundred feet from the point of impact claimed that large sheets of ice fell on their car.

A driver whose car was on the bridge at about the wingtip of the aircraft stated, "I heard screaming jet engines.... The nose was up and the tail was down. It was like the pilot was still trying to climb but the plane was sinking fast. I was in the center left lane... about 5 or 6 cars lengths from where (the red car) was. I saw the tail of the plane tear across the top of the cars, smashing some tops and ripping off others.... I saw it spin...(the red car)... around and then hit the guardrail. All the time it was going across the bridge it was sinking but the nose was pretty well up.... I got the impression that the plane was swinging around a little and going in a straight direction into the river. The plane... seemed to go across the bridge at a slight angle and the dragging text seemed to straighten out. It leveled out a little. Once the tail was across the bridge the plane seemed to continue sinking very fast but I don't recall the nose pointing down. If it was, it wasn't pointing down much. The plane seemed to hit the water intact in a combination sinking/plowing action. I saw the cockpit go under the ice. I got the impression it was skimming under the ice and water.... I did not see the airplane break apart. It seemed to plow under the ice. I did not see any ice on the aircraft or any ice fall off the aircraft. I do not remember any wing dip as the plane came across the bridge. I saw nothing fall from the airplane as it crossed the bridge."

Between 1519 and 1524, a passenger on an arriving flight holding for gate space near Flight 90 saw some snow accumulated on the top and right side of the foselage and photographed Flight 90. (See figure 3.)

No witnesses saw the flightcrew leave the aircraft to inspect for snow/ice accumulations while at the gate. Departing and arriving flightcrews and others who saw Flight 90 before and during takeoff stated that the aircraft had an unusually heavy accumulation of snow or ice on it. An airline crew taxiing parallel to, but in the opposite direction of, Flight 90's takeoff, saw a portion of Flight 90's takeoff roll and discussed the extensive amount of snow on the fuselage. The captain's statment to the Board included the following: "I commented to my crew, 'look at the junk on that airplane,'.... Almost the entire length of the fuselage had a mottled area of snow and what appeared to be ice...along the top and upper side of the fuselage above the passenger cabin windows...." None of the witnesses at the airport could positively identify the rotation or liftoff point of Flight 90; however, they testified that it was beyond the intersection of runways 15 and 36, and that the aircraft's rate of climb was slow as it left the runway. Flightcrews awaiting departure were able to observe only about the first 2,000 feet of the aircraft's takeoff roll because of the heavy snowfall and restricted visibility.

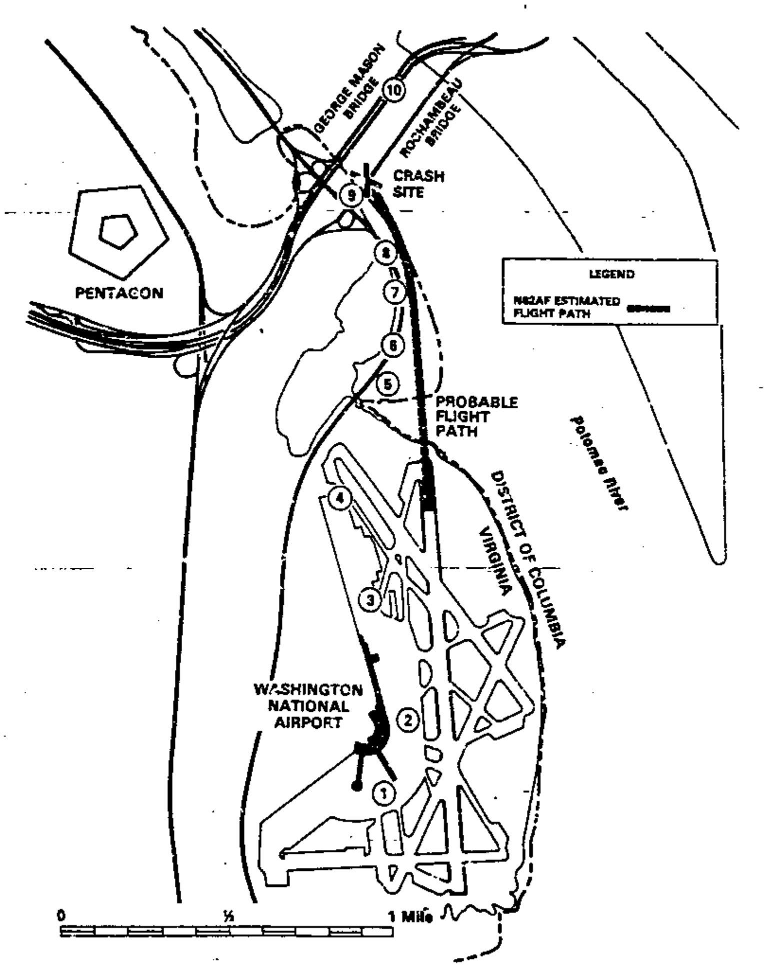



**Figure 1.—Flightpath and witness locations.**

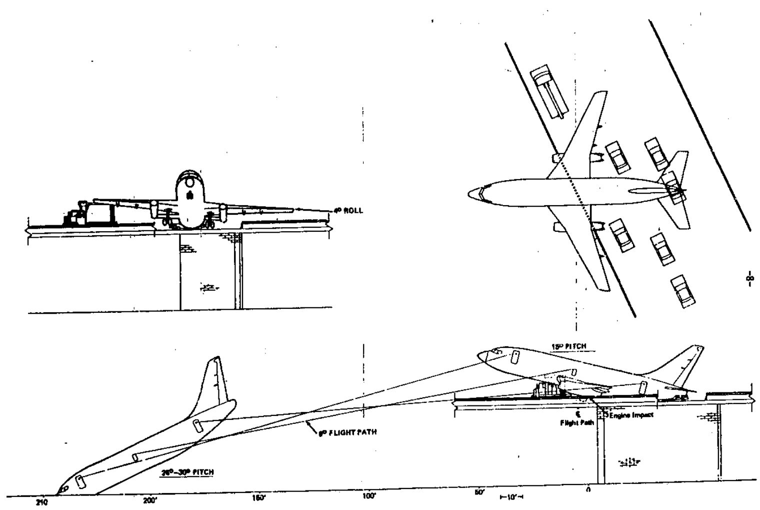



**Figure 2. -- Aircraft Impact Attitude.**

This image is not available at this time.

**Figure 3.—Flight 90 between 1519 and 1524.**

Photo by: Edward J. Kovarik

At 1600:03, as Flight 90 was on the takeoff roll, the local controller had transmitted to an approaching Eastern 727, Flight 1451, "... the wind is zero one zero at one one, you're cleared to land runway three six; the runway visual range touchdown two thousand eight hundred rollout one thousand six hundred." At 1600:11 Eastern Flight 1451 acknowledged, "... cleared to land, over the lights." At 1600:56, the local controller transmitted, "Eastern fourteen fifty-one, turn left at the next taxiway, advise when you clear the runway, no delay clearing."

During witness interviews, one witness on the airport stated,

> *Immediately after I noticed the Air Florida 737, an Eastern 727 landed unbelievably close after (Air Florida) 737. I felt it was too close for normal conditions — let alone very hard snow.*

Flight 90 crashed during daylight hours at 1601:01 at 38° 51' N longitude and 77° 02' W latitude. Elevation was 37 feet mean sea level.

## 1.2 Injuries to Persons

| Injuries | Crew | Passengers | Other* | Total |
|---|---|---|---|---|
| Fatal | 4 | 70** | 4 | 78 |
| Serious | 1 | 4 | 1 | 6 |
| Minor | 0 | 0 | 3 | 3 |
| None | 0 | 0 | 0 | 0 |
| Total | 5 | 74 | 8 | 87 |

*Persons in vehicles on the bridge.

**Including three infants

## 1.3 Damage to Aircraft

The aircraft was destroyed by impact with the bridge, ice, and water.

## 1.4 Other Damage

Seven vehicles in the northbound span of the 14th Street Bridge were destroyed. A section of the bridge sidewall berrier structure and bridge railing were torn away.

## 1.5 Personnel Information

Both pilots were trained and certificated in accordance with current regulations. (See appendix B.)

The captain was described by pilots who knew him or flew with him as a quiet person. According to available information, he did not have any sleep or eating pattern changes recently; the 24 to 72 hours before January 13 also were unremarkable. Pilots indicated that the captain had good operational skills and knowledge and had operated well in high workload flying situations. His leadership style was described as not different from other captains. On May 8, 1980, during a line check in B-737 the captain was found to be unsatisfactory in the following areas: adherence to regulations, checklist usage, flight procedures such as departures and cruise control, approaches and landings. As a result of this line check, the captain's initial line check qualification as a B-737 captain was suspended. On August 27, 1980, he received a satisfactory grade on a line check and was granted the authority to act as pilot-in-command. On April 24, 1981, the captain received an unsatisfactory grade on a recurrent proficiency check when he showed deficiencies in memory items, knowledge of aircraft systems, and aircraft limitations. Three days later, the captain took a proficiency recheck and received a satisfactory grade. On October 21, 1981, the captain satisfactorily completed a B-737 simulator course in lieu of a proficiency check. His last line check was satisfactorily completed on April 29, 1981.

The first officer was described by personal friends and pilots as a witty, bright, outgoing individual. According to available information, he had no recent sleep or eating pattern changes. The 24 to 72 hours before January 13 were spent with his family and were unremarkable. On the morning of January 13, the first officer was described as well rested and in a good mood. Acquaintances indicated that he had an excellent command of the physical and mental skill in, aircraft piloting. Those who had flown with him during stressful flight operations said that during those times he remained the same witty, sharp individual "who knew his limitations." Several persons said that he was the type of pilot who would not hesitate to speak up if he knew something specific was wrong with flight operations. He had completed all required checks satisfactorily.

Neither pilot had any record of FAA violations.

The Safety Board reviewed the winter operations conducted by the captain and first officer and found that the captain, after upgrading to captain in B-737 aireraft, had flown eight takeoffs or landings in which precipitation and freezing or near-freezing conditions occurred, and that the first officer had flown two takeoffs or landings in such conditions during his employment with Air Florida, Inc. The captain and first officer had flown together as a crew only 17 1/2 hours.

## 1.6 Aircraft Information

The aircraft, a Boeing 737-222, serial No. 19556, was acquired by Air Florida from United Airlines on July 28, 1980. It had been certificated, equipped, and maintained in accordance with current Federal Aviation Administration (FAA) requirements. The aircraft's gross takeoff weight was 102,300 pounds; the maximum authorized takeoff weight was 109,000 pounds. The flight was fueled with 26,000 pounds of Jet-A fuel. The aircraft center of gravity was within prescribed limits. (See appendix C.)

The aircraft was equipped with two Pratt & Whitney JT8D-9A turbo-fan engines with a takeoff thrust rating of 14,500 pounds each at sea level on a standard day.10 Engine power settings for Flight 90's takeoff from Washington National Airport were to be 2.04 EPR 11 with air conditioning pecks "off." Normal operating procedures for Air Florida require that air conditioning packs be off for takeoff. The following takeoff data for this flight were extracted from the FAA-approved flight manual for the Boeing 737-222 aircraft:

| | |
|---|---|
| Takeoff gross weight | 102,300 pounds |
| $V_1$ speed | 137 kns |
| $V_R$ speed | 139 kns |
| $V_2$ speed | 144 kns |

The Safety Board computed the required field length for takeoff for the following conditions, using the aircraft flight manual.

| | |
|---|---|
| Outside air temperature | +24°F |
| Wind | 020°/11 kns |
| Flaps | 5 |
| Air conditioning packs | Off |
| Antiskid System | Operative |

The zero wind field length was determined to be 5,900 feet.

## 1.7 Meteorological Information

The following terminal forecast was issued by the National Weather Service (NWS) Forecast Office, Washington, D.C., at 0940 on January 13, and was valid 1000, January 13 through 1000, January 14:

Ceiling -- 1,500 feet overcast, visibility -- 3 miles reduced by light snow, variable ceiling 500 feet obscured, visibility -- 3/4 mile reduced by light snow. After 1300: ceiling 600 feet obscured, visibility -- 1 mile reduced by light snow, wind -- 130° 10 kns, occasionally ceiling 300 feet obscured, visibility -- 1/2 mile reduced by moderate snow. After 1700: ceiling 400 feet obscured, visibility -- 1 mile reduced by light snow, occasionally visibility-- 1/2 mile reduced by moderate snow, chance of light freezing rain, light ice pellets, and moderate snow. After 0100: ceiling 1,500 feet overcast, visibility -- 4 miles reduced by light snow, wind -- 310° 10 kns. After 0400: marginal visual flight rules due to ceiling and snow.

The following SIGMET 12 ALPHA-3 was issued at 1347 on January 13 by the NWS, Washington, D.C., and was valid from 1340 through 1740 for Ohio, West Virginia, Virginia, District of Columbia, Maryland, and Delaware:

From 20 miles northwest of Erie to 60 miles northeast of Parkersburg to Atlantic City to Hatteras to Savannah to 60 miles east of Chattanooga to York (Kentucky) to Cincinnati. Moderate occasional severe rime or mixed icing in clouds and in precipitation above the freezing level reported by aircraft. Freezing level from the surface over Ohio sloping to multiple freezing levels surface to 6,000 feet over central Carolinas, southeast Virginia, and the Delmarva Peninsula. Freezing level 7,000 to 9,000 feet over the coastal Carolinas. Continue advisory beyond 1740.

The following surface observations were taken before and after the accident by observers under contract to the NWS at Washington National Airport.

1558: type--record special; ceiling--indefinite 200 feet obscured; visibility -- 1/2 mile; weather--moderate snow; temperature -- 24°F.; dewpoint -- 24° F; wind -- 010° 11 kns; altimeter -- 29.94 inches; remarks--runway 36 visual range 2,800 feet, variable 3,500 feet.

1614: type—special; ceiling--indefinite 200 feet obscured; visibility -- 3/8 mile; weather--moderate snow; temperature -- 24 ° F.; dewpoint -- 24 ° F.; wind -- 020° 13 kns; altimeter -- 29.91 inches; remarks--runway 36 visual range 2,000 feet, variable 3,500 feet, pressure falling rapidly (aircraft mishap).

The precipitation intensities recorded before and after the accident were as follows:

| Precipitation | Began (time) | Ended (time) |
|---|---|---|
| Moderate snow | 1240 | 1320 |
| Heavy snow | 1320 | 1525 |
| Moderate snow | 1525 | 1540 |
| Light snow | 1540 | 1553 |
| Moderate snow | 1553 | 1616 |

The following are the synoptic observations of precipitation water equivalent and measured snow accumulation:

| Time (From - To) | Water Equivalent | Snow Accumulation |
|---|---|---|
| 0650 - 1252 | 0.07 inch | 2.1 inches |
| 1252 - 1851 | 0.32 inch | 3.8 inches |
| Midnight - Midnight | 0.42 inch | 6.5 inches |

There were two transmissometers in operation before and during the time of the accident. The center of the bascline of the transmissometer for runway 36 was located about 1,600 feet down the runway from the threshold and about 600 feet to the right of the runway centerline. The center of the baseline of the transmissometer for runway 18 was located about 1,700 feet down the runway from the threshold and about 800 feet to the left of the runway centerline. Both transmissometers had a 250-foot baseline.

Runway visual range (RVR) was measured as follows for the times indicated:

| Time | RVR Rwy 36 | RVR Rwy 18 |
|---|---|---|

| | | |
|---|---|---|
| | (feet) | (feet) |
| 1544 | 3,800 | 2,300 |
| 1558 | 2,900 | 1,500 |
| 1600 | 2,100 | 1,400 |
| 1604 | 1,800 | 1,200 |
| 1610 | 2,900 | 1,600 |

Air Florida Flight 90 received weather briefing information from American Airlines at Washington National. The operations agent stated that they did not keep copies of weather information or a log of what was delivered to the flightcrew. In a written statement, the operations agent noted that, in addition to destination information, Air Florida Flight 90 would have received current surface observations at Washington National Airport (excluding a field condition report).

## 1.8 Aids to Navigation

Aids to navigation were not a factor in this accident.

## 1.9 Communications

There were no communications difficulties.

## 1.10 Aerodrome and Ground Facilities

Washington National Airport is located at Gravelly Point, Virginia, on the west bank of the Potomac River. Arlington County, Virginia, is to the immediate west, while the City of Alexandria, Virginia, is to the south. The east boundary of the airport is the Potomac River while the District of Columbia is directly to the north. The areas surrounding the airport are populated, and the general center of Washington, D.C., is about 3 miles north of the airport. Washington National Airport is owned by the U.S. Government and operated by the Federal Aviation Administration, U.S. Department of Transportation. Washington National Airport was opened in 1941.

The landing area consists of three runways: 18-36, 15-33 and 3-21. Runway 36 is served by a Category II instrument landing system (ILS), high intensity runway lights, high intensity approach lighting system with sequenced flashing lights, touchdown zone lights, and centerline lights. Runway 18-36 is hard surfaced with asphalt and grooved; it is 6,869 feet long and 150 feet wide. Edge lights on runway 18-36 are displaced 35 feet on each side of the runway.

Runway 36 at Washington National Airport has a runway safety area (overrun) which complies with current FAA design criteria for existing runway safety areas. The design criteria require that the safety area be 500 feet wide and extend 200 feet beyond the end of the runway. The runway 36 safety area is 500 feet wide and extends 335 feet beyond the end of the runway.

However, FAA design criteria for newly constructed runways require an extended runway safety area in addition to the runway safety area. The extended runway safety area is that rectangular area along the extended runway centerline that begins 200 feet from the end of the usable runway (the 200 feet area is the runway safety area) and extends outward in conformance with criteria in effect at the time of construction. Current FAA criteria for new airports require that the extended runway safety area be 800 feet long and 500 feet wide. The total length of the two safety areas must be 1,000 feet beyond the end of the runway.

FAA Airport Bulletin DCA 7/45, dated October 9, 1981, contains snow and slush emergency procedures which were in effect from date of issue through April 1, 1982. The purpose of the Bulletin was to assign responsibilities and to establish procedures to be followed in removing and controlling snow, slush, ice, sand, and water at Washington National Airport. (See appendix D.)

At 1245 on January 13, airport personnel measured the snow on runway 18-36 and found it to be about 2 inches. Shortly thereafter, the airport operations office decided to remove the snow from the runway. At 1250, an Airport Advisory was issued stating, "Airport will be closed 1330 - 1430 for snow removal." Snow was to be removed using snow plows with rubber boots on the blades. Plows removed snow down to the surface. Brooms were used to sweep away any remaining loose snow after the plows passed, and the runway surface was then sanded.

At 1450, snow removal on runway 18-36 was completed and the airport was reopened. At this time, the air traffic control tower was told "runway 18-36 plowed full length and width, sanded 50 feet each side of centerline. All other surfaces covered with 3 1/4 inches of dry snow."

At 1525, the airport operations officer issued the following Airport Field Report: "runway 18/36 plowed, swept full length and width, sanded 50 feet each side of centerline. All other surfaces covered with 3 1/4 inches of dry snow. Use caution". At 1600, an airport operation officer "estimated that the snow cover on the last 1,500 feet of runway 36 amounted to about three-fourths inch." At 1600:22, the local controller made a general transmission "brakes poor" on runway 36. At 1607, American Airlines Flight 508, a B-727 aircraft, landed on runway 36, and the captain reported that braking action was "poor" and that snow was rapidly covering the runway.

Under the requirements of 14 CFR 139, Certification and Operations: Land Airports Serving CAB - Certificated Air Carriers, certificated airports are required to provide primary crash/fire/rescue protection within the geographical boundaries of the airport. There is no requirement to respond to off-airport accidents.

Advisory Circular 150/5210-13, "Water Rescue Plans, Facilities, and Equipment," dated May 4, 1972, suggests the planning procedures and necessary facilities and equipment to effectively perform rescue operations when an aircraft lands in a body of water, swamp, or tidal area where normal aircraft firefighting and rescue service vehicles are unable to reach the accident scene. The AC states that special water rescue services, where possible, should be under the jurisdiction of the airport management and located on or near the airport. In this and all other situations, it should be coordinated with local emergency services.

With regard to vehicles, the AC states that air cushion vehicles have high speed capabilities over water and adverse terrain conditions which make them ideally suitable for rescue service. If this type of vehicle is available, its use should be included in the emergency rescue plan.

## 1.11 Flight Recorders

A total of 82 divers trained to dive in icy waters were brought from various U.S. Navy, U.S. Army, and U.S. Coast Guard units to conduct salvage operations and rescue operations. Divers searched for the flight data recorder (FDR) and cockpit voice recorder (CVR) using an acoustic sound device to home in on the discrete signals emitted from the recorders. Underwater visibility was 8 inches. Both recorders were recovered from the Potomac River on January 20—7 days after the crash.

The aircraft was equipped with a Fairchild model 5242 FDR, serial No. 6135, and a Sundstrand V-557 CVR, serial No. 2282.

The recorders were only superficially damaged. The foil recording medium was removed from the FDR and examination disclosed that all parameters and binary traces were present and active. The altitude and airspeed traces were derived from the aircraft central air data computer. Other data recorded were magnetic heading, vertical acceleration, and radio transmitter (microphone) keying, all as a function of time. (The FDR readout is presented in appendix E.)

A timing discrepancy was found in the FDR which made it necessary to evaluate carefully all values obtained from this unit. The first two radio transmissions were timed correctly and matched the timing obtained from the CVR and the ATC transcript within 1 second. The third transmission ("okay") came only a measured 3 seconds after takeoff acknowledgement, instead of the 6 seconds indicated by the other sources. This discrepancy affected all recorded traces simultaneously and probably occurred a number of times throughout the accident flight. Examination of data from previous flights showed that it was irregular in occurrence and duration; the foil slowed for short periods of time then speeded up, thus rendering the overall timing correct while leaving short-term timing errors. This was caused by a malfunction of the foil takeoff drive system. Therefore, FDR data were considered reliable only if validated by the other two data sources.

The CVR tape quality was good. Since there is no timing signal recorded on a CVR tape, timing was accomplished by adjusting the tape speed so that the 400 Hz aircraft power signal, which leaks onto the area microphone channel, was of the correct frequency. Copy tapes were made with a standard encoded time signal recorded on one channel. A timed tape was then compared to the tower tapes; tower tapes are recorded with a standard time reference signal from WWV. (WWV is a radio station operated by the National Bureau of Standards which transmits standard radio frequencies, standard time intervals, and time announcements. Timing of CVR data is accurate to WWV time plus or minus 1 second.)

A timed transcript of the cockpit area microphone channel and of radio communications data from the CVR was made. (See appendix F.)

During preparation of the CVR transcript, members of the CVR group could not agree on the response to the checklist callout "anti-ice". The majority believed that the response was "off," but that word was put in parentheses in the transcript to indicate questionable text. The Federal Bureau of Investigation (FBI) Audio Laboratory was requested to perform an independent examination of that portion of the tape. The FBI concluded that the response to the checklist callout "anti-ice" was "off." 13

Events as recorded on the CVR and FDR were compared, and an overall matchup of the data from these two sources was compiled. There was no definitive way to correct absolutely the short-term timing problems of the FDR, so some discrepancies occur in the description below. In addition, FDR altitude and airspeed values are given as recorded, and are not corrected for aircraft static port position error at high angles of attack.

At 1559:24, the tower cleared Flight 90 for takeoff. At 1559:50 (0001:19 elapsed time on the FDR graph), the turn to the runway heading was completed, and 1 second later the captain said, "It's spooled." Airspeed data were not recorded by the FDR below 80 kns, so all plotted values before 1600:10 (001:39) should be disregarded. The first valid airspeed reading was 82 kns at 1600:10. About 1 second earlier, the captain called 30 kns ("yes it is, there's eighty"), and 11 seconds later he called 120 (at that time the FDR read 116 kns; the FDR indicated 120 kns about 4.4 seconds after the CVR callout). The $V_1$ callout occurred at 1600:31, or 10 seconds after the 120 kns callout.

The FDR showed a sharp decrease and then a gentle rise in the altitude trace beginning at 1600:31.6 (0002:00.6); this is characteristic of the change in static pressure caused by aircraft rotation. Airspeed at this time was recorded as 130 knots. The $V_2$ callout occurred at 1600:37, and the sound of the stall warning (stickshaker) began 2 seconds later and continued until impact.

After rotation, the aircraft began to climb at a fairly constant but slightly decreasing airspeed; between 1600:37.6 and 1600:46.0, airspeed decreased from 147 to 144 kns. Altitude at the end of this period was 240 feet and heading had changed about 3° to the right. During the next 7 seconds ending at 1600:53.8, airspeed decreased significantly, from 144 to 130 kns, while heading changed to the left, from 009° to 002.4°; the maximum recorded altitude of 352 feet was achieved at the end of this period. The heading then continued changing to the left, reaching 347.5° 6.6 seconds later; the recording ended 0.6 second beyond this point with a heading of 354.4°.

The altitude trace beyond 1600:54.0 is jagged, with rapid excursions up and down. The FDR altitude stylus was calibrated so that a movement of 0.0033 inch corresponds to a change in altitude of 100 feet (between 1,000 feet and 8,000 feet); hence, any vibration-induced stylus movement such as might be produced by stall buffet would produce significant changes in the altitude trace with respect to the maximum value of 352 feet.

## 1.12 Wreckage

Wreckage recovery was initiated immediately after the accident and simultaneously with the recovery of victims. Recovery operations were conducted in coordination with the National Transportation Safety Board by various segments of the Department of Defense, Department of Transportation, and Metropolitan Washington Police Department, all under the general direction of the Federal Emergency Management Agency (FEMA).

As the aircraft descended, the right wing was structurally damaged when it hit the boom truck, and shortly thereafter, the aircraft struck the steel barrier and railing on the west side of the 14th Street Bridge at an elevation of about 37 feet mean sea level. Fragments of the right wing remained on the bridge. The remainder of the wreckage sank in the Potomac River in about 25 to 30 feet of water. The wreckage area was confined to the south side of the river between the 14th Street Bridge and the Center Highway Bridge of the George Mason Memorial Bridge.(See figure 4.)

After initial impact, the aircraft broke into several major pieces. The fuselage broke into four major pieces which included: (1) nose section with cockpit; (2) fuselage section between nose section and wing center section; (3) fuselage-to-wing intersection; and (4) aft body structure with empennage attached. The wing structure was separated into three major pieces which included: (1) left wing outboard of the No. 1 engine, including all associated flight control surfaces; (2) wing center section, lower surface, including wing lower surface stubs between the No. 1 engine mounts and the No. 2 engine mounts; and (3) right wing outboard of the No. 2 engine with the outboard 20 feet mostly disintegrated. The left main landing gear was separated from the wing, and the right main gear remained attached except for the wheels and oleo piston. The nose landing gear and its attaching structure were separated from the nose section. Both engines and their pylon structures were separated from the wings. There was no evidence of fire on any of the recovered structure.

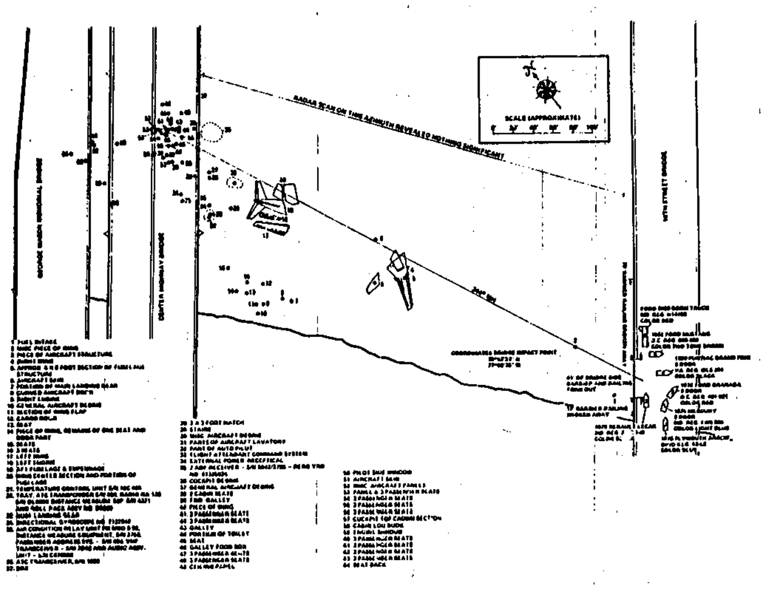


**Figure 4. -- Position of Wreckage in the Water.**

The horizontal stabilizer jackscrew measured 7.75 inches between the upper stop and the traveling nut. The 7.75-inch measurement corresponds to 2.3° stabilizer leading-edge-down, or 5.3 units of trim. This stabilizer setting is in the green band for takeoff.

The B-737 aircraft has four leading edge flaps and six leading edge slats. Erosion was minimal on all of the leading edges and was within specified limits. Actuator extension for leading edge slats 1 and 2 was measured at 8 1/2 inches and 8 inches, respectively, which is consistent with trailing edge flaps 5 extended position. The actuator for Nc. 3 leading edge slat was bent with about 8 1/4 inches of rod extension, which is consistent with the trailing edge flaps 5 position. The aileron trim assembly (in the wheel well) was found with the rig pin holes aligned. This corresponds with a zero trim setting for the ailerons. All segments of the trailing edge flaps sustained varying degrees of impact damage. Measurements taken between the travel nut and plastic cap at the trailing end of the flap jackscrews corresponded to trailing edge flaps 5 extension. All spoiler actuators were in the retracted (down) and locked position.

The right elevator and its trim tab were intact and were attached to the right stabilizer at all hinge points. The left elevator remained relatively intact and attached to the stabilizer. The rudder remained intact and attached to the vertical stabilizer, but no valid rudder trim measurements could be obtained.

Because of the extensive fragmentation, the integrity of the flight control system before impact could not be determined. Nearly all bellcranks, sector pulleys, and other mechanisms were broken, distorted, and separated from their attachment structures.

The nose landing gear was separated from its fuselage attachment structure. The nose gear strut and tires remained intact. There was no visible damage to the tires, and both wheels were free to rotate. The nose gear retract actuator was attached to the nose gear assembly, and the actuator was in the extended position.

The left and right main landing gear was torn loose from the aircraft. The right gear was recovered as a unit; the left gear oleo strut, piston, brakes, wheels, and tires were not recovered. Uplock mechanisms were undamaged and were in a position consistent with a gear-extended position.

Both EPR transmitters had been damaged by impact. By comparing the transmitters from the aircraft with a like-new transmitter, it was determined that the accident aircraft's left transmitter was at the 2.20 EPR position. The transmitter was electrically operated to verify the position for a 2.20 EPR reading. This could not be accomplished since the synchros would not stabilize. The right EPR transmitter was checked. The synchros were found to be moveable and could not be used to determine impact position.

The angle-of-air flow sensor for the stall warning system had been severely damaged by impact. The vane heater was tested and found to be operational. The flap position transmitter had also been damaged severely by impact. The drive motor and synchro had been dislodged by impact and were loose in their case. The stall warning panel module had not been damaged. The switch was in the "normal" position. When electrical power was applied to the stickshaker motor, it operated normally.

The engine instruments were damaged slightly by impact and remained attached to their panels. The gauges indicated the following:

| Indication | Engine No. 1 (Left) | Engine No. 2 (Right) |
|---|---|---|
| N | 0 percent | 78 percent |
| EPR | 2.9 Bug at 2.02 | 2.98, Bug at 2.26 |
| EGT | 820° | 220° |
| $N_2$ | 23 percent | 0 |
| Fuel flow | 3,800 lbs/hr. | 1,200 lbs/hr. |
| Oil Pressure | 72 psi | 53 psi |
| Oil Temperature | Off scale -40°C | 150° C |
| Oil Quantity | 4 gallons | 3.5 gallons |

The antiskid switches were on and guarded in the on position.

## Powerplants

The engines were examined on scene and their condition documented. They were then taken to the facilities of Pratt & Whitney Aircraft Group, Hartford, Connecticut, for disassembly and inspection. No evidence of preimpact malfunction was noted. External and internal examination of both engines' high pressure and low pressure compressors and turbine sections disclosed varying degrees of damage consistent with rotation at impact. There was no evidence of any lack of lubrication on any bearings. The oil systems were not contaminated.

Each of the two engines was equipped with a thermal anti-ice system, composed of three anti-ice valves which are designed to open when the respective engine anti-ice switch is placed ON. The inlet guide vanes and nose cones use 8th stage compressor bleed air and the cowl anti-ice system uses 13th stage air. The left engine's 8th and 13th stage engine bleed air ducting on the right side of the engine was crushed between the 1:30- and 4:00- o'clock positions. The engine's nose cowl thermal anti-ice valve was closed. The main bleed air valve was closed. The fuel heat valve was closed. The left inlet guide vane anti-ice valve was closed. The right inlet guide vane anti-ice valve was open and free to rotate. The air turbine starter was not visibly damaged.

The right engine's right inlet guide vane anti-ice valve was closed. The left inlet guide vane anti-ice valve was not recovered. The nose cowl anti-ice valve vas closed. The engine bleed valve was closed. The modulation/shutoff valve was closed. The fuel heat valve was closed. The air turbine starter exhibited no visible damage. The pressurization and bleed control was not visibly damaged. The control was disassembled and no mechanical discrepancies were noted, except that it was clogged with water and dirt. The 8th stage and two 13th stage antisurge bleed valves functioned normally.

## 1.13 Medical and Pathological Information

There was no evidence of pre-impact incapacitation or preexisting physical or physiological problems which could have affected the flight crew's judgment or performance. The results of toxicological examinations disclosed no abnormal conditions. The captain sustained fatal head injuries and the first officer sustained fatal head and neck injuries.

One flight attendant sustained a fatal head injury and a fracture of the right upper extremity. Another flight attendant sustained fatal injuries to the thorax and abdonien.

Of the 70 passengers killed in the crash, 69 suffered severe injuries considered by the medical examiner to be directly related to the cause of death. One passenger sustained only minor superficial injuries and death apparently resulted from drowning. The most predominant fatal injury suffered was to the head, occurring in 36 of the 70 passengers. Nine of the passengers had fatal injuries of the neck. Twenty-nine passengers sustained injuries to the chest considered to be fatal. There were four fatal abdominal injuries and one fatal injury of the pelvis. Some passengers suffered more than one type of fatal injury. Seventeen passengers received injuries not considered to be immediately fatal. However, except for the person who apparently drowned, all suffered incapacitating injuries due to secondary impact forces, making escape impossible.

Four passengers and one flight attendant received varying degrees for serious injuries and were rescued and hospitalized. Four persons in vehicles on the bridge were killed, one person on the bridge was injured seriously, and three persons on the bridge escaped with only minor injuries.

## 1.14 Fire

There was no fire.

## 1.15 Survival Aspects

At 1602 January 13, the duty officer at the Washington National Airport fire station dispatched CFR equipment based on an intercepted radio transmission between the Washington National Airport Tower air traffic control and the airport operations officer. While he was alerting the CFR crews, the crash phone rang at 1604, reporting the loss of visual and voice communication with an aircraft. The assistant fire chief on duty directed CFR vehicles R-373 and R-397 to respond to the end of runway 36 and directed R-374, R-376, and R-396 to respond north on the George Washington Parkway beyond the airport boundary.

R-396 was the first CFR vehicle to arrive on the river bank nearest to the scene of the crash and the assistant fire chief set up a command post on the shore of the river at 1611. The fire chief arrived on the scene and assumed command of the crash site at 1620. At 1622, the airport airboat was launched. The boat launching ramp was covered with ice and the boat was literally picked up and moved to the frozen river and launched.

In addition to the Washington National Airport CFR equipment, District of Columbia, Arlington County, Fairfax County, and City of Alexandria Fire Departments responded.

For the six occupants who escaped from the aircraft, temperature, both water and air, was the major factor which affected their survivability. Water temperature 4 feet below the surface was 34° F. The survivors were in the icy water from 22 to 35 minutes before being rescued. Survival time noted on the Survival in Cold Water14 chart showed that, based on the water temperature, at least 50 percent of the survivors should have lost consciousness during that time period. All five survivors reported that the cold was so intense that they quickly lost most of the effective use of their hands; however, none reported loss of consciousness.

All but one of the survivors managed to cling to pieces of the floating wreckage. The one exception was the most seriously injured passenger, and she was kept afloat by a lifevest which was inflated by the surviving flight attendant and passed to her and her raveling companion. Her traveling companion helped her don the lifevest. The survivors were unable to retrieve other lifevests that were seen floating in the area. They reported that they experienced extreme difficulty in opening the package which contained the one lifevest which was retrieved. They stated that the plastic package which contained the lifevest was finally opened by chewing and tearing at it with their teeth.

Between 1622 and 1635, a U.S. Park Police helicopter rescued four passengers and one crewmerrber and ferried them to the shoreline. When the rescue helicopter arrived, three of the survivors were still able to function sufficiently to help get themselves into the life ring and/or the loop in the rescue scope that was dropped by the helicopter crew. The other two survivors required hands-on rescue; one was pulled aboard the helicopter skid by the helicopter crewman, the other was rescued by a civilian bystander who swam cut and pulled her ashore.

Three passengers from the aircraft, as well as two persons who participated in the rescue efforts, were placed in an ambulance and treated on scene by paramedical personnel for hypothermia and shock. Radio communications were established with National Orthopaedic Hospital and Rehabilitation Center in Arlington, Virginia, about 2 miles from the crash site. After treatment on scene, the survivors were transported to National Orthopaedic Hospital by ambulance.

The three factors commonly used to determine survivability of an aircraft crash are: (1) that the decelerative forces not exceed the known tolerable limits of the human body, (2) that the restraint system--seatbelts, seat structure, and seat anchorage points--remain intact, and (3) that the occupiable area remain relatively intact to prevent ejection and provide living space for the occupants.

The primary impact forces experienced by the survivors did not exceed the tolerable limits of the human body. However, the secondary impact forces that most occupants experienced as a result of restraint system failures and violation of occupiable area did exceed these limits.

The recovered wreckage showed that the cabin separated from the cockpit and broke into three large sections and many smaller pieces. Virtually none of the cabin floor remained intact. All of the seats, whether empty or occupied, were extensively damaged and most were separated from the floor. The only occupiable space in the aircraft that remained intact and not violated by the collapsing cabin structure and furnishings was the area in the rear of the cabin in the vicinity of the aft flight attendant seat.

## 1.16 Tests and Research

### 1.16.1 Test of Flight Instruments

The captain's and first officer's altimeters and vertical speed indicators were recovered from the river. Since pitot/static system covers had not been used during deicing operations at the gate, the Safety Board sought to determine if deicing fluid had been introduced into the system, and submitted these instruments to the FBI laboratory for analysis. Analysis revealed no trace of glycol. However, because of the prolonged immersion of these instruments in water after the crash, the results of the tests are not to be considered conclusive evidence that deicing fluid was either introduced or not introduced into the pitot/static system.

## 1.16.2 Sound Spectrum Analysis

Spectrum analyses of sounds recorded on the CVR were performed for the takeoff roll and the flight. The CVR cockpit area microphone channel picks up and records sounds which originate or can be heard in the cockpit. In past accident investigations, particularly those involving aircraft with wing-mounted engines, the Safety Board has documented the engine sounds recorded on the cockpit area microphone channel. Experience and tests have shown that the predominant frequencies recorded are associated with the first and second stages of the low pressure compressor fan blades of turbojet and turbofan engines. These frequencies are related to the rotational velocity of the fan by the number of blades in the first and second stages. This frequency in cycle per second, or tone, is called the blade passing frequency (BPF) and can be determined by taking the rotor rpm, multiplying it by the number of blades in the compressor stage, and dividing it by 60

$$(BPF = \frac{\text{rpm X No. of blades})}{60}$$

The percent of maximum low pressure compressor rpm ($N_1$) (engine low pressure compressor speed) is displayed in the cockpit and is an indication of the level of thrust being produced by an engine. This can be determined by dividing the actual rotor rpm by the engine's rated value for 100 percent rpm.

Therefore, percent rotor speed is related to the blade passing frequency as follows:

$$\text{Percent rpm} = \frac{\text{BPF X 60 X 100}}{\text{Maximum rpm x blades}}$$

The validity of this equation was verified by Safety Board investigators during tests at Boeing Aircraft Company, Seattle, Washington, on January 29, 1982.

The perform the spectrum analysis, signals from the Flight 90 cockpit area microphone channel were processed in a spectrum analyzer which displayed the energy content of the signals as a function of their frequencies. A number of these displays were printed to give a time history of the spectral content of the cockpit area microphone channel. It was determined from this procedure that the predominant frequency associated with the engine sound increased at 1559:48 following the words, "your throttles." On the takeoff roll, the engines' first stage fan blade passing frequency was smeared between 3,100 Hz and 3,250 Hz for an average frequency of 3,175 Hz, corresponding to an engine first-stage fan speed ($N_1$) of 80 to 84 percent.

The following table relates time to percent $N_1$ rotor rpm to blade passing frequency.

| TIME | BPF (Hz) | ROTOR RPM (Percent $N_1$) |
|---|---|---|
| 1559:48 | Increasing | Increasing |
| 1559:51 | 3,100 | 80 |
| 1559:53 | 3,400 | 88 |
| 1559:55 | 3,175 | 82 |
| 1600:39 | Indistinct but probably stable | 82 |
| 1600:50 | 3,250 | 84 |
| 1600:55 | | |

| | |
|---|---|
| Rose and became indistinct | 90+ |

The first-stage blade passing frequency was not distinct from 1600:39 to 1600:50; the engine cowl is designed to reduce noises associated with the fans during the takeoff regime. There was also some masking because of the sound of the stickshaker and changes in the CVR tape speed (wow and flutter).

A frequency which could be correlated to the second-stage fan, which has 40 blades, was only briefly identified during the initial engine acceleration. Its steady state frequency could not be identified because it approached the upper limit of the CVR's frequency range and was severely attenuated. It was about 1 1/2 time as high as the frequency associated with the first-stage fan.

## 1.16.3 Engine Tests with Blocked Inlet Pressure Probe ($Pt_2$)

The B-737's primary engine instrumentation consists of: engine pressure ratio (EPR), a direct indication of the ratio of the pressure measured at the turbine discharge pressure ($Pt_7$) to the pressure measured at the compressor inlet ($Pt_2$); the first stage fan or low pressure compressor speed ($N_1$); the high pressure compressor speed ($N_2$); the exhaust gas temperature (EGT); and the fuel flow (F/F).(See figure 5.)

Tests were conducted at The Boeing Co. using a B-737-200 aircraft with JTBD engines having the same blade passing frequency for the first stage fan as the engines on N62AF. During these tests, the $Pt_2$ probe on the No. 1 engine was blocked with tape while the $Pt_2$ probe on the No. 2 engine was left unblocked. The throttles were set to achieve an EPR indicator reading of 2.04 on the engine having the blocked $Pt_2$ probe. The $N_1$, $N_2$, EGT and F/F were read and the throttle on the engine with the unblocked $Pt_2$ probe was adjusted down to match these values. The EPR indication on this engine then read 1.70 with the engine anti-ice switch OFF. The $N_1$, $N_2$, EGT, and F/F were also noted for an unblocked $Pt_2$ probe when the engine throttle was set to an actual EPR of 2.04. (The comparison of the readings between the engine developing an actual EPR of 2.04. (The comparison of the readings between the engine developing an EPR of 1.70 and the engine developing an EPR of 2.04 is shown infigure 6.) The approximate angular differences between the instrument pointers were 30° for $N_1$, 20° for EGT, 15° for $N_2$, and 42° for F/F.

The engine blade passing frequency produced at various EPR settings was recorded. A spectrum analysis of this recording showed the blade passing frequency to be between 3,100 Hz and 3,250 Hz with actual EPR settings of 1.70 to 1.74.

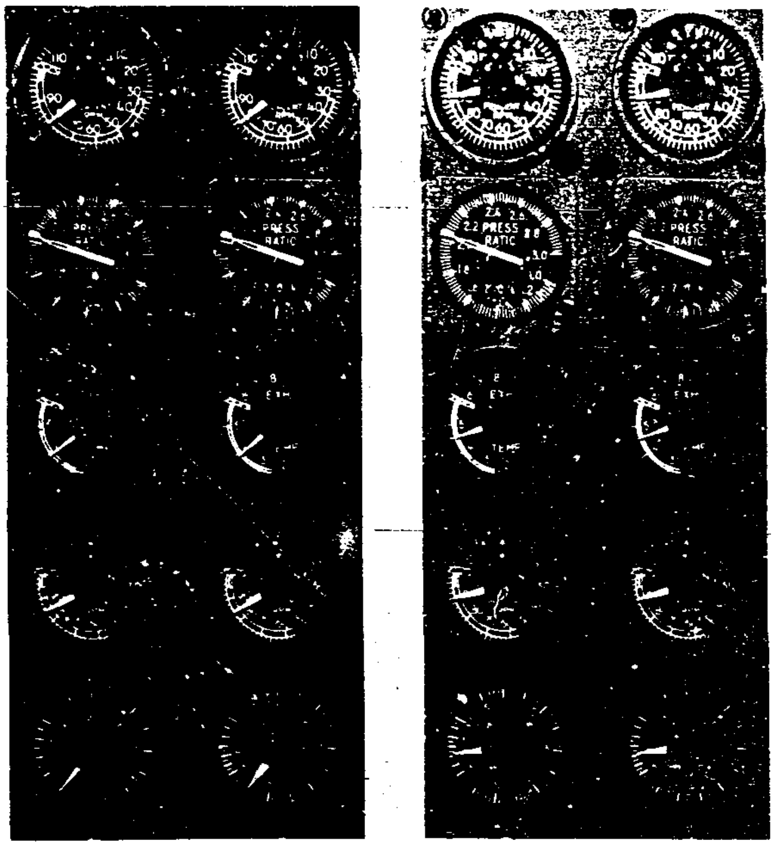
## 1.16.4 Flight Simulator Tests

The performance study of Flight 90 included aircraft simulation flights conducted at The Boeing Co.'s Flight Simulator Center in Renton, Washington. The visual environment (what pilots saw from the simulator windshield) was constructed to represent the runway at Washington National Airport, the two spans of the 14th Street Bridge, and the railroad bridge.

The simulator was programmed to represent the B-737-200 basic model aircraft performance in conditions of no ice and ice contamination of varying degrees. Data for the latter were derived from wind tunnel and flight tests using "corn ice" (30 grit sandpaper) contamination. The effects of icing were programmed into the simulator in terms of degraded coefficient of lift and increased coefficient of drag; coefficient of pitching moment was not varied during these tests.

This image is not available at this time.

**Figure 5. -- Center instrument panel functions.**



Engine Instrument Indication:
1.70 EPR $P_{t2}$ probe blocked
Engine anti-ice-Off

Engine Instrument Indication:
2.04 EPR
Normal Operation

**Figure 6.—Comparison of Instrument Readings -- 1.70 HPR vs. 2.04 EPR.**

Pilots who participated in the tests first validated normal (no ice) aircraft performance and simulator response/feel for the configuration and weight of the accident aircraft. Thrust was set at 2.04 EPR. In their opinion, back yoke pressure was abnormally high during rotation; one unit of additional noseup trim (6 1/2 units total) was sccepted as producing a normal control feel.

When the simulator coefficients were changed to represent the effects of icing, conditions were sought whereby the time and flightpath of the accident aircraft were duplicated. In all flights, landing gear was down, flaps were set at 5, and stabilizer trim setting was not changed. Because spectrum analysis of the CVR tape and tests at Boeing showed that the actual thrust being developed by the accident aircraft was about 10,750 pounds net thrust per engine (1.70 EPR) and not the target value of 14,500 pounds net thrust per engine (2.04 EPR), a thrust level corresponding to 1.70 EPR was used in the tests.

The stall warning (stickshaker) in the accident aircraft estivated shortly after liftoff according to CVR information. Therefore, a pitch attitude was sought for the flight simulations which would provide the correct relationship between the time of rotation and stickshaker activation, liftoff, and distance to impact. Several test runs were performed using 1.70 EPR and the lift, drag, and pitching moment coefficients determined for corn ice. The desired pitch attitude was determined to be 18° noseup.

The simulator pilots did not, on any flight, spontaneously activate the stickshaker with the programmed pitching moment. To activate the stickshaker and keep it activated, simulator pilots had to hold positive back stick force, in some cases, 10 pounds or more. If back stick force was released during the first 10 to 15 seconds of flight, the simulator would fly out of the stickshaker regime. Thus, although airplane behavior in terms of climb and acceleration performance could be simulated and valuable information derived from these flights, pilot control forces and responses were not necessarily representative of Flight 90. Variations in aircraft pitching moments may have produced different control forces and pilot responses. Recovery of the simulator in most cases could be accomplished simply by adding full power, releasing back stick pressure, or a combination of both.

In attempts to duplicate the accident sequence and cause the simulator to crash at or near the 14th Street Bridge in the simulator visual environment, the simulator was flown according to CVR event timing using lift and drag coefficients believed to be representative of different ice contamination. Rotation rates for takeoff were also varied. Using 1.70 EPR with no in-flight thrust adjustment, a left turn of 5° bank was initiated 12 seconds after liftoff while attempting to maintain a target pitch attitude of 18° with the stickshaker activated until impact. Five flights were found to be representative of the accident flight profile, timing, and position of impact. All of these flights used degraded lift and drag coefficients representative of wing contamination.

The next sequence of tests attempted to define conditions of possible aircraft recovery using combinations of pitch and added thrust. Using 1.70 EPR and simulated corn ice contamination, the simulator was flown without crashing with a 14° pitch attitude. Conversely, using a pitch attitude of 18° and corn ice and an initial thrust setting of 1.70 EPR, in some cases, increased thrust levels applied at various times after liftoff effected recovery. During the run most representative of marginal recovery, target pitch attitude was held fairly constant at 18° and maximum available thrust (2.23 EPR) was applied about 15 seconds after liftoff. Vertical velocity and pitch attitude then oscillated for the next 15 seconds, and about 18 seconds after maximum thrust was applied, a positive rate of climb was established, the stickshaker ceased, and climbout was continued in stall buffet.

The effect of retracting the landing gear in the simulator tests was small compared to the effect of any other action. After sustaining a stalled condition for 15 seconds or more, recovery of the simulator usually was not possible.

## 1.16.5 Tests on Deicer Fluid Samples

Union Carbide Aircraft Deicing Fluid II PM 5178 deicer is composed of 2 percent wetting agents and corrosion inhibitors, 7 percent water, and 91 percent ethylene glycols. The 91 percent of glycols is actually 81 to 83 percent of simple ethylene glycol and 8 to 10 percent of another ethylene glycol. Both have essentially the same deicing properties. Diluted to a 25 percent deicer/75 percent water minture, the solution would be expected to contain about 22 percent ethylene glycols (20 percent simple ethylene glycol).

Immediately following the accident, the National Transportation Safety Board secured samples of deicing fluid similar to that used to deice/anti-ice N62AF before it left the gate. Samples of the deicing fluid, the deicing fluid/water mixture, and water were taken from the American Airlines Trump vehicle No. 5058 and were submitted to the FBI laboratory for testing. Two separate samples of the deicing solution mixed at the nozzle of Trump vehicle No. 5058 were tested; one sample with 25 percent deicer fluid and 75 percent water selected, and the other sample with 30 percent deicer fluid and 70 percent water selected. Test results showed that the simple ethylene glycol content of the samples was 12 percent and 18 percent, respectively. The freezing points of these solutions are about 22° F and 20°, respectively. Undiluted samples of deicer fluid were taken from both the main storage tank on the airport and the tank on Trump vehicle No. 5058; the percent of simple ethylene glycol in these samples was 83 percent and 80 percent, respectively.

## 1.16.6 Metallurgical Examination of Wing Leading Edge Slat Skin

The B-737 Structural Repair Manual 57-50-3, page 14, dated August 1, 1981, under the heading of "Wing Leading Edge Slat-Skin Erosion Repair" states in part: "Flight operation is not allowed if leading edge roughness is equivalent to or greater than that of 240 grit sandpaper." While this operations limitation is not in the FAA-Approved Flight Manual, it is a guide to inspection and maintenance personnel as to the conditions under which an aircraft should or should not be released for flight operations.

In order to determine the surface roughness of representative sections of leading edge slat skin, specimens were taken from each of the slats of H62AF. Samples of 240, 320, 400, and 600 grit sandpaper 15 were compared to each of the six skin sections. The comparisons were made by rubbing each of the surfaces with the fingertips applying the same relative pressure. Numerous laboratory personnel performed the test. In all cases, the six slat skin specimens were found to be smoother than 600 grit sandpaper.

A sample of the slat leading edge skin surface and samples of 240 and 600 grit sandpaper were examined with the aid of a scanning electron microscope. Results of the examination also disclosed that the slat skin leading edge outer skin surface was smoother than 600 grit sandpaper.

## 1.17 Additional Information

### 1.17.1 Engine Anti-ice System

The B-737 FAA-Approved Flight Manual and the Air Florida B-737 Operations Manual prescribe that the engine inlet anti-ice system shall be on when icing conditions exist. Additionally, the manuals prescribe that the engine anti-ice system shall be on when icing conditions are anticipated during takeoff and initial climb. (See appendix H.) The flight manual defines icing conditions as follows:

> Icing may develop when the following conditions occur simultaneously: The dry-bulb temperature is below 8°C (46.4°F) The wet-bulb temperature is below 4°C (39.2°F) Visible moisture, such as fog, rain, or wet snow is present.
>
> Fog is considered visible moisture when it limits visibility to one mile or less. Snow is wet snow when the ambient temperature is -1°C (30°F) or above.

The EPR measurement system in the B-737 aircraft senses an air pressure measured at the aircraft inlet engine nose probe, known as $Pt_2$, and sets up a ratio between inlet air pressure and engine exhaust gas pressure measured at the engine exhaust nozzle, known as $Pt_7$. The EPR ($Pt_7/Pt_2$) is determined electronically and displayed continuously in the cockpit. It is the primary instrument used by the crew to set engine power for takeoff. The $Pt_2$ probe is subject to icing but may be deiced with the engine anti-icing system. When the engine anti-ice system is manually activated by the crew, engine 8th stage compressor bleed air is supplied to the engine inlet guide vanes and is discharged into the engine nose cone and to the engine inlet upstream of the inlet guide vanes. This hot air keeps ice from forming or melts ice on the inlet probe by passing warm air around the probe which is mounted in the nose cone.

With the engine operating, a false indication of the actual EPR can be indicated in the cockpit when ice blocks the inlet probe. Under this condition, the $Pt_2$ probe is vented to the nose cone pressure through a siphon-break hole in the sense line. The interior of the engine nose cone is vented to the engine inlet static pressure, which is lower than the engine inlet total pressure normally sensed by the $Pt_2$ system. Under severe icing conditions, if the engine inlet anti-icing air bleed system is shut off and the normal $Pt_2$ sensing port is blocked with ice, the $Pt_2$ sensor will sense the lower pressure at the vent port in the nose cone. The cockpit indication may become slightly erratic as icing begins to block the probe and will indicate a significantly higher reading when ice fully blocks the probe. Tests have demonstrated that with a blocked probe at takeoff, engine power can indicate an EPR of about 2.04 with the engine actually operating at an EPR ratio of 1.70. Under these circumstances, a pilot would unknowingly attempt takeoff at a considerably lower thrust than desired. However, the pilot has available other indications of engine operation displayed in the cockpit, such as a lower $N_1$, $N_2$, EGT, and F/F consistent with the reduced engine thrust.(See figure 6.)

Should the pilot activate the engine inlet anti-icing system with a blocked probe, he would immediately notice a substantial drop in the indicated EPR, incorrectly indicating a low engine thrust as long as the normal $Pt_2$ sensing port remains blocked. This results from the introduction of engine anti-icing air flow into the nose cone and resultant increase in the pressure in the interior of the nose cone. This pressure is higher than that which would be sensed at the normal $Pt_2$ port. Falsely low indicated EPR's have been detected by pilots when they found that they were unable to set takeoff power without exceeding redline $N_1$, $N_2$, and EGT.

## 1.17.2 History of the Use of Ethylene Glycol as a Deicing Agent

The use of ethylene glycol as a deicing agent was started about 1956. At that time, it was used by the United States Air Force (USAF) in its cold weather operations, and a military specification was developed. After civilian operators started using the same formula about 1960, they found that the deicing/anti-icing needs for commercial use were substantially different from those of the USAF, which was using ethylene glycol and propolene glycol in a 3 to 1 ratio. Union Carbide's recommendation for commercial use of its deicer fluid for deicing follows:

Use a 50% dilution of UCAR ADF II (40% for the milder ice conditions). Apply it at a temperature between 150 and 180° F. (66 and 82° C.) for the most effective removal of frost and ice from aircraft surfaces. Remove most of the heavy snow before spraying. A coarse stream of spray loosens and displaces ice from aircraft surfaces.

For anti-icing Union Carbide recommends the following:

UCAR ADF II is most efficient in its concentrated form for icing protection of ice-free aircraft. This allows fluid retention on the aircraft surface, prolonging icing protection.

Do NOT use diluted deicing fluid for anti-icing treatment of ice-free aircraft.

Jefferson Chemical Company, a former subsidiary of Texaco, also manufactures a deicing fluid, "WD-30." Its Technical Service Bulletin No. 3029 describes its deicing fluid and presents recommended methods for its use. Bulletin 3029 states that light ice and frost may be removed from aircraft exteriors by application of either a warm solution of diluted WD-30 or unheated, concentrated WD-30. Either warm diluted or undiluted WD-30 should be used to remove heavy ice formations. Temperatures in the range of 180° F. are recommended. It further states that WD-30 may be used to prevent the formation of ice from freezing rain and frost. The duration of protection and frequency of application will depend on weather conditions. Wing deicing fluid WD-30 is not recommended to protect aircraft from snow deposits. Slush is formed where the deicing fluid is diluted by melting snow, which freezes and is extremely difficult to remove. Snow is best removed by mechanically sweeping or brushing it from the aircraft surfaces.

### 1.17.3 The Trump Deicer Vehicle

Trump vehicle No. 5058 is a Model D40D tank truck unit capable of heating, premixing, mixing, and delivering deicer fluid/water mixtures to aircraft surfaces. The unit used for deicing Flight 90 incorporated a glycol/water proportioning system which allows the operator to blend the fluid mixture to meet the conditions required at the time and allow for "a more economical use of glycol." The unit did not incorporate the "mix monitor" which allows the operator to ascertain that the desired mixture is indeed being delivered at the nozzle.

The following procedures for setting the proportioning valve were set forth in the February 1979 revision to the Trump Vehicle Operator's Manual:

| Ambient Temperture (° F.) | Glycol (Percent) | Condition |
|---|---|---|
| 28 or higher | 0 | Use with [nozzle set at] 95 gpm [gallon per minute] or 125 gpm to rapidly remove snow or ice with hot water. |
| 20 to 27 | 30 | Use with 30 gpm nozzle setting to apply a light coating of glycol after hot water deicing. Use with 60 gpm [nozzle] setting to remove moderate to heavy snow or ice. For more rapid removal of heavy snow, it may be necessary to increase the flow to 95 gpm with a 22% mixture. |
| 10 to 20 | 50 | Use 30 gpm [nozzle] setting. |
| Below 10 | 60 | Use 30 gpm [nozzle] setting. |
| Anti-icing | 65 | Use 30 gpm nozzle setting and apply only enough fluid to cover aircraft, avoid as much run off as possible. |

Although the revised 1979 Trump Vehicle Operator's Manual cited specific percentages of glycol to be used at certain temperatures and conditions, the president of Trump, Inc., testified at the Safety Board's public hearing into this accident that he first learned the exact composition of the UCAR ADF-II deicing fluid during the testimony at the hearing.

## 1.17.4 American Airlines Deicing Procedures

Personnel directly involved in the deicing/anti-icing of Flight 90 were employees of American Airlines and were primarily using the American Airlines General Maintenance Manual procedures for performing the required deicing operations. At the time of the accident, American Airlines did not operate any B-737 aircraft nor had any American Airlines personnel received specific training on B-737 aircraft. The General Maintenance Manual cites general precautions related to snow and ice accumulation on aircraft and the Federal Aviation Regulations which prohibit takeoff with snow, frost, or ice adhering to critical parts of the aircraft.

While the American Airlines Maintenance Manual contained special instructions for deicing DC-10 aircraft and precautions regarding snow removal from the areas of vortex generators on B-707 and B-727 aircraft vertical stabilizers, it did not contain any instructions pertaining to the B-737 aircraft.

The manual provided the following directions for the use of the Trump D40D vehicle and Union Carbide ADF II:

**For Trump deicers No. 4535 and higher with casket-mounted proportioning valves --**

| Outside Temperature | 1,500-gallon Water Tank | 300-gallon Glycol Tank | Set Proportioning Valve for: Deicing (Removal) Anti-Icing (Final) | |
|---|---|---|---|---|
| (° F) | | | (Percent) | (Percent) |
| 26 & Above | Water only | Concentrated deicing fluid | 0 | 25 |
| 25 to 20 | Water only | Concentrated deicing fluid | 25 | 25 |
| Below 20 | Water only | Concentrated deicing fluid | 25 | 40 |

## 1.17.5 Jet Exhaust Data

Jet exhaust temperatures and velocities at given distances and power setting behind the exhaust nozzles of JT8D turbofan engines were determined to provide an indication of their effects on following aircraft.(See figure 7.)

## 1.17.6 Boeing 737 Waintenance Manual Instructions For Ice and Snow Conditions

The B-737 Maintenance Manual lists MIL SPEC MIL A-8243 "Anti-icing, Deicing, and Defrosting Fluid" as an acceptable fluid for deicing Boeing aircraft. This manual prescribes conditional inspections of the aircraft whenever icing or snow conditions exist prior to flight as follows:

Examine for the following:

> Fuselage, wings, control surfaces, balance panel areas and hinge points for ice and snow. If snow or ice exists, refer to 12-50-0, "Cold Weather Maintenance."
>
> Engine inlet cowl for ice and snow, secondary inlet doors for freedom of movement, and the first stage compressor for freedom of rotation.
>
> Light coatings of frost up to 1/8-inch thick on lower wing surfaces only are permissible; however, all control surfaces, tab surfaces and balance panel cavities, wing leading edge slats, and wing upper surface must be completely free of snow or ice before takeoff (Ref. 12-50-0, Cold Weather Operation).

The B-737 Maintenance Manual also cautions against removal of snow from any surface of the aircraft by application of deicing solution "since dilution of solution with melted snow can result in the mixture refreezing and becoming more difficult to remove." Boeing recommends snow removal from wings and empennage areas with long handled brooms.

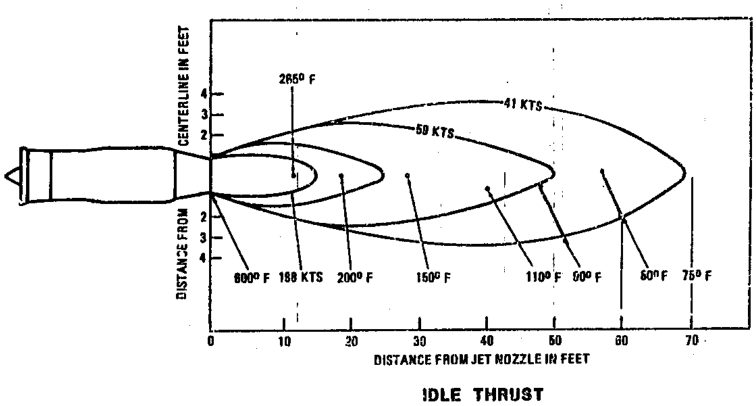



**Figure 7.--JT8D turbofan exhaust gas temperatures and velocities.**

### 1.17.7 Air Florida Maintenance Manual, Instructions For Winter Operations

The Air Florida Maintenance Manual, under the general heading of "Cold Weather Procedures," states in part that special dispatching procedures must be used during cold weather operations and that the following effects of winter weather must be guarded against and eliminated:

Ice, snow and frost accumulation on aircraft, frozen control-surface hinges, snow or ice accumulations in the control surface air seal diaphragms, cold cockpit conditions impairing instrument operation.

The manual further refers to the "Manufacturer's Maintenance Manual." Specific instructions are set forth in the manual to plug or cover airframe and ponerplant openings with the appropriate plugs when an airplane is exposed to "heavy snow on ice for even short periods." Air Florida procedures also state that: "No aircraft will be dispatched and no take-off will be made when the wings, tail surfaces have a coating of ice, snow or frost." (emphasis added). Further, maintenance dispatch conditions and restrictions require that:

> Flights may be dispatched when it is agreed by the captain and the man responsible for the release of the aircraft that snow on the surface of the aircraft is of such consistency that it will dissipate or blow off during taxi or the start of the take-off run and that no take-off will be made with ice, snow, or frost adhering to any part of the airplane structure which, in the opinion of the captain, might adversely affect performance.
>
> Prior to application of solution, covers and plugs will be installed. In applying the deicing solution around openings in the airplane care must be taken to limit the application to the amount required for anti-icing. Avoid directing the fluid stream into openings or the use of excess solution in ducting or appliances served by the openings.

Contrary to these instructions, no openings on the airframe or powerplants were covered during the exposure of the aircraft to heavy snow or during the deicing operations. The Air Florida maintenance representative testified that he had "never seen airplanes deiced with the covers on them."

## 1.17.8 Boeing 737 Wing Leading Edge Contamination and Roughness

Since 1970 there have been a number of reports by operators of B-737 aircraft who have experienced an aircraft pitchup or rolloff immediately after takeoff in weather conditions which were conducive to the formation of ice or frost on the wing leading edges. The Safety Board is aware of 22 such reports during the period. In some of these incidents, the aircraft's stall warning system activated and the pilot used full or nearly full control column movement to recover.

As a result of incidents involving B-737 aircraft which experienced a sudden roll after takeoff, The Boeing Co. on October 24, 1974, issued Operations Manual Bulletin No. 74-6. The bulletin advised operators of the incidents in which asymmetrical clear ice had built up on the leading edge devices during ground operations involving the use of thrust reversers in light snow conditions with cross winds. It appeared that the snow melted due to hot engine gases and refroze on contact with the cold leading edge devices. The presence of the ice resulted in a tendency to roll at higher angles of attack during ensuing takeoffs. The bulletin cautioned flightcrews to assure compliance with all ice and snow removal procedures prior to takeoff under suspected icing conditions and to avoid maneuvers requiring unnecessary "g" loads immediately following takeoffs in weather conditions under which icing might be suspected. This bulletin had been incorporated into Air Florida Flight Manuals.

The continuation of reports of pitchup/rolloff occurrences prompted The Boeing Co. to examine further the B-737 aircraft sensitivity to leading edge contamination. In 1977 plans were formulated for wind tunnel and flight tests. Even before conducting these tests, The Boeing Co. on February 23, 1979, issued Operations Manual Bulletin 79-2 to advise flightcrews of a possible inadvertent pitchup/rolloff after takeoff due to ice accumulation on leading edge devices. The bulletin stated that several operators of B-737's had reported pitchup and/or rolloff after takeoff caused by ice accumulations on leading edge devices and that such incidents had usually occurred following the application of reverse thrust while taxiing on snow-covered taxiways. In order to advise flightcrews of this condition, the following note was incorporated in the revised portion of the "Adverse Weather" section in the B-737 Operations Manual.

A buildup of ice on the leading edge devices may occur during ground operations involving use of reversers in light snow conditions. Snow is melted by the deflected engine gases and may refreeze as clear ice upon contact with cold leading edge devices. This buildup, which is difficult to see, occurs in temperature conditions at or moderately below freezing. Crosswind conditions can cause the ice buildup to be asymmetrical, resulting in a tendency to roll at higher angles of attack during subsequent takeoffs.

These bulletins had been incorporated into Air Florida Flight Manuals and had been disseminated to all Air Florida B-737 flightcrews.

As part of its investigation of the reported incidents, The Boeing Co. flight tested a B-737-200 advanced airplane in the fall of 1980 to quantify the aerodynamic effects of contaminated leading edge slats. The leading edge slats were coated with an epoxy potting compound and the surface was roughened with a paint roller to simulate a coating with corn ice. A series of stalls was conducted with flaps up, and at flap positions of 1, 15, and 40. The stall characteristics with both symmetric and asymmetric leading edge contaminations were characterized by a very apparent pitchup, yaw rate, and rolloff. These characteristics were more pronounced at flap settings less than 5 when the slats were sealed, that is, when there was no gap between the leading edge slat and the basic wing such as that which occurs when the slats are fully extended coincident with flap settings between 10 and 40. The Boeing Co. concluded that "...when takeoffs are executed during suspected icing conditions or adverse weather conditions, sound operational techniques must be employed. Wings should be kept clear of ice and other forms of contamination, and rotation rates should not exceed 3°/second." It also concluded that additional speed margins were advisable when operating in adverse weather such as snow, sleet, or rain at near freezing temperatures.

As a result of the flight tests, a third Operations Manual Bulletin, 81-4, was issued on June 5, 1981. It stated that heavy frost or rime ice on the leading edge would increase stall speeds by 8 to 10 kns at takeoff flap settings. The following operating procedures were recommended and the B-737 manual was to be revised accordingly.

> All crews should be reminded that the recommended rotation rate for the 737 is approximately 3°/sec. At light gross weights and cold temperatures, this rate will result in an initial climb speed above $V_2$ + 15. Initial climb speeds up to $V_2$ + 25 will not significantly affect the climb profile.
>
> If leading edge flap roughness is observed or suspected for any reason, care should be exercised to avoid fast rotation rates (in excess of 3° per second) and/or over rotation.

When operating in adverse weather conditions, improved stall margins can be achieved by the following:

> If excess runway is available use Improved Climb procedures for flaps 1, 2, or 5.
>
> If runway limited for the planned takeoff flap setting, consideration should be given to using the next greater flap position with Improved Climb Performance. This will provide additional stall

> margins with minimum performance penalties.
>
> If pitch up and/or roll off is encountered after lift off, use aileron, rudder and elevators as required to maintain desired flight path. Smooth, continuous flight control inputs should be used to avoid over controlling.
>
> Currently recommended procedures in the Boeing Operations Manual for operation in icing conditions are once again emphasized.

This bulletin had also been incorporated into Air Florida Flight Manuals. In addition to Operations Manual Bulletin 81-4, The Boeing Co. printed articles relating to the B-737 leading edge contaminations and the flight test program in the July-September 1981 and the October-December 1981 issues of The Boeing Airliner, a quarterly publication distributed to operators through the Boeing Customer Support Representative.

Prior to the issuance of Operations Manual Bulletin 81-4, the United Kingdom Civil Aviation Authority (CAA) had expressed its concern that flightcrew advisories and cautions were not sufficiently positive actions to prevent incidents particularly under conditions such as darkness when the crew might be unable to detect small amounts of contaminant on the leading edge. Consequently, the CAA, in May 1981, proposed a requirement that carriers ban the use of 1 and 2 flap positions for B-737 takeoff whenever outside air temperatures were less than 5°C and that improved climb performance procedures be used to provide higher stall speed margins. The Boeing Co. reply to the CAA proposal objected to the ban for 1 and 2 flap positions. The CAA subsequently modified its proposal to allow the lower flap settings with the additional speed increment.

The Boeing Co. internal memoranda examined by the Safety Board showed that it was considering an engineering change to the wing thermal anti-ice (TAI) system to permit the use of that system on the ground to assure a clear leading edge. An evaluation test report dated November 5, 1981, showed that this concept was feasible. Therefore, in response to the CAA's formal release of its intention to require additional speed margins on October 28, 1981, at least one British carrier objected to the procedures suggesting instead that the wing TAI system be used on the ground prior to takeoff. This procedure would alleviate the weight penalty which would be incurred at certain airports as a result of the modified airspeed schedule defined in the CAA proposal. Another Boeing Co. internal document dated January 7, 1982, showed that The Boeing Co. agreed with the carrier that the wing TAI system could be used even without modification by holding a spring loaded test switch in the test position for 30 seconds before takeoff and that this procedure should preclude imposition of the overspeed requirement. The same document proposed a modification to the wing TAI system to incorporate a "ground" mode which would be more compatible with normal operation.

Two days after the Air Florida Flight 90 accident, the CAA issued Airworthiness Directive 010-01-82 requiring that, under conditions where visible moisture existed and the outside air temperature was less than 5°C, 2 kns must be added to the airspeed schedule for the B-737 standard aircraft during takeoff with flaps in the 1 and 2 positions and 5 kns must be added to the B-737-200 advance aircraft under the same circumstances. There was no mention of exemption for the ground use of the wing TAI system. The CAA proposed an amendment to AD 010-01-82 on February 15, 1982, which would require in addition that 5 kns be added to the speed schedule when using a takeoff flap setting of 5 in any B-737 and further that a flap setting greater than 5 would be required when taking off from a runway contaminated with water, snow, or ice.

Boeing documents disclosed that following the accident, it continued to evaluate the engineering modifications to the wing TAI system. On June 2, 1982, Boeing issued an Engineering Change Order to incorporate the modification and noted that a Service Bulletin was planned to accommodate retrofit on aircraft in service.

## 1.17.9 Other Boeing-737 Operations Mammal Information

Section 3A-7, page 2, of the August 20, 1973, issue of the B-737 Operations Manual, Supplementary Procedures, Ice and Rain Protection, "Wing Anti-ice," states:

> There are two methods recommended for operating the anti-icing. The primary method is to use it as a deicer, by allowing the ice to accumulate before turning it on. This procedure will provide the cleanest airfoil surface, the least possible runback ice formation, and the least thrust and fuel penalty. Normally, it will not be necessary to shed ice periodically unless extended flight through icing conditions is necessary (holding). Ice less than 3 inches thick will have little effect on airplane handling, therefore, the ice accumulation may be allowed until the icing condition has been passed. The secondary method is to turn the wing anti-ice switch on when wing icing is possible and use the system as an anti-icer.
>
> If the TAT reading is at or below 10°C and visible moisture is present, the wing anti-icing can be activated to prevent ice accumulation on the wing leading edges. The windshield wiper arms give the first indications of ice forming on the airplane.
>
> Federal Aviation Regulations 14 CFR 121.629(b) prohibit takeoff when frost, snow or ice is adhering to the wings, control surfaces or propellers of the aircraft.

## 1.17.10 Air Florida Flightcrew Training

Air Florida's B-737 flight training program consists of four phases. Initial training is required and conducted for crewmembers who have not qualified in the type of aircraft and served in the same capacity on another aircraft of the same group. Transition training is required and conducted for crewmembers who have previously qualified and served in the same capacity on another aircraft of the same group. Upgrade training is required and conducted for crewmembers who have qualified on a type of aircraft and served as second-in-command before they are eligible to serve as pilot-in-command on that aircraft. Differences training is required and conducted for qualified flight crewmembers on a new model of the same type of aircraft; for example, a 737-100 qualified crewmember would be required to take differences training, for the 737-200 series.

Once a flight crewmember is fully qualified and *[sic]* as either second-in-command or pilot-in-command on a specific type of aircraft, recurrent training is required. Such recurrent training consists of ground school for captains and first officers once a year. Recurrent training in the flight simulate is required every 6 months for qualified captains and once a year for qualified first off *[sic]*. All training consists of a combination of video presentations, films, slides, and lectures. Training material is derived directly from the Air Florida Flight Operations and Training Manuals.

Video presentations used during each initial and recurrent B-737 class include B-737 winter operations, takeoff (rotation effects on initial climb performance) and landing performance, wet stopping - mark II antiskid, windshear, upset, and landing illusions.

Programmed hours are also dedicated to discussions of determination of maximum allowable takeoff weights with various conditions of temperature, pressure altitude, wind, and runway contamination through the use of performance crafts. Performance computations are also discussed for anti-ice systems "off" and "on" as are the computations of EPR for both takeoff and go-around. While there is no specific program for winter operations training, such training is included in the standard training programs. Air Florida does not offer any specific command decision, resource management, or assertiveness training to its pilots nor is such training required under existing Federal Aviation Regulations.

Air Florida's Training and Operations Manuals contain the following normal takeoff procedures:

> The airplane is certificated for setting thrust either statically prior to brake release or while rolling after brake release. Do not waste time and fuel trying to accurately set thrust or to check engine performance prior to brake release. The pilot flying will advance all thrust levers to the vertical position and allow the engines to stabilize. This minimizes thrust asymmetry caused by differences in individual engine acceleration, aids in preventing overshooting the desired thrust setting, and eliminates engine surge caused by a crosswind.
>
> When all engine instruments have stabilized, the pilot flying will advance the thrust levers to approximately takeoff EPR and call "SET MAXIMUM THRUST" or "REDUCE THRUST SET" at which time, the pilot not flying will adjust the thrust levers to desired EPR. Final takeoff thrust adjustments are to be made prior to 60K. Pilot not flying will call out "MAXIMUM THRUST SET" or "REDUCE THRUST SET".
>
> Rolling takeoffs are performed without stopping at the end of the runway. As the airplane rolls onto the runway, smoothly advance the thrust levers to the vertical position and hesitate to allow the engines to stabilize and proceed as above. Rolling takeoffs can also be made from the end of the runway by advancing the thrust levers from idle as the brakes are released.
>
> The same takeoff EPR setting is good for both static and roiling. There is no appreciable ram offect on EPR up to 60 knots.
>
> If EPR is quickly set, there will be a small overshoot in EPR. A slight EPR adjustment should be made to correct the overshoot. A max overshoot of .01 EPR recommended or covered on P&W [Pratt & Whitney] warranty.
>
> The takeoff $N_1$ setting is a preliminary setting and will change with increased airspeed. $Nub_1$ is to be used primarily when an EPR gage is inoperative. Use EPR as the "fine" setting and do not retard the thrust levers for $N_1$ variation unless $N_1$ exceeds the maximum limitation.

Air Florida flightcrews are taught the following flightcrew duties for takeoff:

> Prior to reaching takeoff position, the captain will advise the first officer if he is to make the takeoff. Takeoff roll will be started either from a static position on the runway or as the airplane rolls onto the runway. Set thrust prior to 60 knots and rotate at $V_R$ to approximately 15° nose up.
>
> Climb at $V_2$ + 15K to at least 600 feet above field elevation. Set climb thrust. Continue climb at $V_2$ + 15K to 3,000 above field elevation. Retract flaps on schedule. Normal enroute climb. After gear retraction maximum body angle 20°.
>
> When $V_2$ + 15K cannot be maintained with a body angle of 20°, increase speed as necessary above $V_2$ + 15K. Retract flaps on schedule, if required, by this speed increase.

Pilots are trained to reject a takeoff "when engine failure occurs before $V_1$ or if takeoff warning horn sounds before $V_1$." The training manual states that:

On recognition of the engine failure, either pilot will call out the malfunction, e.g. "ENGINE FAILURE", "ENGINE FIRE", and state engine number (not left or right). The captain makes the decision to reject.

The Air Florida Training Manual also sets forth procedures for "engine failure recognition;" it states:

> Under adverse conditions on takeoff, recognition of an engine failure may be difficult. Therefore, close reliable crew coordination is necessary for early recognition.
>
> The captain ALONE makes the decision to "REJECT."
>
> On the B-737, the engine instruments must be closely monitored by the pilot not flying. The pilot flying should also monitor the engine instruments within his capabilities. Any crewmember will call out any indication of engine problems affecting flight safety. The callout will be the malfunction, e.g., "ENGINE FAILURE," "ENGINE FIRE," and appropriate engine number.
>
> The decision is still the captain's, but he must rely heavily on the first officer.
>
> The initial portion of each takeoff should be performed as if an engine failure were to occur.

The Air Florida Flight Operations Manual prescribes procedures and flightcrew duties for rejecting a takeoff. The manual requires that upon recognition of failure or warning light, either pilot will call out "engine failure," "engine fire," or "takeoff warning." There are no written procedures for rejecting takeoff for other engine or aircraft anomalies. The manual does not recommend rejecting a takeoff solely for the illumination of the amber "master caution" light once thrust has been set and the takeoff roll has been established.

The specific duties for the captain and first officer for normal takeoff and a rejected takeoff are set forth in the Air Florida Flight Operations Manual. (See figure 8 and figure 9.) When the first officer is making the takeoff, the duties are simply reversed; however, no specific manual material is published on this subject. For the purpose of practical application of the flight crewmembers duties, the column marked captain is considered the "flying crewmember" and the first officer the "nonflying crewmember." However, no matter which crewmember is making the takeoff, the captain is solely responsible for rejecting the takeoff.

### 1.17.11 Air Traffic Control Handling of Flight 90