PB82-910408

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

**AIR FLORIDA, INC.
BOEING 737-222, N62AF
COLLISION WITH 14TH STREET BRIDGE,
NEAR WASHINGTON NATIONAL AIRPORT
WASHINGTON, D.C.
JANUARY 13, 1982**

NTSB-AAR-82-8

UNITED STATES GOVERNMENT

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16. 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.

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Abstract continued

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.

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WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

Adopted: August 10, 1982

AIR FLORIDA, INC., BOEING 737-222, N62AF, COLLISION WITH 14TH STREET BRIDGE NEAR WASHINGTON NATIONAL AIRPORT WASHINGTON, D.C. JANUARY 13, 1982

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.

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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

1/ All times herein are eastern standard time, based on the 24-hour clock.
2/ American Airlines Inc., provided, certain services to Air Florida, Inc., under a contractual agreement.

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 Ninety, 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 aircraft 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

3/ Palm 90 is an air traffic control (ATC) designation for Air Florida Flight 90.

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 nose 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 line behind a. . . Apple 4/ . . .DC Nine." Flight 90 acknowledged this transmission at 1538:47. Flight 90 then fell in behind the New York Air DC-9. Nine air carrier aircraft 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

4/ Air traffic control designation for New York Air.
5/ Chocks are blocks placed by tires to prevent a parked aircraft from moving---also the designation for the area where the aircraft is parked for passenger loading.

airspeed bug settings of 138 kns (V_1) 6/; 140 kns (V_R) 7/ and 144 kns (V_2). 8/ Between 1558:26 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 automobiles 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.

6/ Takeoff decision speed - The speed at which, if an engine failure occurs, the distance to continue the takeoff to a height of 35 feet will not exceed the usable takeoff distance, or the distance to bring the airplane to a full stop will not exceed the acceleration - stop distance available. V_1 must not be greater than the rotation speed, or less than the ground minimum control speed, V_{mcg}.

7/ Rotation speed - The speed at which rotation is initiated during the takeoff to attain climb speed at the 35-foot-height.

8/ Climb speed - The scheduled target speed to be attained at the 35-foot-height.

9/ A device which activates to warn the flightcrew of an impending stall.

At 1603, the duty officer at the airport fire station notified 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 tail 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 fuselage 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.

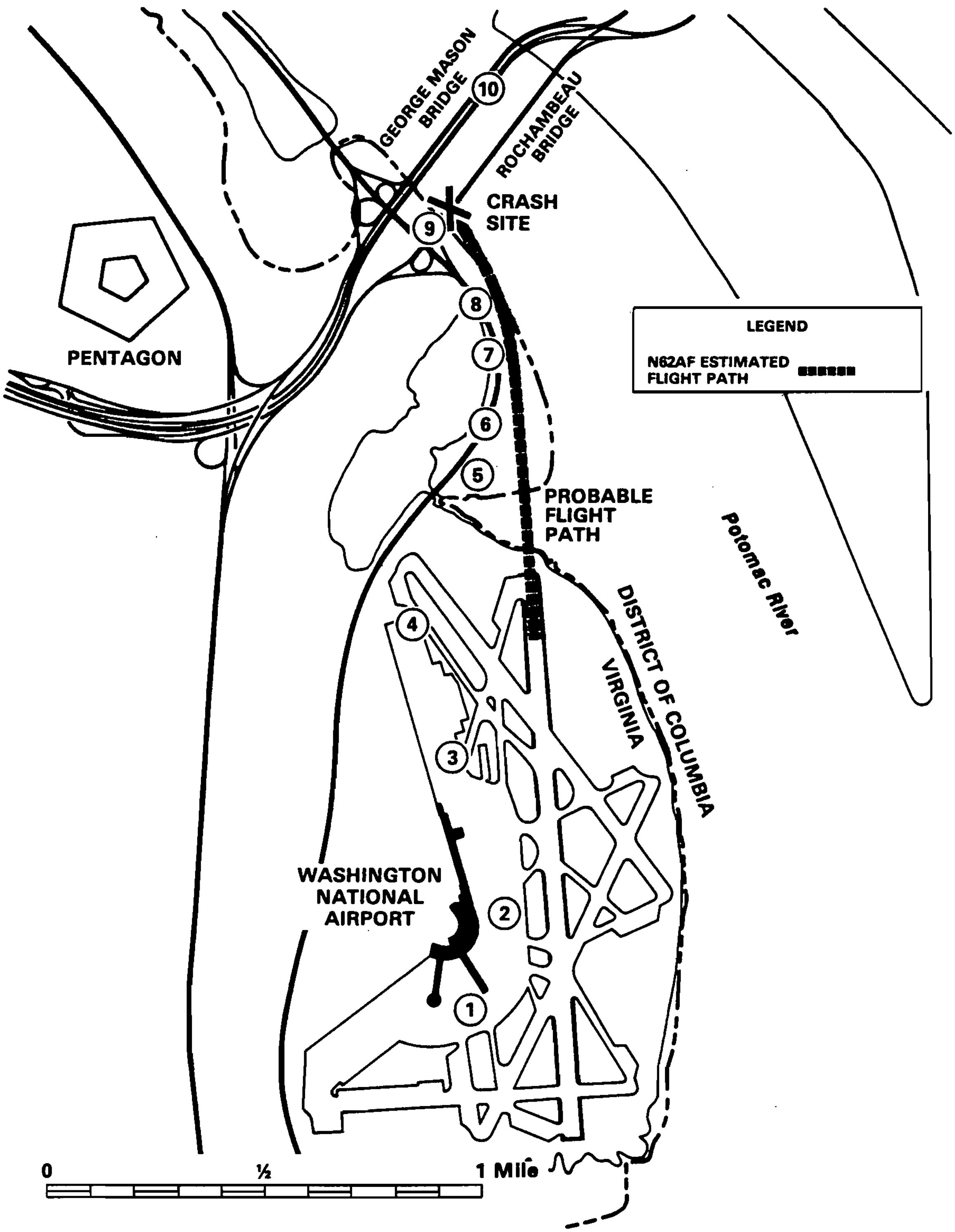


Figure 1.—Flightpath and witness locations.

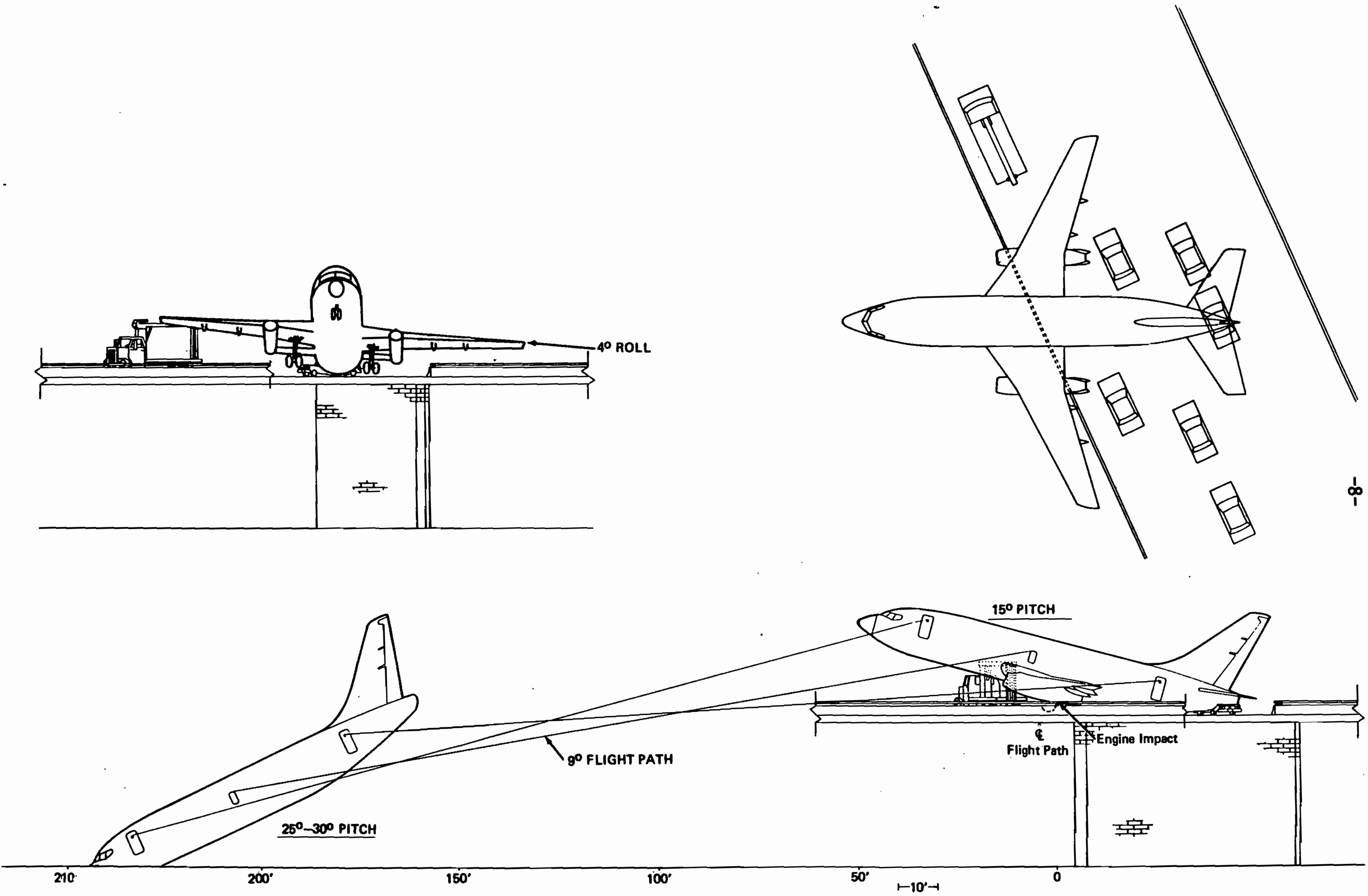


Figure 2. -- Aircraft Impact Attitude.

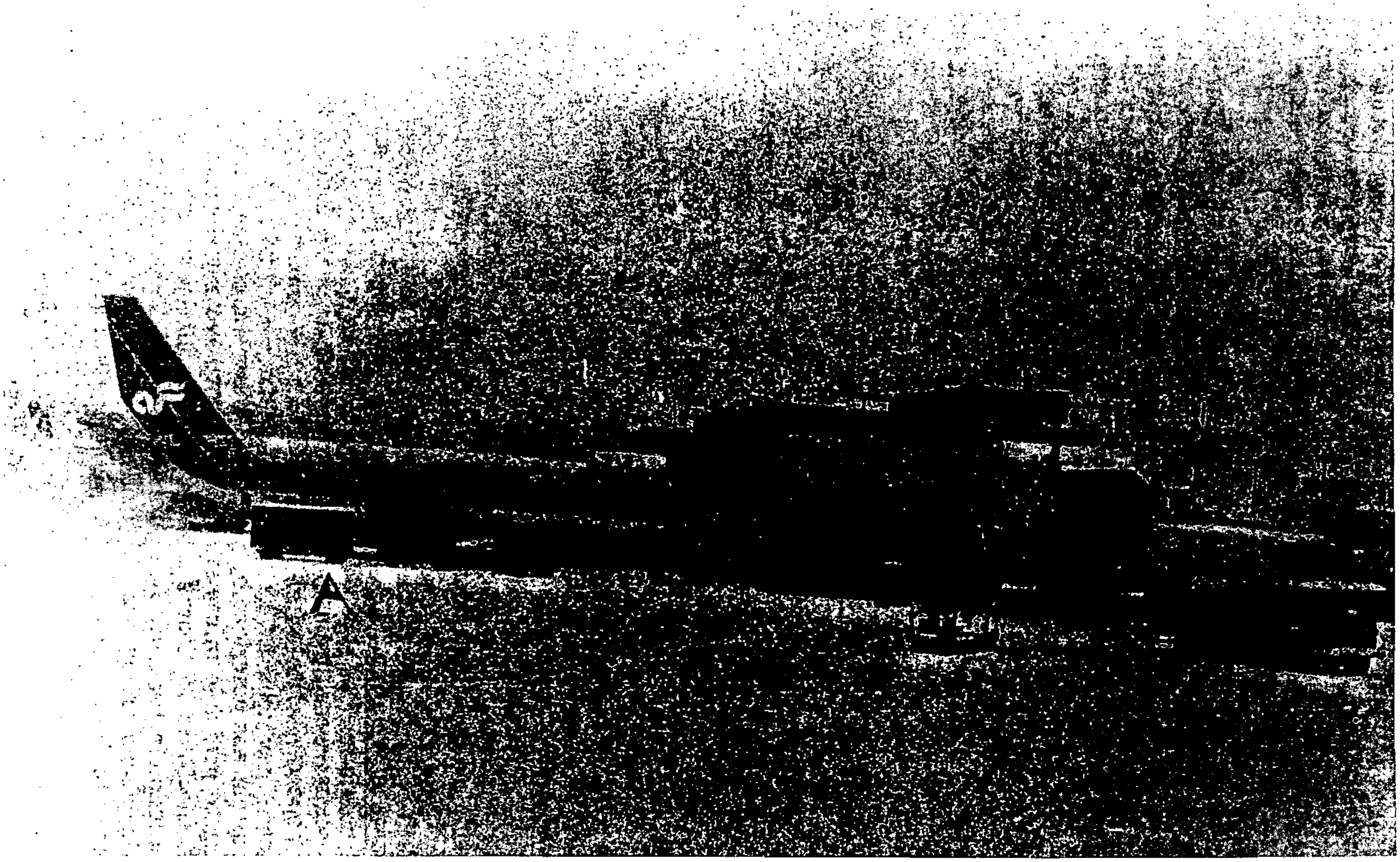


Photo by: Edward J. Kovarik

Figure 3.—Flight 90 between 1519 and 1524.

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 barrier 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 aircraft, 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 packs "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

10/ Standard day temperature for engine performance calculation is 59° F.
11/ Engine pressure ratio is the turbine discharge total pressure (Pt_7) divided by the total pressure at the compressor inlet (Pt_2).

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.

12/ Significant meteorological information.

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 baseline 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 (feet)	RVR Rwy 18 (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 80 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.

13/ Federal Bureau of Investigation File No. 95-247269. (See appendix G.)

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.

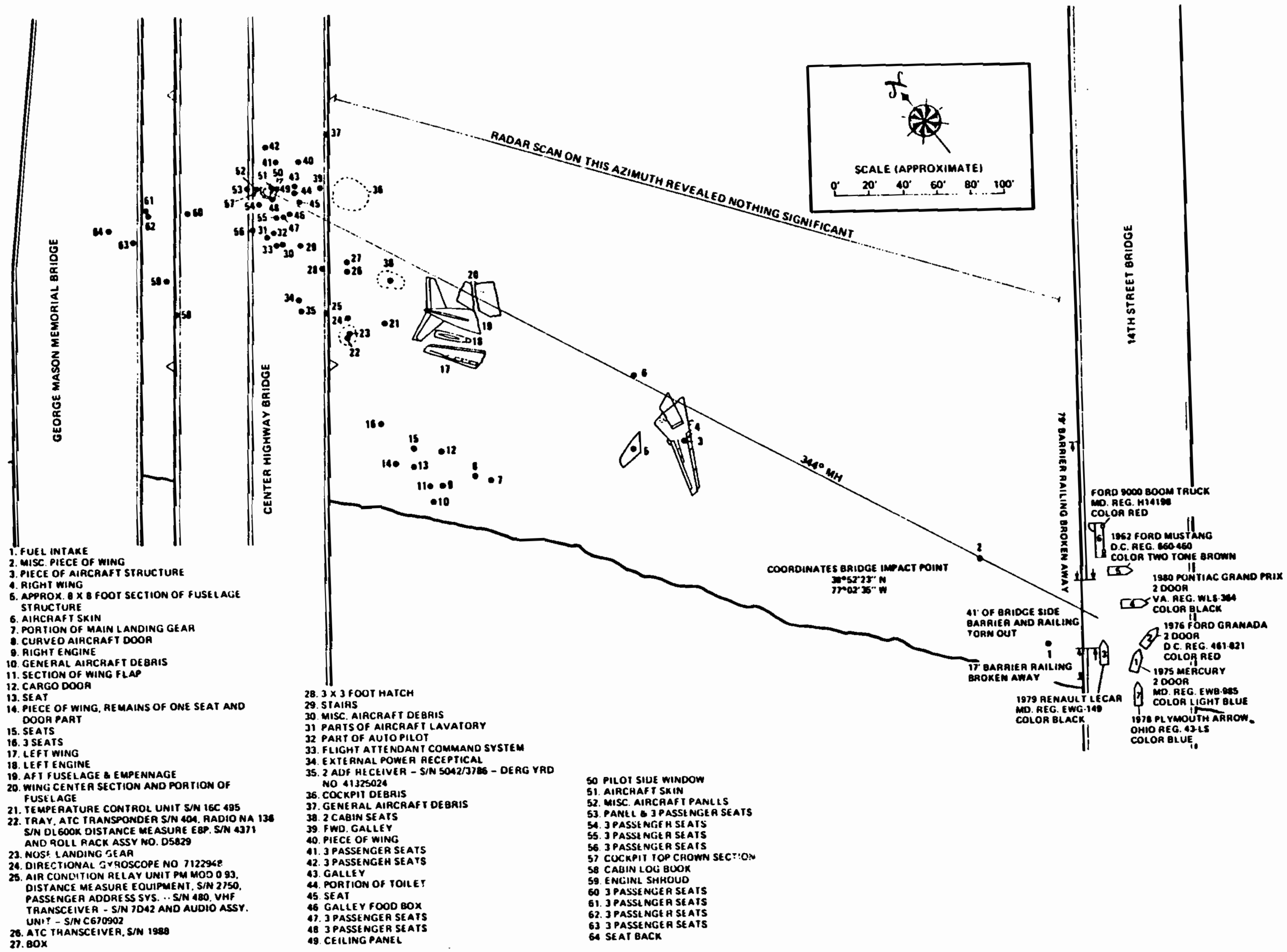


Figure 4. -- Position of Wreckage in the Water.

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 No. 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_1	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 was 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 flightcrew'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 abdomen.

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 of 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 1603 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 Water 14/ 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.

14/ Bioastronautics Data Book, National Aeronautics and Space Administration (NASA) SP-3006, Page 121.

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 traveling 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 crewmember 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 rope 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 out 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.

To 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 times 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 JT8D 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 EPR of 1.70 and the engine developing an EPR of 2.04 is shown in figure 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.

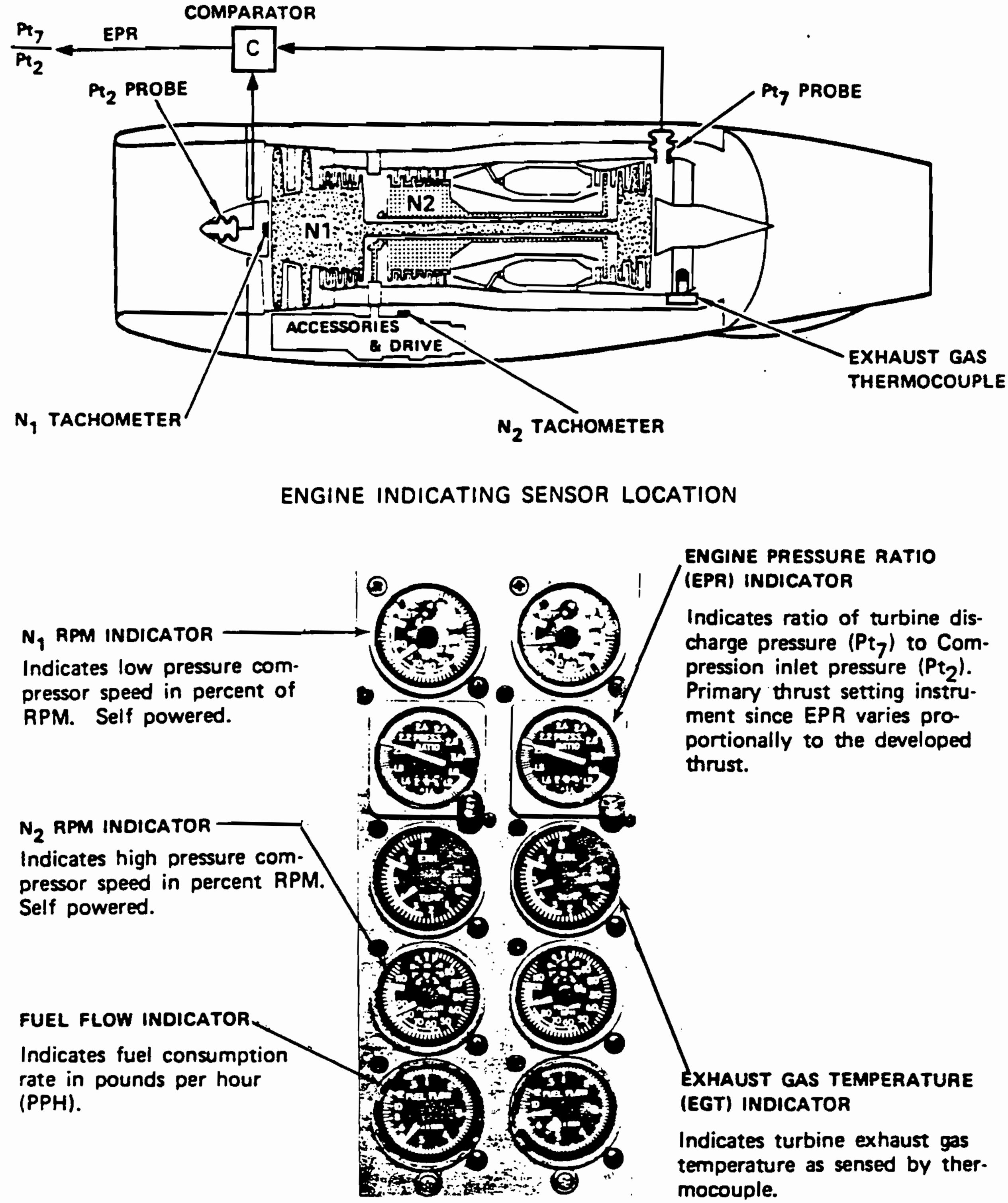
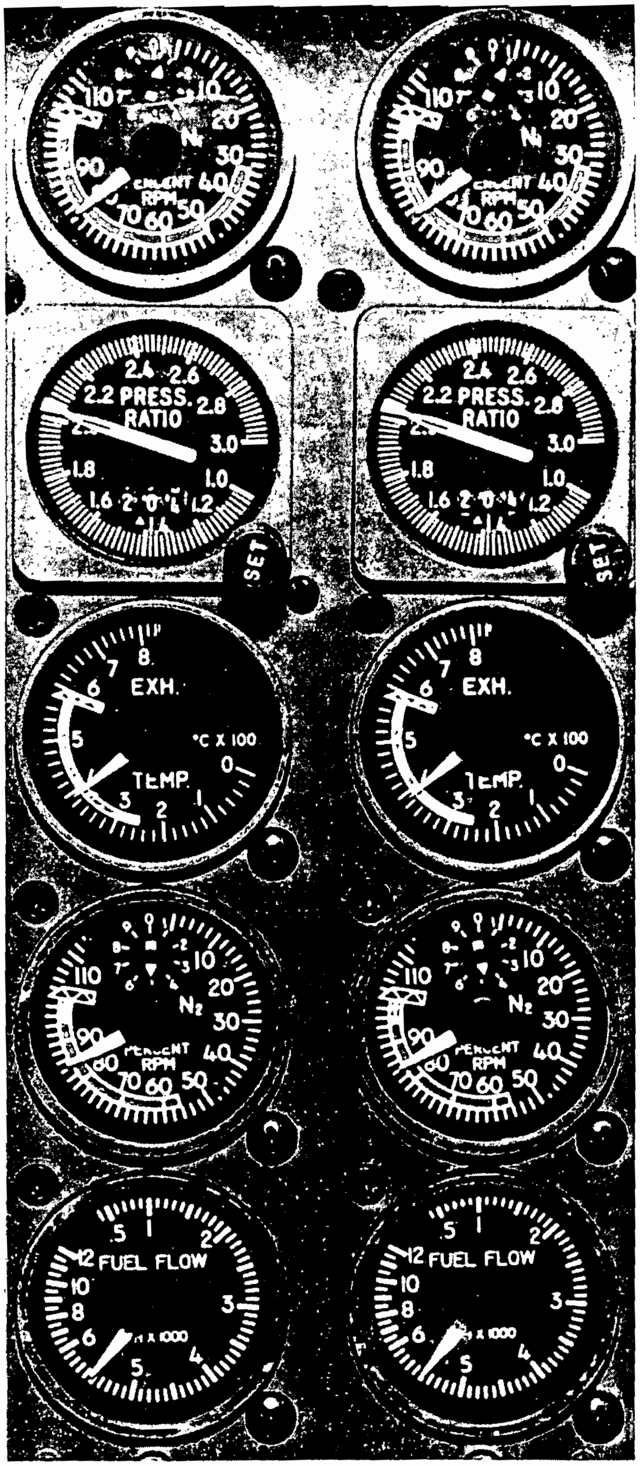
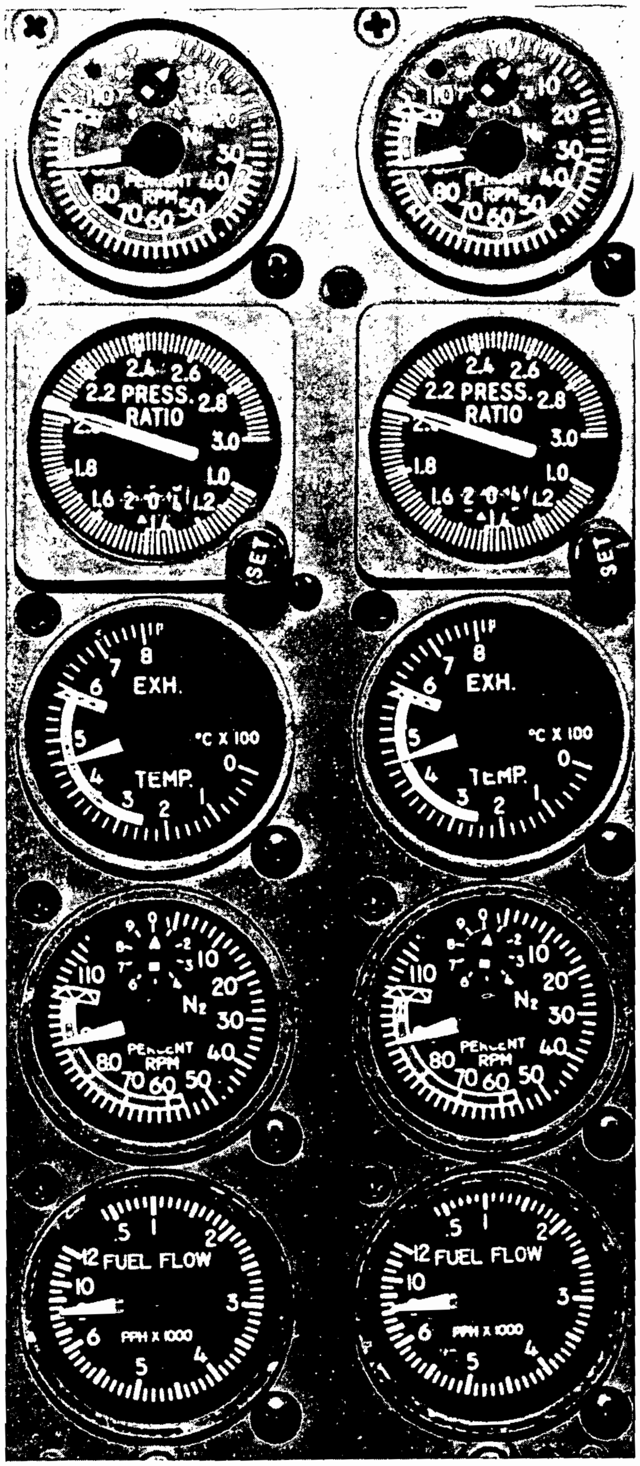


Figure 5. -- Center instrument panel functions.



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 EPR 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 accepted 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 activated 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 mixture, 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 N62AF. 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.

15/ The higher the number of the sandpaper, the finer (smoother) the surface.

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 basket-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 Maintenance 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.

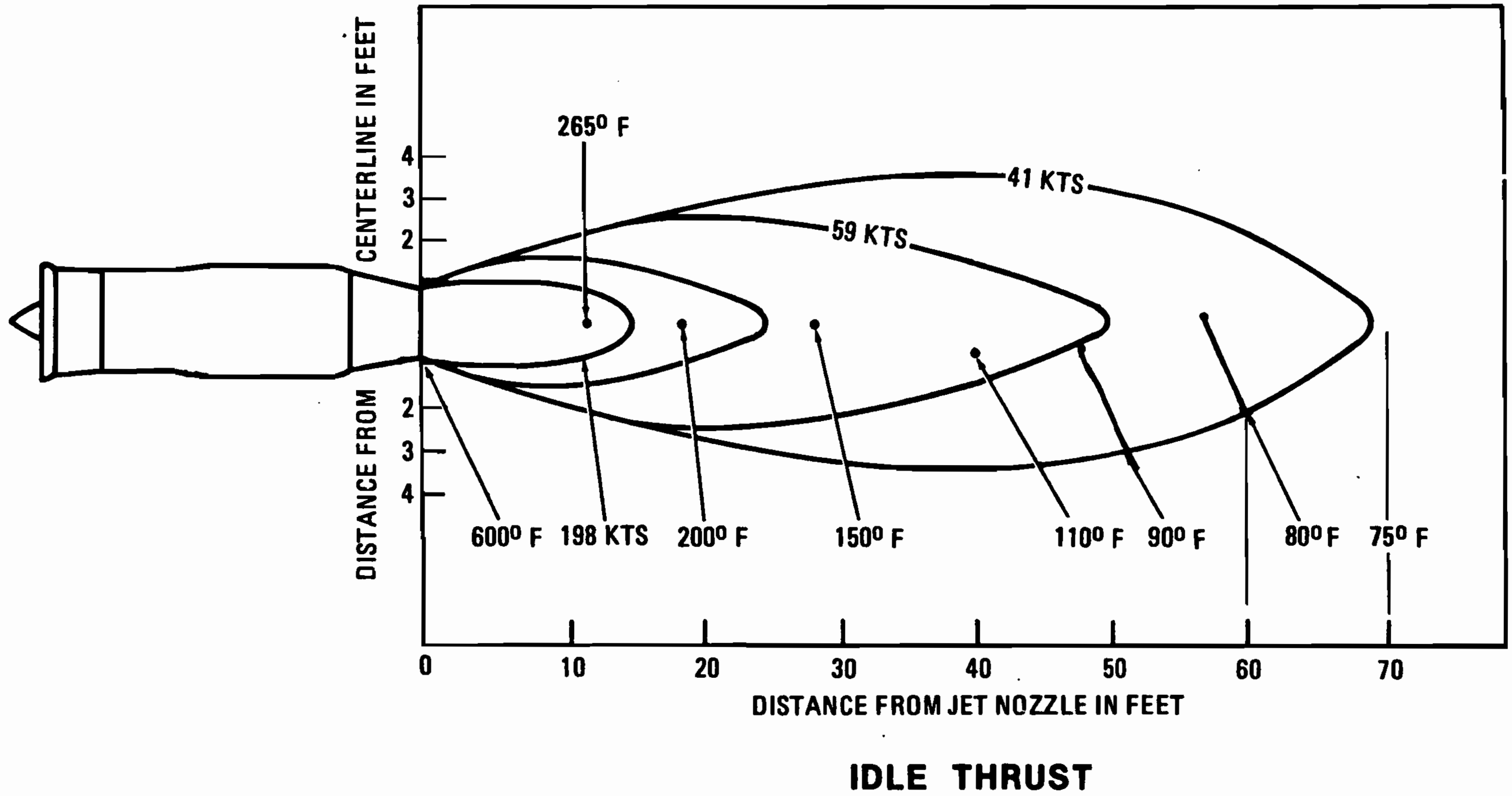


Figure 7.—JT8D turbofan exhaust gas temperatures and velocities.

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 powerplant openings with the appropriate plugs when an airplane is exposed to "heavy snow or ice for even short periods." Air Florida procedures also state that: "<u>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</u>." (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. 74-8. 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 Manual 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 serves 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 simulator is required every 6 months for qualified captains and once a year for qualified first officers. 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 charts. 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 rolling. There is no appreciable ram effect 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. N_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 figures 8 and 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

1.17.11.1 ATC Information to Pilots

The FAA's Air Traffic Control Handbook 7110.65B requires that runway visual range (RVR) or runway visibility value (RVV) be issued for runways in use when the prevailing visibility is 1 mile or less, regardless of the value indicated, or "When RVR/RVV indicates a reportable value regardless of the prevailing visibility" and "to issue mid-rollout RVR when the value of either is less than 2,000 feet and less than the touchdown value."

Neither RVR nor RVV was issued by air traffic control to Flight 90. The RVR was, however, issued to landing aircraft as they were cleared to land.

The Automatic Terminal Information Service (ATIS) is a continuous broadcast of recorded noncontrol information in selected terminal areas. It is intended to improve controller effectiveness and to relieve frequency congestion by automating the repetitive transmission of essential, but routine information, such as weather conditions, runway

TAKEOFF PROCEDURE

CAPTAIN	FIRST OFFICER
Align airplane on runway.	
Advance thrust levers to approximately 1.4 EPR (levers in vertical position).	
Check engine instruments normal.	
Advance thrust levers rapidly to takeoff EPR.	Follow thrust lever advance and adjust takeoff EPR prior to 80 knots if required.
Hold light forward pressure on control column, maintain directional control and monitor thrust levers until V_1 speed.	Monitor engine instruments.
Verify 80 knots.	Call out 80 knots.
Monitor airspeed, noting V1, and rotate smoothly at VR.	Call out "V_1," and "Rotate" at VR. Monitor flight instruments.
When positive rate of climb, call "Gear Up" and accelerate to V_2 + 15.	Position landing gear lever UP.
Cross check airspeed and pitch attitude indications.	

Figure 8.--Normal takeoff procedures.

REJECTED TAKEOFF PROCEDURE

Rejected takeoff is required when engine failure, fire or takeoff warning is recognized before V_1.

Upon recognition of failure or warning either pilot will call out "engine failure," "engine fire" or "takeoff warning."

Rejecting the takeoff solely for the amber Master Caution light, once thrust has been set and takeoff roll has been established, is not recommended.

CAPTAIN	FIRST OFFICER
Simultaneously: Thrust Levers – IDLE Brakes – APPLY MAXIMUM WHEEL BRAKES	
Speed Brake – FULL UP	Check Speed Brake FULL UP.
Apply reverse thrust rapidly as required.	Engine Instruments – MONITOR Advise Captain of any engine limit or abnormality.
Stop airplane and evaluate the problem. If conditions permit, taxi clear of the runway	

Figure 9.--Rejected takeoff procedures.

conditions, temperatures, and altimeter settings. Pilots are expected to monitor ATIS preliminary to departure from or arrival at an airport and to advise ATC of the code of the ATIS message. FAA's Facility Operation and Administration Manual 7110.3F, Section 3, para. 1230, requires that messages be brief and concise, and not exceed 30 seconds unless required for message content completeness, and that each message be identified by a phonetic alphabet letter code word at both the beginning and end of the message. A new recording is to be made upon receipt of any new official weather regardless of whether there is or is not a change of values; a new recording is also to be made when there is a change in any other pertinent data, such as runway change, instrument approach in use, new or canceled NOTAMS/SIGMETS/PIREPS. On the day of the accident, ATIS information was not updated with changes in braking action.

ATIS Alpha was broadcast from 1514 to 1531. Braking action had been reported as fair by multiengine commuter aircraft. Ground control also received braking reports at 1511 as "POOR, ESPECIALLY AT TURNOFF" from a U.S. Air BAC-111 and "FAIR TO POOR" from an Eastern DC-9 aircraft. ATIS Bravo was broadcast from 1532 to 1537 and contained no braking report. Subsequent Bravo broadcasts from 1538-1544 and from 1545-1602 listed braking as POOR as reported by a B-727 aircraft. (According to the requirements of the manual, the second and third Bravo broadcasts should have been Charlie and Delta, respectively.) Flight 90 did not tell clearance delivery or ground control that it was in receipt of ATIS, and clearance delivery or ground control did not ask the crew of Flight 90 if it was in receipt of ATIS.

1.17.11.2 Separation Criteria

Criteria for the separation between departing and arriving aircraft are set forth in the FAA's Air Traffic Control Handbook 7110.65B Section 6, paragraph 743 as follows:

> DEPARTURE AND ARRIVAL
>
> (TERMINAL)
>
> Except as provided in 744, separate a departing aircraft from an arriving aircraft on final approach by a minimum of 2 miles if separation will increase to a minimum of 3 miles (5 miles when 40 miles or more from the antenna) within 1 minute after takeoff.

The FAA Air Traffic Control Handbook requires that the controller determine the position of an aircraft before issuing taxi information or takeoff clearances to it. Such position determination may be made visually by the controller, by pilot reports, or by the use of airport surface detection equipment radar equipment. With regard to Flight 90, because of limited visibility, the local controller could not see the B-737 when he cleared him "into position and hold" and "be ready for an immediate [takeoff]". There is no airport surface detection equipment at the Washington National Control Tower.

Using the ATC tape, FDR readout from Eastern Flight 1451, radar data from Eastern 1451, radar performance data for Flight 90, the Safety Board calculated of the distances between the landing aircraft, Eastern Flight 1451, and Flight 90 and found that there was between 1,500 feet and 4,000 feet. Discrepancies in the FDR on Flight 1451 precluded more precise calculations.

The FAA Air Traffic Control Handbook 7110.65B, paragraph 743, Traffic Training Program Lesson Plan stresses "not TO CLEAR A DEPARTURE FOR TAKEOFF WHEN THE ARRIVAL IS 2 MILES FROM THE RUNWAY, IT'S TOO LATE THEN. NORMALLY, DEPARTURE ACTION MUST BE TAKEN AT 3 MILES TO REALIZE 2 MILE MINIMUM." Additionally, this provision is also contained in the written "Local Control Test No. 1" which was given to Washington National Airport controllers as part of their initial training.

1.17.11.3 Controller Experience

On January 13, 1982, the local control, ground control, clearance delivery, and departure control positions were manned. This staffing represents a full complement, identical to that of July 1981, before the controllers strike. Ground control, clearance delivery, and departure control positions were manned by developmental controllers who had all been checked out in their respective positions.

The local controller handling Flight 90 at the time of the accident was a working controller and was also the team supervisor. He began his career as a military controller in 1959 and had worked at Washington National Airport since 1964. His training records at the time of the accident indicated that he was checked out on all operating positions. His training file indicated that his last "over the shoulder" check was administered and completed satisfactorily on September 9, 1977. The "over the shoulder" training review is required to be administered semiannually. Testimony at the Safety Board's public hearing indicated that he had been given these required checks, but written documentation could not be provided.

1.17.11.4 Gate-Hold Procedures

Washington National Tower did not use gate-hold procedures on the day of the accident. Gate-hold procedures were initially developed as a fuel conservation measure. FAA Air Traffic Control Handbook 7210.3F, Section 3, paragraph 1232, outlines these procedures as follows:

GATE HOLD PROCEDURES

a. The objective of gate hold procedures is to achieve departure delays of 5 minutes or less after engine start and taxi time. Facility chiefs shall ensure that gate hold procedures and departure delay information are made available to all pilots prior to engine start up. Implement gate hold procedures whenever departure delays exceed or are expected to exceed five minutes.

b. Facility chiefs shall meet with airport management and users to develop local gate hold procedures within the guidelines of 1230 and in accordance with limitations imposed by local conditions. Include the following general provisions in the procedures:

(1) Pilots shall contact GC[ground control]/CD [clearance delivery] prior to starting engines to receive start time. The sequence for departure shall be maintained in accordance with initial callup unless modified by flow control restrictions.

(2) Develop notification procedures for aircraft unable to transmit without engine(s) running.

Note.—Inability to contact GC/CD prior to engine start shall not be justification to alter departure sequence.

(3) The operator has the final authority to decide whether to absorb the delay at the gate, have the aircraft towed to another area, or taxi to a delay absorbing area.

(4) GC/CD frequency is to be monitored by the pilot and issued a new proposed engine start time if the delay changes.

The chief of the Washington National Tower stated that because of airport space limitations gate-hold procedures could not be implemented and that Washington Tower Letter to Airmen 79-1, subject: Departure Delay Procedures -Fuel Conservation, was in compliance with subsection b of paragraph 1232. The Washington Tower letter to Airmen 79-1, went into effect November 20, 1979, and expired November 20, 1981; it had not been renewed.

Between 1517:13 and 1547:55, there were a total of 22 communications between ground control and aircraft on the ground at Washington National relative to flightcrew's concerns over departure information. The tower was unable to provide these departing flightcrews with reasonable estimates of anticipated departure delays.

1.17.12 Ground Proximity Warning System

A ground proximity warning system (GPWS) was installed on N62AF. Mode 3 of the 5-mode system indicates altitude loss after takeoff or go-around. The system is armed when the radio altimeter senses 100 feet, and it will sound an alarm when the barometric altitude loss is as little as 15 feet. However, if the aircraft never reaches 100 feet or never has a barometric altitude loss of at least 15 feet, the GPWS will not sense and, therefore, will not give an aural or visual warning. There is no evidence that the GPWS activated at any time during the flight of N62AF.

1.17.13 Human Performance Data

Air Florida pilots stated that their relationship with management is good, and that there is no pressure from management to keep to schedules in disregard of safety or other considerations. Current company statistics show that the upgrading period from first officer to captain averages about 2 years.

There are three series of B-737 aircraft which are flown by Air Florida pilots-- the -100 basic, the -200 basic, and the -200 advanced. The accident aircraft was a -200 basic series B-737. There are some differences among these aircraft. In the -200 basic, there is a difference in the placement of engine instruments, the N_1 and EPR gauges are in reversed positions. (See figure 2.) The N_1 gauges are at the top of the engine instrument panel. Pilots indicated that they had not experienced any transition problems between the different aircraft types.

B-737 pilots told Safety Board investigators that they had not experienced any problems reading or interpreting the instrument displays or reaching or manipulating the controls. The NASA Aviation Safety Reporting System indicated that it had received no incident reports regarding crew station design in the B-737 aircraft.

1.18 New Investigative Techniques

None.

2. ANALYSIS

2.1 Aircraft and Crew

The aircraft was properly certificated, equipped, and maintained in accordance with existing regulations and approved procedures. The flightcrew was properly certificated and qualified in accordance with applicable regulations for the scheduled domestic passenger flight. The flight attendants were also qualified and currently trained in B-737 equipment.

2.2 The Accident

The facts developed during the investigation from witness accounts, surviving passenger accounts, FDR parameters, and CVR conversation provided indisputable evidence that the aircraft's performance was significantly below normal from the beginning of the takeoff roll. The aircraft was observed to accelerate more slowly and lift off farther down the runway than normal B-737 departures. Although the FDR airspeed and altitude parameters showed that the aircraft reached the target liftoff speed and initially achieved a climb, the stall warning stickshaker activated almost immediately after liftoff and the airspeed and rate of climb began to deteriorate.

That weather conditions which had prevailed for several hours before and were prevailing at the time of the attempted departure were a significant factor leading to this accident is beyond question. The weather was characterized by subfreezing temperatures and almost steady moderate to heavy snowfall with obscured visibility. Although the aircraft had been deiced before its departure from the ramp area, a lengthy delay -- about 50 minutes-- was encountered before the initiation of takeoff, and the observations of airport witnesses and surviving passengers as well as the discussion between the pilots recorded by the CVR confirmed that some snow or ice had accumulated on the aircraft before the takeoff.

Therefore, the investigation and analysis of this accident were directed toward the effects of the weather and other environmental factors on aircraft performance; the pretakeoff events including deicing of the aircraft and air traffic control delays; the flightcrew's judgment and performance before and during the flight; and those factors which may have influenced the flightcrew's performance. In addition, the crash response and rescue efforts as well as Washington National Airport facilities and their relation to the crash of Flight 90 were examined.

2.3 Factors Affecting Aircraft Acceleration and Climb Performance

The evidence is conclusive that the aircraft's acceleration during the takeoff roll and its subsequent climb and acceleration were subnormal. A normal B-737 at the weight of the accident aircraft and under the existing environmental conditions should accelerate in about 30 seconds to a liftoff at about 145 kns indicated airspeed (KIAS) using about 3,500 feet of runway. The aircraft should then climb more than 2,000 feet/minute while transitioning to the climb configuration. By contrast, the CVR and FDR showed that the accident aircraft took about 45 seconds and used about 5,400 feet of runway before it lifted off at an airspeed between 140 and 145 kns. The accuracy of the FDR recorded altitude following liftoff is questionable; however, it appears that the aircraft achieved an initial, short-term rate of climb of about 1,200 feet/minute. The stickshaker, indicating an approach to stall angle of attack, activated almost immediately after liftoff. Upon reaching an altitude of between 200 and 300 feet, the airspeed began to decrease and the FDR vertical acceleration parameter and the descriptions provided by surviving passengers showed that the aircraft encountered stall buffet before descending to hit the bridge.

In determining the causes for the subnormal performance of the accident aircraft, the Safety Board considered those obvious performance parameters which affect acceleration and climb -- increased drag, both aerodynamic and rolling, and deficient thrust. While both increased aerodynamic drag, such as that produced by an accumulation of airframe ice, and increased rolling drag, such as that produced by an accumulation of snow or slush on the runway surface, would result in subnormal acceleration, the Safety Board did not believe that these factors alone would account for the performance deficiency evident in this accident. Furthermore, the recorded cockpit conversation between the captain and first officer during takeoff indicated that the first officer was concerned about the appropriateness of some cockpit instrument readings. This suggested possible uncertainty about the engine thrust level. Therefore, the CVR tape was analyzed to correlate the dominant frequencies of the recorded engine noise with engine rotational speed and thrust. This sound spectrum analysis disclosed a significant disparity between the engine (N_1) rotational speed developed during and following the takeoff roll and the rotational speed which would correspond to the target takeoff power setting.

Icing of Engine Pt_2 (Pressure) Probe.--The primary instrument used by B-737 pilots to set and monitor thrust on the Pratt & Whitney JT8D engines is EPR, a direct indication of the ratio of the pressure measured at the engine discharge (Pt_7) to the pressure measured at the compressor inlet (Pt_2). The target value for takeoff is determined for existing conditions before the flight. For the accident flight, the appropriate takeoff EPR setting was determined to be 2.04.

Since the weather conditions at the time of the accident were conducive to the formation of ice on the Pt_2 pressure probe as well as on other parts of the airframe, the Safety Board conducted extensive tests and analyses to determine the effects of an ice-blocked Pt_2 probe on engine EPR indications. The tests confirmed that ice blockage of the Pt_2 probe will affect the EPR reading such that the flightcrew will observe a false indication of takeoff thrust when the throttles are set for takeoff. The tests further showed that the direction of the EPR indication error is dependent upon whether the engine anti-ice system is on or off. With engine anti-ice off, the EPR instrument will indicate higher thrust level than is actually being developed by the engine. The tests and analysis showed that had the flightcrew set the throttles to achieve an EPR indication of 2.04, the actual thrust which would be developed presuming an ice blocked Pt_2 probe would equate to an (unblocked Pt_2 probe) EPR of 1.70. The corresponding engine rotational speed for this reduced thrust level correlated closely with the engine rotational speeds actually developed on the accident aircraft during takeoff, as determined from the CVR sound spectrum analysis.

One function of the engine anti-ice system is to maintain a flow of heated air at the Pt_2 probe to prevent ice formation and blockage. Strong evidence from the accident investigation -- namely the postimpact closed position of the engine anti-ice valves, valves which are electrically motor driven and thus not susceptible to position changes by impact loading -- indicates that the engine anti-ice system was off at the time of impact. The CVR recording substantiated that the engine anti-ice system had not been used during the pretakeoff ground operation.

Therefore, the Safety Board concludes that the engine anti-ice system was not used by the crew of Flight 90; that ice accumulation blocked the inlet of the Pt_2 probe on both engines; that the flightcrew set the throttles to achieve the target EPR indication of

2.04; and that the erroneous EPR indication caused by the blocked Pt_2 probe resulted in a significantly lower thrust level being used than desired.

Following this accident, several examples of similar occurrences were brought to the attention of the Safety Board. In most instances, the flightcrews had rejected the takeoff because they had observed an EPR reading below their takeoff target value as the throttles were moved beyond the normal throttle position. In those cases, the flightcrews had reported that the engine anti-ice systems had been on when setting takeoff thrust. In a few instances, the circumstances were similar to those described in the analysis of the accident. In those, takeoff was rejected because, even though the target EPR was reached, the flightcrew detected that other engine instruments, such as N_1, N_2, EGT, and fuel flow, showed corresponding low indications. In at least one case, the takeoff was continued with a thrust level less than indicated or desired, but sufficient for flight. The flightcrew detected the problem when normal climb rate was not achieved and turned on engine anti-ice. The EPR indication subsequently dropped back to indicate a low thrust condition.

Although the ice blockage of a Pt_2 probe would similarly affect the operation of other types of aircraft having the same engines and EPR indicating systems, the Safety Board notes that nearly all of the reported occurrences have involved B-737 aircraft and that they have occurred with anti-ice both on and off. The Safety Board, therefore, believes that the underwing position of the engines with their resultant proximity to the ground and to the exhaust of other aircraft during ground operations may increase the susceptibility of the B-737 to engine inlet pressure probe icing. Furthermore, there is no assurance that the amount of heat provided by the engine anti-ice system during prolonged ground operation with the engines at low power will prevent ice from forming on the probe.

With the engine anti-ice system off, the circumstances are more dangerous and more insidious when the Pt_2 probe is blocked since the erroneous EPR reading can result in a takeoff or attempted takeoff with deficient thrust. The Safety Board strongly advocates that the proper use of engine anti-ice and that the requirement to crosscheck all engine instrument readings be emphasized in operational procedures and flightcrew training. The Board issued two Safety Recommendations on this subject on January 28, 1982. (Safety Recommendations A-82-6 and 8).

Airframe Ice.--The theoretical performance of a B-737 at the weight of the accident aircraft and for the existing environmental conditions was examined both analytically and in the engineering simulator at The Boeing Co. for the actual thrust levels indicated by the CVR sound spectrum analysis (1.70 EPR). The acceleration and climb performance theoretically achievable by the B-737 were then compared with the best known takeoff roll and flight trajectory information for the accident aircraft to determine whether the subnormal performance could be attributed solely to the reduced takeoff thrust.

The takeoff roll acceleration for the accident aircraft, as indicated by airspeed, time, and distance, correlated closely with performance expected at 1.70 EPR, indicating that increases in aerodynamic drag and rolling drag caused by snow or slush on the runway had little effect on the takeoff roll. However, once airborne, a B-737 with a 1.70 EPR thrust level should achieve a climb rate of more than 1,000 feet/minute in free air at a constant indicated airspeed of 145 kns, or conversely it should be capable of continued acceleration at lower climb rates. Since the accident aircraft was not able to climb and maintain an airspeed margin above the stall, factors other than reduced thrust were affecting its performance.

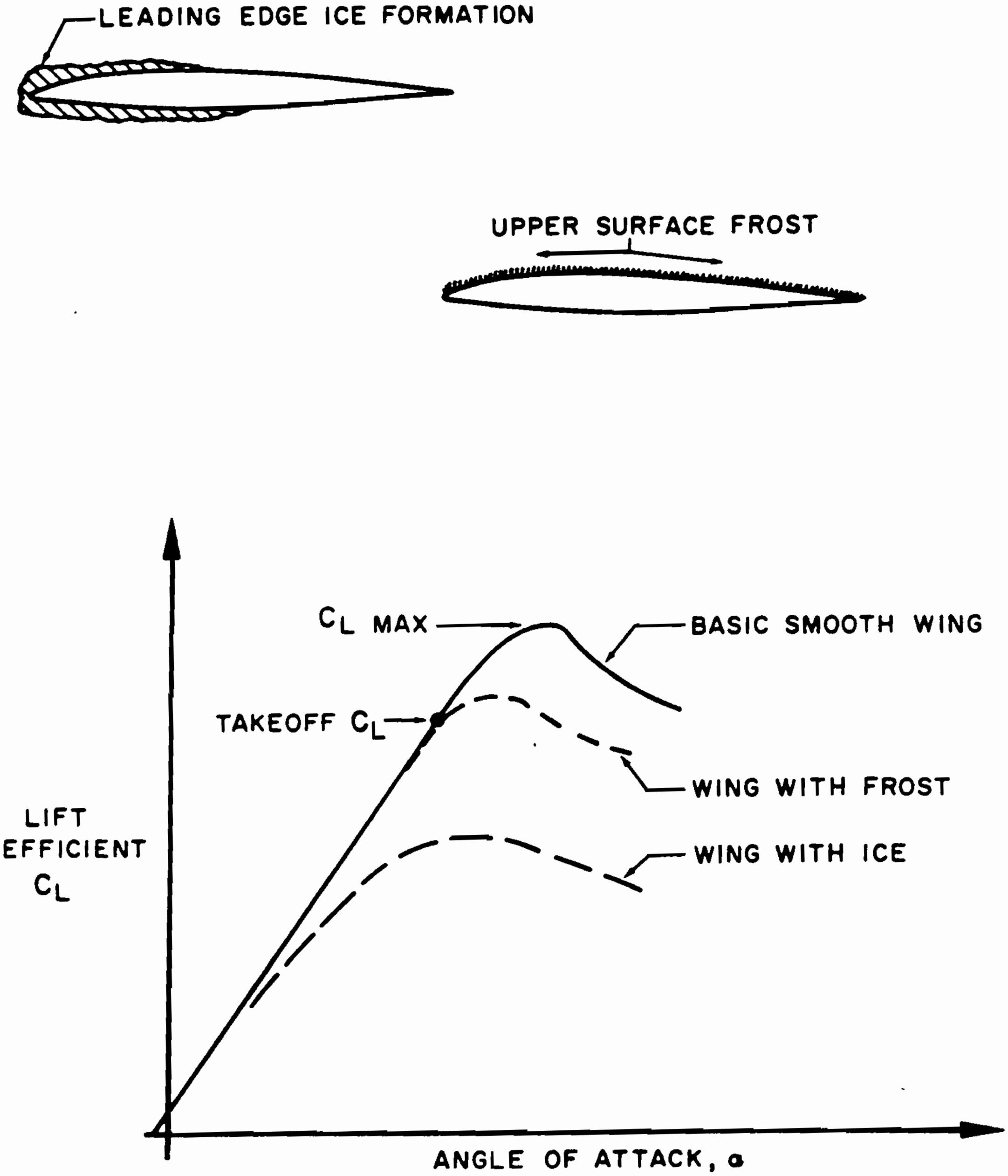
Ground witnesses and surviving passengers stated that they had observed an accumulation of snow or ice on the upper fuselage and wings of the aircraft before and during the takeoff roll. The conversation between pilots as recorded on the CVR also indicated that they were aware that 1/4 to 1/2 inch of snow was present on the wing surfaces. Snow or slush adhering to the surfaces of an aircraft, particularly to the airfoil surfaces, will degrade any aircraft's aerodynamic performance.

The lift which is developed by a wing or any other airfoil depends on the angle of attack -- that is the relative angle of the impinging air to the wing chord line 16/ -- and the speed of the air passing over the wing. The higher the angle of attack and the higher the speed, the greater the amount of lift developed so long as the airflow over the wing is smooth and adheres to its contour surface. When the airflow separates from the surface, the lift produced by the wing diminishes. The airflow starts to separate from any wing when its angle of attack reaches a critical value. As the angle of attack is increased further, it will reach a value at which maximum lift is developed, after which higher angles of attack will produce a rapid decay in lift. The aircraft is stalled when the maximum lift which can be developed by the wing is not sufficient to support the weight of the aircraft. The beginning of the airflow separation from the airfoil surface contour generally causes buffet, such as was described by surviving passengers and evident on the vertical acceleration parameter recorded on the FDR on the accident aircraft.

The most significant effect of even a small amount of snow or ice on the wing surface is the influence on the smooth flow of air over the surface contour. Changes in the contour shape and roughness of the surface will cause the airflow to begin to separate from the wing at a lower angle of attack than normal and cause a reduction in the lift which will normally be developed by a wing at a given angle of attack and a given airspeed. Both the maximum lift which can be developed and the angle of attack at which it will be developed will be reduced significantly. (See figure 10.) Since the total lift developed depends upon both airspeed and angle of attack, an aircraft having snow or ice on the wings will be maintaining a higher-than-normal angle of attack at a given airspeed, or conversely must maintain a higher airspeed at a given angle of attack, in order to produce the lift required to support the aircraft's weight. Stall buffet and stall will be encountered at a higher-than-normal airspeed.

Most air carrier aircraft are equipped with a stickshaker or some other type of alarm to alert the pilot that his aircraft is approaching the stall angle of attack. In the B-737, the stickshaker is activated when a fuselage-mounted vane aligns itself with the airflow and reaches a preset angle of attack which is less than the stall angle of attack. The normal alarm margin is equivalent to about 10 percent of the stall airspeed. Since the stall warning activation is independent of the actual airflow conditions on the wing, the angle of attack at which it will activate is not affected by snow or ice contamination on the wing. However, if the wing's lift-producing efficiency is reduced by such contamination, the aircraft will be maintaining a higher than normal airspeed when flown at the angle of attack at which the stickshaker will activate in order to compensate for the degraded efficiency of the wing. Thus, the stickshaker will activate at a higher-than-normal airspeed. Furthermore, the angle of attack margin, and thus the airspeed margin, between stall warning, stall buffet, and stall will be reduced significantly or negated entirely.

16/ A straight line connecting the leading and trailing edges of the airfoil.



Where total lift developed by wing equals $(L) = C_L \frac{1}{2} \rho V^2 S$

C_L = Lift coefficient for airfoil section

ρ = Density of air

V = True airspeed

S = Wing area

Figure 10.--Effect of Ice and Frost on Aircraft Performance. (From Aerodynamics for Naval Aviators (NAVWEPS 00-80T-80).

At the weight of the accident aircraft, the B-737 stickshaker would theoretically activate at an indicated airspeed of about 133 kns. Initial buffet would be encountered as the airspeed decreases to about 130 kns and the aircraft would stall about 121 kns. The CVR disclosed that the stickshaker on Flight 90 activated almost immediately after liftoff and remained activated until impact. The FDR showed that the indicated airspeed after liftoff was about 145 kns, about 12 kns above the normal stickshaker-activation speed. During the approximate 24 seconds of flight, the indicated airspeed varied between 145 kns and 131 kns. A distance integration showed that the indicated airspeed averaged about 137 kns during the period. The FDR vertical acceleration parameter was consistent with the testimony of surviving passengers that the aircraft was encountering buffet during much of the period.

Therefore, the Safety Board concludes that the activation of the aircraft's stickshaker and the onset of stall buffet at airspeeds significantly higher than the airspeeds at which those events would theoretically occur are positive evidence that snow or ice was adhering to the airplane and degrading its aerodynamic performance.

Aside from altering the lift-producing properties of the wing surfaces, the most significant detrimental effect of snow or ice contamination on performance is the increase in the aircraft's total drag, that is, the force which resists the aircraft's forward motion through the air. The total drag has two components, induced drag and parasite drags both of which vary with the aircraft's speed. Induced drag is that drag which is produced by the generation of lift. It is proportional to lift and the proportion increases as angle of attack increases. Therefore, since a contaminated wing must fly at a higher angle of attack at a given airspeed to produce the required lift, the induced drag generated at that airspeed will be higher than the induced drag of an uncontaminated wing. Parasite drag, is that force produced by the frontal area of the aircraft as it pushes the air aside and the friction created as the air moves over the aircraft surface. Although the parasite drag component is most significant at high speed, there can be a considerable increase in parasite drag at any speed if an aircraft is contaminated with snow. The aircraft's frontal area is increased by the increased angle of attack required and by the additional area of the contaminant itself. The friction created will increase because of the roughness of the contaminated surface. Therefore, the total drag of an aircraft will be greater at any given airspeed when snow or ice adheres to its surface.

The total effects of snow or ice contamination on lift efficiency and drag increase are further compounded by the added increment of weight of the contaminant. While the lift-producing capability of the wing is diminished, the lift required is greater because of the added weight, and since drag is a function of lift, it, too, is increased.

Aircraft Capability to Climb or Accelerate After Liftoff.--The increased drag of the aircraft caused by the snow contamination was a major factor in this accident, particularly when combined with the lower-than-normal takeoff thrust brought about by the erroneous EPR indication. In order to maintain stabilized, level and unaccelerated flight, the aircraft's lift must equal its weight and the thrust produced by the engines must be equal to the drag. To climb at a steady airspeed, to accelerate to a faster airspeed in level flight, or to achieve any combination of climb and acceleration, thrust must be greater than drag.

The analysis of the performance aspects of Flight 90 must consider the way in which the aircraft's drag varies with airspeed. Since induced drag increases with higher angles of attack, or lower airspeeds, and since parasite drag increases with increasing airspeed, there is some optimum airspeed at which the total of the two components is at a minimum. At this airspeed, the aircraft will achieve the maximum climb rate that can be achieved for a given thrust level provided that thrust level is greater than the minimum drag. If the aircraft is at a faster airspeed, at the same thrust level, its climb rate can be increased by slowing. However, if the aircraft is at a slower airspeed than that at which minimum drag is developed, slowing the aircraft will result in reduced climb capability. If the airspeed is reduced to a point at which the increased drag equals the thrust being developed, the aircraft cannot sustain a climb and it must descend in order to accelerate unless more thrust can be and is added. If thrust cannot be added, any attempt by the pilot to climb will result in a further increase in drag and any subsequent attempt to even maintain level flight would be unsuccessful and would lead to an aerodynamic stall.

The analysis of Flight 90 must also consider the effect of flight near the ground on aerodynamic drag. When an aircraft is flown near the ground, such as during takeoffs and landings, the lift efficiency of the wing will be increased, with a consequent reduction in the induced drag component for a given airspeed. As height above the ground increases, this effect diminishes rapidly, losing significance when the height above the ground is equal to the aircraft's wingspan, about 100 feet for the B-737. This ground effect explains why an aircraft which has adequate performance at a given thrust to become airborne will rapidly lose its performance margin as it gains altitude.

Effects of Wing Leading Edge Contamination on Aircraft Longitudinal Trim.--While snow, slush, or ice contamination on any part of the aircraft's wing surface will be detrimental to its aerodynamic performance, the extent and way that performance will be affected depends on the position of the contaminant on the wing as well as the nature of the contaminant. Generally, contamination of the forward leading edge of the wing will be the most degrading to the lift-producing efficiency of the wing. Furthermore, it is unlikely that the contaminant will be uniformly distributed or have a uniform effect along the aircraft's entire wing span so that the lift-producing efficiency of some spanwise parts of the wing will be more affected than others.

The B-737, like other modern jet transports, has a swept wing. The distribution of lift along the entire wing span of a swept wing is important to the longitudinal balance of the aircraft. That is, if all of the lift developed along the entire wing were to be represented by a single vertical force, the fore and aft location of that force along the aircraft's longitudinal axis (known as the center of lift), when combined with the location of the aircraft's center of gravity and the aerodynamic force developed by the aircraft's tail surfaces, determines whether the aircraft is balanced longitudinally or whether it will pitch noseup or nosedown. If the outboard portion of the wings of a swept wing aircraft contains more snow or ice than the inboard sections or if they are more influenced by contamination, the lift distribution along the wing span will change such that the inboard part of the wings, which are farther forward, will produce a proportionately greater amount of the total lift. Thus, the center of lift will be farther forward along the aircraft's longitudinal axis than if there were no wing contamination.

An aircraft is normally "trimmed" for takeoff by setting tail control surface trim so that the aerodynamic load on the tail balances the wing lift and the weight acting at the center of gravity to minimize the control forces and pitching moments during liftoff and climb. This preset trim is computed on the basis of the calculated weight and center of gravity of the aircraft, assuming the theoretical lift distribution of the wing. If snow or ice are present outboard on the wing, the lift distribution along the wing span will be changed so that the aircraft will be out of trim during takeoff. As it approaches takeoff airspeed and during initial rotation, the forward movement of the center of lift will cause the aircraft to pitch noseup. If the flightcrew failed to, or was unable to, counter the pitchup moment of the aircraft with sufficient forward control column force, the aircraft could become airborne at an excessively high pitch attitude. The aircraft would not accelerate and it would retain a high angle of attack and high drag.

Although any swept wing aircraft is vulnerable to such flight characteristics if takeoff is attempted with the outboard portions of the wings contaminated with snow or ice, the B-737 appears to be particularly susceptible as indicated by several occurrences reported by operators who have experienced severe pitchup or rolloff just after takeoff. Abnormal control force and the use of nosedown stabilizer trim were required to effect recovery. The majority of these incidents involved takeoff conditions where the air temperatures were near freezing and snow, sleet, or rain had been falling during the pretakeoff ground operations.

Analysis of These Factors As They Affected Flight 90.--The Safety Board believes that the flightpath of Flight 90 exemplified the combined effects of a thrust level which was less than intended or normal for takeoff and the presence of snow or ice on the fuselage and wings of the aircraft. The longer-than-normal takeoff roll was attributable primarily to the lower thrust level although increased aerodynamic and rolling drag may have impeded slightly the aircraft's acceleration.

The aircraft did reach a normal takeoff airspeed and both theoretical analysis and engineering simulations showed that it should have been capable of liftoff, continued acceleration, and climb, albeit at a less-than-normal rate, even with the low thrust. The aircraft failed to perform as theoretically expected after liftoff because of the reduced aerodynamic efficiency and the resultant high drag produced by the snow or ice contamination. The engineering simulation showed that high drag combined with the low thrust made continued flight marginal. The simulation further verified that the aircraft's performance after liftoff was highly dependent upon initial rotation and the pitch attitude at liftoff.

The Safety Board interprets the captain's comment, "Easy," closely following the "Vee one" callout as a typical reaction to an abnormally abrupt or nose-high rotation. Based upon the experiences reported by other B-737 operators under similar environmental conditions, the Safety Board concludes that the airframe snow or ice contamination produced a noseup pitching moment during rotation and liftoff which was not or could not be immediately countered by the pilot controlling the aircraft and which aggravated the subsequent deterioration of the performance of the aircraft.

The sustained activation of the stall warning stickshaker 3 seconds after liftoff showed conclusively that the aircraft failed to accelerate to the airspeed at which minimum drag would be produced. A B-737 uncontaminated by snow or ice at the accident aircraft's weight would have minimum drag, and thus would be capable of maximum climb at about 155 KIAS; the minimum drag airspeed for an aircraft with contaminated wing would likely be significantly higher.

The rate of climb achieved by the accident aircraft immediately after liftoff can be attributed to the enhanced aerodynamic efficiency provided in ground effect and the tradeoff of airspeed for climb rate. The engineering simulation of the flight, which took into account degraded performance produced by wing contamination, verified that the initial rate of climb probably exceeded 1,000 feet per minute. This rate of climb, along with the stickshaker warning, most likely prompted the captain's directions, "Forward, forward," "Easy," and "We only want five hundred." The Safety Board believes that the captain was referring to a desired rate of climb of 500 feet per minute. As ground effect diminished, so did the aircraft's performance margin. The peak altitude reached could not be precisely determined from the FDR altitude data. These data appeared to oscillate probably because of the altitude stylus' sensitivity to vibration as the aircraft experienced buffet loads and the minuscule total movement of the stylus over the small range of altitude achieved.

The aircraft's GPWS should have armed as the aircraft climbed through 100 feet above ground level and should have activated if the aircraft began to descend before reaching 700 feet. The GPWS logic altitude signals are provided by the aircraft's radio altimeter. The absence of the GPWS alarm on Flight 90 prompted the speculation early in the investigation that the aircraft never reached more than 100 feet above the ground. However, the flights conducted in the engineering simulation indicated that the aircraft most probably reached a peak altitude between 200 and 300 feet. The Safety Board believes it is possible that the GPWS takeoff descent mode may have dearmed prematurely because of the sensitivity of the radio altimeter signal to excessively high pitch attitude and attenuated signals reflected from the frozen river surface.

The aircraft's airspeed began to decay during the climb and the drag produced at the increasing angle of attack soon exceeded the thrust being developed by the engines. At this point, the aircraft theoretically might have been recoverable with the combined corrective actions of full thrust and nosedown pitch control. However, the engineering simulation indicated in actual practice that recovery within the altitude and time available was not likely. Also, the aircraft's pitch control authority may not have been sufficient to counter the noseup pitching moment produced as the contaminated outboard portions of the wing neared full stall. Upon recognizing that the aircraft was not recovering, the flightcrew added thrust as they attempted to counter altitude loss. However, by that time the aircraft was nearing a full aerodynamic stall. Witnesses confirmed that the aircraft was at an extreme noseup pitch attitude as it descended steeply to hit the bridge.

The Safety Board concludes that neither the low thrust used during the takeoff nor the presence of snow or ice on the aircraft, alone, would likely have led to the crash. In most other reported incidents in which B-737's have pitched up during takeoff, the flightcrews had sufficient control authority with forward control column force and stabilizer trim to overcome the pitching moment, reduce the pitch attitude, accelerate to a lower angle of attack, and climb out successfully. The Safety Board believes that if the proper thrust level (that for 2.04 EPR) had been used for the takeoff this flightcrew could have recovered from any difficulties caused by the contamination - induced aerodynamic performance penalties.

Furthermore, based upon the engineering simulation, the Safety Board concludes that even with the low thrust during the takeoff roll and the aerodynamic penalty of the snow or ice contamination, the accident was not inevitable as the aircraft lifted off. However, both immediate recognition of the situation and positive effective actions by the flightcrew to both counter the noseup pitching moment and add thrust were required. With these actions, the aircraft should have been capable of continued acceleration and achieved a sufficient performance margin for climbout.

The Safety Board's belief that the aerodynamic performance penalty imposed by the snow or ice contamination alone may not have led to this accident does not, under any circumstances, imply that the Board condones flight operations with a contaminated aircraft or that such contamination cannot cause catastrophic accidents. Indeed, the Board's aircraft accident records clearly illustrate that aircraft have crashed solely as a result of attempted flight with contaminated wings.

2.4 Analysis of Events Preceding Takeoff

The operation of aircraft in freezing temperatures and continuing precipitation poses major problems to airline maintenance and dispatch personnel, airport operators, and air traffic controllers, in addition to the flightcrews themselves. Safety considerations dictate, and the Federal Aviation Regulations require, that the surface of the aircraft be free of frost, snow, or ice before takeoff. Obviously, it is difficult to comply with this requirement under some circumstances. Even if all accumulations of contaminant are removed before the aircraft is released for flight, when delays are encountered before the aircraft can actually takeoff, the risk of additional contamination exists. Consequently, the final assessment of the aircraft's condition immediately before takeoff is the sole responsibility of the pilot-in-command, the captain.

Deicing Operations.--Until the mid-1950's, the common methods used to clean the frost, snow, or ice from an aircraft were strictly mechanical; ice was scraped from the surface and snow was swept from the wings and fuselage much as one might remove such contamination from an automobile. As aircraft became larger, the smoothness of their aerodynamic surfaces became more critical and the dependence upon mechanical techniques of deicing became impractical. Consequently, by the early 1960's commercial airlines had accepted the use of deicing solutions which could be applied to the aircraft's surfaces more easily and quickly to remove snow or ice contamination. Initially, the deicing solutions were a composition of ethylene glycol, propylene glycol, and water (about 10 percent). The fluids were applied without being heated using an agricultural-type spray apparatus. While this procedure effectively melted frost or ice, time was required for the glycol to react with the frozen contaminant, and some mechanical effort or pressure application was necessary to remove the softened snow or melting ice. Through the years, the application of deicing solutions has been refined and special equipment has been developed to deliver large volumes of fluid under sufficient pressure to remove the snow or ice. Equipment design refinements have resulted in deicing equipment which allows the operator to mix water and deicing solutions and thus control the concentration to suit the environmental conditions.

Using this equipment, which delivers to the aircraft surfaces a high volume of hot liquid under pressure, heat melts the contaminant and pressure removes it. The liquid may be water alone or a mixture of water and deicing solution. Generally, if conditions are conducive to refreezing of any residual moisture which could present control difficulties, deicing solution manufacturers recommend that aircraft surfaces be sprayed with a high concentration of deicing solution after the contaminant is removed. Since any residual high concentrate deicing solution remaining on the surfaces can provide some protection against refreezing of continuing precipitation, the concept of deicing/anti-icing has become common.

The Safety Board has stated its concerns about the effectiveness of deicing solutions to provide anti-icing protection. While some protection may be afforded, there has been little or no research to define the level of protection in terms of the environmental conditions and the length of exposure to these conditions. Both the producers of deicing solutions and the manufacturers of the application equipment recognize the uncertainties regarding anti-icing protection and do not attempt to define or speculate on the level of protection or to provide guidance to maintenance personnel and pilots.

The Board recognizes the complexity of the variables involved in the anti-icing concept. The thickness and concentration of the protective film remaining on the aircraft following the deicing operation depend on the amount of glycol in the mixture, the amount applied to the aircraft surface, the pressure of the application and temperature at which it was applied, the design or runoff properties of the aircraft surfaces, and the ambient temperature and dewpoint. Even if the thickness and properties of the film remaining on the aircraft immediately after deicing are predictable or known, its effectiveness to prevent ice or snow accretion will depend on the rate and type of precipitation. The water content of the precipitation will further dilute the deicer film, raising its freezing temperature. If the aircraft is exposed to precipitation long enough, the freezing temperature of the diluted surface film will reach the ambient temperature and the film will freeze either before or after takeoff, degrading aircraft performance. If exposed to certain kinds of precipitation for sufficient time, the film remaining on the aerodynamic surfaces after a heavy overspray of highly concentrated deicer solution might result in the formation and accumulation of a thicker layer of contamination than would result if a lesser concentration or no solution had been applied. This is particularly true if the surface ambient air is subfreezing, not saturated, and the precipitation is frozen--such as powdery snow. In fact, under these environmental conditions, a cold, dry surface to which frozen precipitation will not stick would be optimum and, though not practical, removal by sweeping would likely provide the best anti-icing protection.

In its review of technical literature regarding recommended deicing/anti-icing practices, the Safety Board found that the practices are not uniform. The anti-icing recommendations published by Union Carbide state unequivocally that its deicing fluid is most efficient in its concentrated form to protect ice-free aircraft from new icing. Recommendations for use further emphasize that this allows fluid retention on the aircraft surface, prolonging icing protection and that diluted deicing fluid is not to be used for anti-icing treatment of ice-free aircraft. These recommendations differ from those contained in the manual prepared by Trump. The Trump manual specifies dilution of the deicing solution to 65 percent deicer/35 percent water. The American Airlines Manual specifies an even more diluted solution (25 percent deicer/75 percent water) for ambient temperatures of 20° to 25° F. For temperatures below 20° F, a mixture of 40 percent deicer/60 percent water is specified. The Air Florida manual contained no instructions regarding deicing solutions.

The Safety Board believes that in view of the differences in data published within the industry, a comprehensive research program is needed to establish the optimum procedures for deicing with ethylene glycol solutions and to determine the anti-icing protection, if any, they provide. Once optimum procedures are developed, they should be made standard throughout the industry. As a result of previous accidents, on November 14, 1980, the Safety Board addressed Safety Recommendation A-80-113 to the FAA. The Safety Board recommended that "the FAA initiate a study of the effectiveness of ethylene glycol-based deicing fluid concentrations as an anti-icing agent under differing icing and snow conditions." The FAA responded that such a study was begun in February 1981 in response to the Safety Board's recommendation. However, testimony at the Safety Board's public hearing following this accident disclosed that the initial effort had received limited support within the FAA and that resources devoted to the effort were inadequate. Since the hearing, the FAA has informed the Safety Board that limited testing is being planned to verify analytical and empirical estimates of ice/snow formations under various atmospheric conditions combined with different deicing mixtures, and to verify analytical techniques for estimating fluid film thickness as a function of selected variables.

The Safety Board is concerned that pilots may erroneously believe that there is a positive protection provided for a period following the application of deicing/anti-icing solution which eliminates the need to closely monitor the aircraft for contaminants during ground and takeoff operations. The Safety Board concludes that the only way to assure that the deicing process has been effective and that the aircraft is clean of adhering ice, snow, or frost is by observation by the flightcrew just before the takeoff roll.

Deicing of Flight 90.—Flight 90 was deiced by American Airlines maintenance personnel in accordance with Air Florida's existing service agreement with American Airlines. The investigation disclosed that there had been little communication between Air Florida and American Airlines about procedures to be used to deice the B-737 aircraft. The Air Florida Maintenance Manual includes little information regarding deicing, but it specifically states that covers for pitot/static ports and plugs for engine inlets must be in place when deicing fluid is applied. American Airlines, however, did not comply with this requirement nor did the evidence indicate that the personnel actually involved in the deicing operation were aware of the Air Florida requirement. While the Safety Board does not believe that the installation of these devices would have affected subsequent events, the Board concludes that there should have been more complete discussions between Air Florida and American regarding procedures to be applied during B-737 maintenance so that respective responsibilities were fully understood. This is particularly applicable since American did not operate B-737 aircraft.

After analyzing the service agreement and interviewing the principals from both Air Florida and American Airlines, the Safety Board has determined that more specific responsibilities should have been defined for the the Air Florida Washington maintenance representative with respect to deicing Flight 90. Testimony indicated that his duties were nonspecific and his orientation training upon assignment to this position was limited. This situation illustrates a need for more FAA attention to contract maintenance operations.

Notwithstanding the existence of a maintenance agreement and irrespective of the maintenance representative's role, the Board concludes that the Air Florida dispatch responsibility at Washington National Airport is delegated to the captain. Therefore, although he probably relies on the assigned maintenance representative for ensuring that necessary maintenance is conducted properly, it is the captain's responsibility to ascertain that the aircraft is properly prepared for dispatch, including assuring that his aircraft is free of snow, frost, or ice before taxiing for takeoff.

The deicing operation on Flight 90 was begun about 1420, but was discontinued after completing only a portion of the left side when the captain determined that the airport would be closed and there would be a longer gate delay. The aircraft was observed to have about 1/2 inch of wet snow adhering to its surfaces at that time. Deicing resumed between 1445 and 1450. Trump Vehicle No. 5058 which was used to apply the deicing solution mixes water and deicing solution stored in separate holding tanks, heats the mixture, and delivers it to the aircraft under pressure at an adjustable flow rate. The left side of the aircraft was deiced first; the operator selected a mixture of 30 to 40 percent deicer and 60 to 70 percent water with a flow rate of 30 gallons per minute. The setting was used both to remove the contaminant and to provide the final overspray in a single operation. This operator was relieved by another who started and completed the deicing of the right side of the aircraft. The right side was deiced with 100 percent water and the final overspray was applied with a 20 to 30 percent deicer to water solution selected. The deicing operation was completed at about 1510.

Subsequent tests of deicing fluid/water solution taken from the Trump vehicle showed that the mixture dispensed differed substantially from the mixture selected. The percent of deicing fluid in solution was about 18 percent rather than 30 percent.

The Safety Board determined that the inaccurate mixture was attributed to a replacement nozzle on the delivery hose. The standard Trump nozzle, which is specially modified and calibrated, had been replaced with a nonmodified, commercially available nozzle. The Safety Board believes that such actions indicate that operators and maintenance personnel may fail to appreciate that properly maintained ground support equipment may be critical to flight operations, and that insufficient attention is given to this aspect of maintenance by both the carrier and FAA surveillance personnel.

A device called a mix monitor was available as an option from Trump, Inc., and is standard equipment on later Trump deicing vehicles. The device monitors the accuracy of the flow and proportioning valve assemblies and provides the operator with a visual reading of the actual solution/mixture coming out of the nozzle. Without the mix monitor, the operator has no means by which to determine if the flow and proportioning valves are operating satisfactory. A mix monitor was not installed on Trump Vehicle No. 5058.

While the diluted mixture delivered from the Trump vehicle may have affected the thickness and concentration of the glycol film remaining after the final overspray and thus the protection afforded against freezing and accumulation of the continuing snowfall, the Safety Board is not able to determine that this was a causal factor in the accident. The complexity of the variables affecting the amount and the water content of subsequent snow accumulations on the aircraft combined with the absence of research data preclude meaningful comparison of the effectiveness of the procedures used on Flight 90 with other procedures. Regardless of whether the deicing operation was causal to the accident, the deicing process used was not consistent with recommended practices and is thus considered deficient. The evidence provided by a photograph taken between 10 to 15 minutes after the completion of Flight 90's deicing indicated that some new snow had already accumulated on the top and upper right side of the aircraft's fuselage. The wings and empennage were not clearly depicted on the photograph. (See figure 3.)

Ground Operations After Deicing.—Although the Safety Board could not determine whether the aircraft was completely free of snow or ice immediately after the deicing operation was completed, the evidence is conclusive that snow had accumulated on the surfaces during the nearly 50 minutes of exposure to moderate to heavy snowfall before Flight 90 was cleared for takeoff.

Since other flights departing Washington National Airport during the snowfall on January 13 also experienced extensive delays and performed without apparent difficulty during takeoff, one might conclude that the deicing procedures used on those aircraft were more effective than those used on Flight 90. However, the exact conditions, such as temperature and ground accumulation on ramps and taxiways, the length of time the aircraft was exposed to critical wind conditions, and the proximity of the aircraft to the exhaust gases of other aircraft after deicing, are all factors which could have made the difference between a successful takeoff and an unsuccessful one. While other departing aircraft may also have had some snow on their surfaces, the Safety Board believes that the manner in which the flightcrew of Flight 90 operated their aircraft before and during the taxi and ground delay increased the aircraft's susceptibility to aerodynamically degrading contamination.

2.5 Flightcrew Performance

The cockpit conversation between the captain and first officer during the takeoff delay clearly indicated that the crew was aware of and concerned about the weather and airport conditions. Accordingly, the Board would have expected the crew to have exercised all possible precautions to minimize operational hazards. Such precautions include (1) close inspection of the aircraft following the deicing operation, (2) adherence to flight-manual-recommended procedures regarding the use of thrust reversers and engine anti-ice, (3) maintaining adequate distance behind taxiing aircraft so as not to allow exhaust gases to turn snow to slush, (4) assurance that the aircraft's wings were free of sticking snow or ice before beginning takeoff, (5) early action to reject a takeoff upon detection of instrument anomalies, and (6) positive corrective action to counter a developing post-takeoff aircraft performance problem. Therefore, the Safety Board examined the flightcrew's performance in each of these areas as well as those factors which may have influenced their judgment and actions.

Inspection of Aircraft Following Deicing.—Although the captain was solely responsible for assuring that the aircraft was ready for flight when it left the gate, no witnesses specifically recalled seeing either the captain or the first officer leave the cockpit to inspect the aircraft from outside for remaining snow or ice contamination. Surviving passengers testified that the crew remained in the cockpit following the deicing operation. The Safety Board, therefore, concludes that the flightcrew's assessment of the aircraft's condition was based entirely on their discussions with maintenance personnel and any observations made from the cockpit. Although the Safety Board places no causal significance to the postdeicing inspection because of the subsequent ground operations and the lengthy exposure of the aircraft to the continuing snowfall while awaiting takeoff clearance, it believes that good practice dictates that one of the flight crewmembers observe the aircraft from outside. Furthermore, the Safety Board believes that an outside observation of the conditions may have influenced the crew's assessment of the wet/dry characteristic of the falling snow, an assessment which may have affected their later decisions.

Use of Reverse Thrust During Pushback.—The surface condition in the gate area was slippery and the tug which was connected to the aircraft for the pushback after the aircraft was deiced could not develop the traction needed to move the aircraft. After it was apparent that the aircraft could not be moved with the tug, the flightcrew started the engines and used reverse thrust to help pushback, contrary to advice from the tug operator that the use of reverse thrust was prohibited by American Airlines' policy. Witnesses estimated that the engines were operated for 30 to 90 seconds during which time snow and slush were blown around the aircraft. The aircraft failed to move even with the combined effort of reverse thrust and the tug, and the engines were shut down.

During its investigation, the Safety Board determined that Boeing Operations Bulletins warning against the use of reverse thrust because of occurrences of takeoff pitch control anomalies with the B-737 aircraft after ground operation in freezing conditions, had been incorporated into Air Florida flightcrew's manuals.

The Safety Board cannot conclusively determine whether the use of reverse thrust affected the amount or character of the contaminant which subsequently adhered to the aircraft. An American Airlines mechanic stated that he did examine the engines following the use of reverse thrust and other personnel in the area stated that they did not see any water or slush on the wings. However, heat developed from the engines and reversers and the blowing snow and slush could have deposited a wet mixture, particularly on the wing leading edge, which was not significant to observers, but which subsequently froze and increased the leading edge area's susceptibility to further accretions during the continuing precipitation.

The Safety Board believes that the flightcrew was influenced by the prolonged airport closure and by additional delays at pushback, leading them to use reverse thrust to expedite operations. Regardless, the Safety Board concludes that the flightcrew's actions in using reverse thrust contrary to advice and guidance provided indicates a lack of professional judgment consistent with their total performance. Whether the flightcrew was familiar with the guidance in the Operations Manual and consciously disregarded it cannot be determined.

Use of Engine Anti-ice System.—The Safety Board's investigation established conclusively that the engine anti-ice system was not used during ground operations of Flight 90. The crew's response to anti-ice during the "after-start" checklist was "off." Additionally, the closed position of four of the six motor-driven thermal anti-ice valves and the level of engine rotation speed during the takeoff were explainable only if the engine anti-ice system was "off." The Safety Board discarded the possibility that the anti-ice switch was placed "on" by the flightcrew but the system failed to operate. When the engine anti-ice switches are placed on, six individual lights on the forward overhead panel will illuminate "bright." When the motor-driven valves reach to the open position, the lights will "dim." If the valves do not open, these lights will remain "bright." The Safety Board must accept the premise that the flightcrew would have checked the status of these lights and then consequently would have noted that the valves failed to open. After the checklist response, there was no further mention of engine anti-ice by the flightcrew. The FAA-Approved B-737 Flight Manual, which is used by the Air Florida crews, prescribes that the engine inlet anti-ice system shall be on when icing conditions exist or are anticipated during takeoff and initial climb. The manual defines icing conditions when dry-bulb temperature is below 8° C (46° F), wet-bulb temperature is below 4° C (39° F), and visible moisture such as fog, rain, or wet snow is present. The manual provides further guidance that snow should be considered as wet when the outside air temperature is higher than 30° F. Although the outside air temperature was below 30° F at the time, the Safety Board believes that the slippery conditions encountered during pushback, their obvious concern about snow sticking to the wings, and their later observations of icicles on other aircraft should have caused the crew to assess the snow as "wet." Since there are no restrictions to the use of engine anti-ice during ground operations and no significant performance penalty during takeoff and climb, the Safety Board would expect the flightcrew to act cautiously in marginal weather and use engine anti-ice. However the checklist response seemed without hesitation and there was no discussion regarding the existing weather conditions, and thus no evidence that the flightcrew even considered the use of engine anti-ice.

About 1549, while the aircraft was in line for departure, the first officer commented, "See the difference in that left engine and right one," and 2 minutes later, "This thing's settled down a little bit, might a been his hot air going over it." The Board believes that the first officer was referring to an erratic EPR indication probably as a result of ice forming on the engine inlet probe. When the probe was solidly blocked, the indications would settle down as the first officer observed. But, even this indication did not prompt either of the flight crewmembers to consider engine inlet icing or to check or question the status of the engine anti-ice system. The crew's action may have been due to a lack of winter operating experience, a lack of understanding of turbine engine operating principles, and perhaps, deficiencies in their training regarding winter operations.

The Safety Board concludes that the flightcrew's failure to use engine anti-ice was a direct cause of the accident. Had the engine inlet Pt_2 probes not been blocked by ice, the correct EPR values would have been indicated during the takeoff power adjustments, and the engines would have been set for and developed normal thrust for takeoff and climb. The engineering simulation showed that even with the airframe ice/snow contamination, the additional thrust would have provided a positive performance margin for acceleration and climb following takeoff. Moreover, if the crew had turned on engine anti-ice before takeoff, but the Pt_2 probes remained blocked, the flightcrew would have been unable to set power at the target EPR. This would undoubtedly have prompted them to abort the takeoff attempt until they could evaluate the problem.

The Safety Board notes that a B-737 flightcrew's attention is directed to engine anti-ice on the after-start checklist and that this item does not appear on the taxi and takeoff checklist. Although it may not be pertinent to the conditions existing on January 13, 1982, the Safety Board can conceive of situations involving lengthy ground delays wherein significant changes in ambient conditions will occur between the conduct of the after-start checklist and the initiation of takeoff; changes which may require a reassessment of the use of engine anti-ice. The Safety Board can only speculate whether a taxi and takeoff checklist entry for engine anti-ice would have prompted the flightcrew to turn it on for takeoff. Had the crew turned it on at that time, the accident would probably have been averted. In assessing the significance of the taxi and takeoff checklist in this accident, the Safety Board considered its expectations regarding an experienced professional flightcrew. The Board believes that a flightcrew preparing for takeoff in conditions as they existed on January 13, 1982, would routinely have checked all items related to safe operations in subfreezing weather, such as pitot heat and engine anti-ice, regardless of whether such items appeared on a checklist. While the Board, therefore, did not include the omission of anti-ice from the taxi and takeoff checklist as a factor in the cause of this accident, the Board believes that the checklists of all transport category aircraft could profitably be reviewed to determine if they include all items pertinent to safety.

Spacing Between Taxiing Aircraft.—The CVR-recorded conversation between the captain and first officer as they awaited their sequenced departure indicated that the captain intentionally positioned his aircraft close behind another aircraft in an attempt to use heat and blast from exhaust gases to remove visible snow or slush from the wings. Within 3 minutes after the engines were started, the first officer commented, "It's been a while since we've been deiced." Five minutes later, the captain stated, "Tell you what, my windshield will be deiced don't know about my wing." The first officer responded, "Well, all we really need is the inside of the wings anyway, the wingtips are gonna speed up by eighty anyway, they'll shuck all that other stuff." About a minute later the following exchange took place:

Captain:	"(Gonna) get your wing now."
First Officer:	"D' they get yours? Can you see your wing tip over'er."
Captain:	"I got a little on mine."
First Officer:	"A little," "this one's got about a quarter to half an inch on it all the way."

The Safety Board believes that the heat of the exhaust gases may have turned snow, which otherwise might have blown off during takeoff, into a slushy mixture. The mixture then froze on the wing leading edges and the engine inlet nose cone. The Safety Board believes that the captain's actions to position the aircraft in the area of heated exhaust gases of preceding aircraft may have contributed to this accident by increasing the amount of the frozen contaminant which adhered to critical parts of the aircraft prior to and during the takeoff.

The Safety Board views the action to taxi close to the aircraft ahead as an example of the captain's lack of awareness of, or disregard for, the contents to the flight manual. Operations Manual Bulletin No. 74-8, issued by The Boeing Co. on October 24, 1974, called specific attention to the cold weather procedures of the FAA-Approved Flight Manual. The manual states, "Maintain a greater distance than normal between airplanes when taxiing on ice or snow covered areas. Engine exhaust may form ice on the ramp and takeoff areas of the runway and blow snow and slush which freezes on surfaces it contacts." The Safety Board believes that pilot training programs and materials should emphasize the hazards of taxiing too close behind another aircraft during icing conditions.

Initiating Takeoff With Visible Snow Adhering to Aircraft.—The evidence is conclusive that the flightcrew was aware that the top of the wings were covered with snow or slush before they attempted to takeoff. The captain and first officer continued to discuss the weather conditions until they were first in line for takeoff clearance. There is no evidence that the flightcrew made any last minute visual assessments of the amount or character of the snow or slush on the wings before taxiing into the takeoff position. The lack of increased background noises indicating that windows were opened or pertinent conversation on the CVR are consistent with the conclusion that neither crewmember left the cockpit to observe the wings from the cabin nor opened the cockpit windows to enhance observation from the cockpit. The Safety Board believes that the flightcrew accepted the fact that snow or ice had accumulated on the aircraft and believed that while such accumulation may have some deteriorating effect, it would not affect significantly the aircraft's takeoff and climb performance. The flightcrew was probably influenced by the prolonged departure delay and was thus hesitant to forego the takeoff opportunity and return to the ramp for another cycle of deicing and takeoff delay. The flightcrew was probably also influenced by their observations of other aircraft departing ahead of them and successfully completing the takeoff and climb. 17/

Although all of the flight training received regarding winter operations and advisory materials related to such operations provided during a pilot's career stress the importance of "clean" wings for takeoff, the Safety Board is concerned that some pilots may not fully appreciate the extent to which even a small amount of contaminant can degrade an aircraft's performance. Personal encounters with airframe icing during cruise flight and flight manual statements regarding the ability of the aircraft to cope with icing during cruise flight might lead a pilot to believe that some wing contamination can be tolerated without danger. In fact, the Safety Board believes that this crew's decision to takeoff with snow adhering to the aircraft is not an isolated incident, but rather is a too frequent occurrence. 18/

Regardless of the many factors which may have influenced the flightcrew, the Safety Board concludes they should not have initiated a takeoff with snow visible on the aircraft wings. The Federal Aviation Regulations are very specific, requiring that "no person may take off an aircraft when frost snow or ice is adhering to the wings, control surfaces, or propellers of the aircraft." Since the snow or ice on the wings of Flight 90 degraded the aerodynamic performance significantly, the Safety Board concludes that the flightcrew's decision to take off with snow or ice on the wings was a direct cause of the accident.

17/ Data has indicated that such factors as crew cognitive patterns, interpersonal relations and communications patterns can potentially influence pilot performance. Resource Management on the Flight Deck. Proceedings of a NASA/Industry Workshop Held at San Francisco, California, June 26-28, 1979. NASA Conference Publication 2120, March, 1980.

18/ Aircraft Accident Report: Allegheny Airlines, Inc., Nord 262, Mohawk/Frakes 298, N29824, Benedum Airport, Clarksburg, West Virginia, February 12, 1979 (NTSB-AAR-12); Aircraft Accident Report: Ozark Air Lines, Inc., Douglas DC-9-15, N9742, Sioux City Airport, Sioux City, Iowa, December 27, 1968, (File No. 1-0039); Aircraft Accident Report: Redcoat Air Cargo, Ltd., Bristol Brittania 253, Boston, Massachusetts, February 18, 1980 (NTSB-AAR-81-3).

<u>Continuation of Takeoff With Instrument Anomalies.</u>—As the aircraft ahead of Flight 90 moved onto the runway for departure, the crew of Flight 90 taxied up to the taxiway line demarking the safe distance from landing aircraft to hold and await further clearance. The crew then began the query-response takeoff checklist. With the existing weather conditions, the Safety Board would have expected the captain to respond to the "takeoff briefing" with special attention to procedures to be followed during the takeoff. The briefing should have included discussion of the coordination between the captain and the first officer, which would be required in case of a rejected takeoff on the slippery runway. Even though the first officer appeared to be seeking advice when he commented, "Slushy runway, do you want me to do anything special for this or just go for it," the captain's response was noncommital, and no detailed takeoff briefing was given.

The Air Florida Operations Manual procedures for takeoff recommend a rolling takeoff. The procedures specify that the captain use nosewheel steering (controlled by the tiller) until the aircraft is aligned with the runway. After alignment with the runway, the captain shifts his left hand from the nosewheel tiller to the control column and sets takeoff power, keeping his right hand on the engine thrust levers. Directional control of the aircraft is maintained through rudder pedal steering. The captain's visual attention would be primarily outside to monitor directional control with a secondary scan of flight instruments to monitor airspeed. The first officer's duties include a check of the engine instruments after thrust is set. He should then continue to monitor and crosscheck all of the instruments and callout 80 knots, V_1, and V_R speeds. Testimony at the public hearing disclosed that the decision to reject the takeoff is the responsibility of the captain.

Flightcrews routinely reverse duties on alternate legs of flight; however, the captain remains in the left seat. On the accident flight, the first officer was to conduct the takeoff. There are no written procedures in the Air Florida Operations Manual to specify the reversal of duties between the captain and first officer; however, such procedures are standardized during training. The captain must still control the aircraft until it is aligned with the runway centerline using the nosewheel steering tiller. The first officer will set the engine thrust levers to the target EPR value. When the aircraft is aligned with the runway, the first officer will assume directional control of the aircraft using the rudder pedal steering. He will release his left hand from the throttle levers, and the captain will make final power adjustments and keep his right hand on the throttle levers so that he may initiate a rejected takeoff if necessary. During the takeoff acceleration, the first officer would normally be looking outside to maintain directional control with a scan to the airspeed indicator. The captain's attention would be directed to checking engine instruments and monitoring flight instruments. He would make the required 80-knot, V_1, and V_R calls. Even with the reversal of takeoff duties, the captain remains responsible for the final decision to reject a takeoff.

The traffic flow as Flight 90 awaited clearance was being sequenced alternately to departing and arriving traffic. Flight 90 was given the clearance to "taxi into position and hold" as landing traffic was on the rollout and was told to "be ready for an immediate [takeoff]." The first officer responded to the "position and hold" clearance within 4 seconds and the FDR showed that the aircraft began to taxi about 8 seconds later. The crew completed the takeoff checklist and made the public address announcement for flight attendants to be seated. At 1559:24, 29 seconds after being cleared into position, Flight 90 was cleared for takeoff; the first officer responded and the local controller added, "No delay on departure if you will, traffic's two and a half out for the runway." Flight 90 at that time was still taxiing onto the runway and just beginning the 120° turn to align the aircraft with the runway. The turn took about 18 seconds, and the flightcrew began advancing the throttles before the aircraft was aligned to the takeoff heading.

As the first officer brought the throttles up, the EPR indication probably overshot the 2.04 target value. Crew comments, "Ho," "Whoo," "Really cold here," "Got'em," "Real cold," and "God, look at that thing," all were indicative of the crew's observation of the rapid increase and overshoot in EPR as power was added. The CVR sound spectrogram study confirmed that the engine rotational speed peaked and was immediately reduced to a nearly stabilized value which corresponded to an actual EPR of 1.70—the error resulting from the false reading due to the ice blocked Pt_2 probe. The aircraft continued to accelerate for takeoff. Within 10 seconds of the initial power adjustment, the first officer commented, "That don't seem right does it?" "Ah, that's not right." The captain's only response was "yes it is, there's eighty" (knots). The first officer again expressed concern, "Naw, I don't think that's right." Again, there was no response from the captain. This last statement by the first officer was simultaneous with a radio transmission from the crew of the arriving Eastern aircraft that they were "cleared to land, over the lights." With no further comment from the captain, Flight 90 continued the takeoff. The first officer continued to show concern as the aircraft accelerated through a "hundred and twenty" (knots). The aircraft reached V_1, the theoretical engine failure go/no go decision speed, about 41 seconds after the beginning of the takeoff roll.

The Safety Board considered several factors in analyzing the flightcrew's performance and judgment during the takeoff. The air traffic situation and the local controller's instructions to takeoff with "no delay" may have predisposed the crew to hurry. The CVR and FDR data show that the crew probably expedited their actions to the extent possible; they taxied to the runway and began the takeoff from the turn to runway heading without stopping. Consequently, they did not take the opportunity to advance engine power in a static situation to verify performance and instrument readings. Additionally, the slippery surface of the runway probably would have made a static engine power check before takeoff difficult. Both the captain and the first officer detected the EPR overshoot when the throttles were advanced. That the target EPR indication was obtained at a throttle position other than normal probably prompted the initial awareness that something was "not right." It is not possible to determine to what extent either of the pilots cross-checked the other engine instruments at that time. The captain's comment "real cold" could refer to his observation of the engine exhaust gas temperature which would have been lower than normal for the intended takeoff thrust though corresponding to the actual takeoff thrust; however, the Safety Board believes that it more probably reflected a belief that a higher-than-normal EPR resulted because of cold ambient temperatures.

Since the captain was the nonflying officer during the takeoff, the Safety Board would have expected that he would have been the most attentive to the engine instruments and the most observant of any anomalies. Instead, it was the first officer who continually expressed concern that something was not right. The Board finds no positive evidence that the captain tried to evaluate the reason for the EPR overshoot by comparison with other instruments—N_1, N_2 exhaust gas temperature, and fuel flow. All of these indications are needle dial analog type and all would have been reading lower than normal for takeoff power. (See figure 6.) The Board recognizes that there are several factors which could hinder a pilot's properly evaluating the situation confronting the crew of Flight 90. First, there is no requirement for a pilot to precompute precise target values for any of these parameters during takeoff. Second, since both engines are presenting similar readings with no readily apparent common problem, a pilot might accept them as valid though confusing. Third, the acceleration of the aircraft at low speeds would be less than normal, but the reduction probably would not have been perceived by the crew until higher speeds were attained. Therefore, the Safety Board can understand the difficulty that a flightcrew would have in analyzing the problem. In fact, the Safety Board believes that the first officer was astute in his observation that something was wrong and was highly concerned about that observation.

Although the first officer advised the captain of his concerns several times, the captain apparently chose to ignore his comments and continue the takeoff. It is not necessary that a crew completely analyze a problem before rejecting a takeoff on the takeoff roll. An observation that something is not right is sufficient reason to reject a takeoff without further analysis. The problem can then be analyzed before a second takeoff attempt. On a slippery runway, a decision to reject must be made as early as possible. An engineering analysis based on the FDR-indicated performance and theoretical performance of the B-737 showed that the accident aircraft had traveled about 1,250 feet before it reached 80 kns. Analysis also showed that the aircraft could have been brought to a stop from 80 kns in less than 2,000 feet even on an extremely slippery runway--one having a coefficient of braking of 0.1. In fact, the analysis showed that the flightcrew should have been able to stop the aircraft safely within the runway length even if the action to reject had been delayed until the aircraft reached 120 kns. While the runway condition may have been an influencing factor at higher speeds, the Safety Board does not consider it a contributing factor to the captain's lack of action when the engine instrument anomaly was first called to his attention. The Safety Board also considered the possibility that the captain was aware of and concerned about the decreasing separation between his aircraft and the aircraft landing behind him. The Board believes that this would likely have become a factor only after the landing aircraft reported "over the lights." This was 9 seconds after the first officer first observed, "that don't seem right," and 1 second after Flight 90 had reached 80 kns. Further, there are no comments on the CVR to indicate that the captain ever considered rejecting the takeoff. Therefore, the Safety Board concludes that there was sufficient doubt about instrument readings early in the takeoff roll to cause the captain to reject the takeoff while the aircraft was still at relatively low speeds; that the doubt was clearly expressed by the first officer; and that the failure of the captain to respond and reject the takeoff was a direct cause of the accident.

Reaction to Stall Warning After Takeoff.—If the extent to which the aircraft's performance was degraded was not recognized by the flightcrew during the takeoff acceleration, it should have been immediately apparent that a serious condition existed after the takeoff rotation. The Safety Board believes that the first officer was probably surprised as the aircraft nose pitched up abruptly during rotation because of the trim change caused by the wing contamination. The forward control column force required to lower the nose attitude may have been much higher than anticipated. In fact, some stabilizer trim change may have been needed to augment elevator control; however, stabilizer trim actuation was not evident on the CVR or on the stabilizer trim jackscrew. The flightcrew would also have been surprised and probably confused when the stickshaker stall warning activated at a normally acceptable indicated airspeed. However, the flightcrew's reaction to this warning should have naturally been to bring thrust to the takeoff level and reduce the noseup attitude of the aircraft. In the accident circumstances, the crew, believing that thrust was already at the the takeoff limit, would likely have limited their initial actions to correcting pitch attitude. The captain's comments, "Forward, forward," "Easy," "We only want five hundred," "Come on forward," and "just barely climb," all were evidence that the captain was directing his concern to pitch attitude.

The Safety Board believes that the crew probably reduced nose attitude at first, but later increased it to prevent descent into the ground. It should have been apparent from the continuation of the stickshaker and the continuing decrease in airspeed that the aircraft was not recovering from a serious situation. The Safety Board believes that, with the aircraft near to stall and close to the ground, the crew should have responded immediately with a thrust increase regardless of their belief that EPR limits would be exceeded. Furthermore, in this case the crew should have known that all other engine parameters — N_1, N_2, and exhaust gas temperature—were well below limit values.

The frequency recorded on the CVR which corresponded to engine rotational speed was not distinct on the sound spectrogram after the aircraft's stickshaker activated. Although a transient frequency which may have been associated with an increase in engine rotational speed was discernible about 16 seconds after stickshaker activation, the Safety Board does not believe this to be sufficient evidence on which to base a positive conclusion that the crew waited 16 seconds before pushing the throttles forward. The Board does believe that power was added before impact. However, since the engineering simulation showed that had full thrust (equivalent to 2.23 EPR) been added immediately following the activation of the stickshaker, the aircraft could probably have accelerated to a safe stall margin and continued flying, the Board believes that the flightcrew hesitated in adding thrust because of the concern about exceeding normal engine limitations which is ingrained through flightcrew training programs.

The Safety Board is concerned that pilots are so indoctrinated not to exceed engine parameter limitations that they will withhold the use of available thrust until it is too late to correct a developing loss of control. Pilot training programs should be reviewed to ensure that they place proper emphasis on adherence to engine limitations, but that they also stress the use of available thrust beyond those limits if loss of an aircraft is the other alternative.

2.6 Flightcrew Experience and Training

Both the industry and the traveling public have come to expect the highest degree of performance and professionalism from flightcrews of scheduled air carrier operations and particularly from airline captains. It would further be expected that the basics of turbo jet operations would be clearly ingrained in the mind of an experienced, well trained airline captain, and that under the weather conditions existing at Washington National Airport on January 13, 1982, these basics would have dictated checking the wings for snow or ice, using engine anti-ice, and rejecting of the takeoff when the engine instruments appeared anomalous. An airline captain should have assimulated or gained thorough knowledge of these procedures and of the conditions which warrant their use. He should have done so both through actual experience and through formal training as he progressed through the various stages of his career. By the time a pilot qualifies as an airline captain, he should be capable of detecting and coping with not only the situations demonstrated in this accident, but with every phase of reasonably anticipated transport aircraft operations.

The captain and first officer of Flight 90 were certificated and qualified in accordance with applicable regulations. However, the Safety Board believes that the flightcrew's performance on January 13 reflected an insufficient concern for the hazards of cold weather operations which was not consistent with the intent of the regulations. The Safety Board could not determine the level of training in cold weather operations or the amount of exposure to actual cold weather conditions that either crewmember had before his employment with Air Florida. Certainly, however, any such experience would have been gained in other types of aircraft and probably would have involved considerations other than those involved during the operation of jet transport aircraft. Although cold weather considerations generally apply to all types of aircraft, specific procedures and requirements related to such aircraft systems as engine and airframe anti-ice, considerations for congested airport operations, and even the sensitivity of the aircraft to wing contamination may differ significantly.

The captain's flying experience before his employment with Air Florida, Inc., included flying light aircraft, twin reciprocating aircraft and turboprop-powered aircraft. Much of his flying is known to have been in the southern United States. All of his jet transport training and experience were obtained with Air Florida. Before his checkout as a B-737 captain, his jet flight experience consisted of about 1,200 hours as a first officer on DC-9 and B-737 aircraft. Since upgrading to captain, he had accumulated about 1,100 hours. The Safety Board's review of his operating experience as a captain disclosed only eight previous occasions where arrivals or departures were conducted during weather conditions conducive to icing. In contrast to this captain's prior experience, testimony at the hearing disclosed that the average pilot currently hired by Air Florida for first officer duties has more than 2,000 hours flying time in turbojet transport aircraft and 85 percent possess Air Transport Pilot certificates.

The first officer's experience before his employment with Air Florida, Inc., was gained as a military jet fighter pilot. His direct experience in jet transport-type aircraft consisted of about 1,000 hours as a first officer in B-737 aircraft. The Safety Board's investigation disclosed only two occasions during that period where he had conducted ground operations in conditions conducive to icing. Thus, neither of the flightcrew had much experience in operating jet transport aircraft in weather conditions like those at Washington National Airport on January 13, 1982.

The training that the flightcrew received did cover cold weather operating procedures in classroom presentations during initial and recurrent training and discussions during flightchecks. All of the various aspects of cold weather operations would have been covered in one form or another during the Air Florida Training Program. Such training usually does not include detailed discussions or specific problems, such as engine probe icing and related instrument indications with and without the engine anti-ice system. It would be unusual to encounter conditions during training flights or checkflights which would allow an instructor to demonstrate actual cold weather operating procedures or to observe a trainee's ability to deal with cold weather operations. Air Florida did circulate a periodic newsletter which contained general discussions of cold weather procedures and hazards. While the Safety Board encourages periodic dissemination of such material, it is not a substitute for more formal training to emphasize the significance of winter operational hazards. The Safety Board is concerned that existing training programs, particularly those conducted during warmer seasons or in Southern climates may not provide for an objective measurement of a flightcrew's appreciation for the hazards of winter operations.

The Safety Board concludes that the flightcrew's limited training and low experience in jet transport winter operations in snow and ice conditions were contributing factors in this accident. The Board believes that the captain of Flight 90 missed the seasoning experience normally gained as a first officer as a result of the rapid expansion of Air Florida, Inc., from 1977 through 1981, wherein pilots were upgrading faster than the industry norm to meet the increasing demands of growing schedules. The Safety Board's informal survey of major trunk carriers showed that pilots upgrading to captain had served an average of 14 years as a first or second officer with the carrier.

The Safety Board also reviewed the evidence in this accident as it related to the relative roles of the captain and first officer and their interaction. The captain of the aircraft is responsible for the safety of the aircraft at all times and is expected to exert leadership and authority. The captain of Flight 90 did not give a detailed takeoff briefing nor did he respond directly to specific questions from the first officer regarding operational procedures before the beginning of the takeoff. Most significantly, the captain did not react to the first officer's repeated comments that something was not right during the takeoff roll; in fact, there is no evidence that he took decisive action even when the stickshaker activated after takeoff.

With regard to the first officer, while he clearly expressed his view that something was not right during the takeoff roll, his comments were not assertive. Had he been more assertive in stating his opinion that the takeoff should be rejected, the captain might have been prompted to take positive action.

The Safety Board strongly believes that pilot training programs as well as initial selection and upgrading criteria should include considerations for command decision, resource management, role performance, and assertiveness. As a result of previous accidents in which circumstances included shortcomings in crew communication and coordination, in June 1979 the Safety Board issued Safety Recommendation A-79-47 recommending that the FAA urge operators to indoctrinate flightcrews in the principles of flightdeck resource management with emphasis on the merits of participative management for captains and assertiveness training for other cockpit crewmembers. As a result, the FAA issued an Air Carrier Operations Bulletin instructing Principal Operations Inspectors to urge carriers to include such training. Several air carrier operators have recognized a need for enhanced flightcrew management and have developed command training programs, including principles of leadership, management skills, human relations, and problem solving in the operational environment. However, there are no specific requirements or syllabus guidelines for resource management training or criteria, and many carriers, including Air Florida, place little or no emphasis on these aspects of training.

2.7 Other Factors Relevant to the Accident

B-737 Known Inherent Pitchup Characteristics With Wing Leading Edge Contamination and Related Boeing Actions.—The engineering simulation of Flight 90's flight profile disclosed that the aircraft's rate of acceleration after liftoff, below normal because of the reduced thrust, was further impaired by a high noseup pitch attitude attained during the takeoff rotation. Consequently, the aircraft did not reach an airspeed safely above the stall speed. The high pitch attitude occurred because the flightcrew failed to, or was unable to, react quickly enough to counter the aircraft's longitudinal trim change produced by the wing leading edge contamination. The reports since 1970 by other operators who have experienced abrupt pitchup or rolloff immediately after liftoff of B-737 aircraft indicate that the B-737 may have a greater known inherent pitchup characteristic than other aircraft in this regard a result of small amounts of frost, snow, or ice on the wing leading edge. The Safety Board could not determine whether the aerodynamic design makes the B-737 more sensitive to pitching or rolling moments when the wing is contaminated, or whether more frequent operation of these aircraft in environmental conditions conducive to snow or ice accretion during ground operations, coupled with the near to the ground wing placement, accounts for the higher number of reported B-737 pitchup/rolloff incidents. Regardless, the Safety Board concludes that the pitchup tendency of the aircraft because of leading edge contamination contributed to the accident. However, to place this contributing factor in perspective, the Board notes that no aircraft design requirements include the ability to perform with snow or ice contamination and that any known contamination, regardless of the amount or depth, must be viewed as potentially critical to a successful takeoff. For this reason, flightcrews are not only dissuaded, but are prohibited, from attempting a takeoff with such contamination.

The Safety Board, however, agrees with the United Kingdom Civil Aviation Authority that there are times, such as night time operations, when a small amount of contaminant may not be detectable by the flightcrew and that precautionary procedures should be developed and implemented to reduce the potential of control problems if a takeoff is conducted under those circumstances. The occurrences of pitchup or rolloff were first reported over 10 years ago and although they prompted The Boeing Co. to examine the B-737's flight characteristics during flight tests, preventive actions taken by both the manufacturer and the Federal Aviation Administration have been limited solely to the dissemination of advisory information. Even this information is couched in a manner which may fail to impart the hazard potential to the reader. For example, Operations Manual Bulletin No. 81-4 advises pilots, "If leading edge 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." Such a statement could imply that it is safe to operate the aircraft provided the pilot exercises care. The Safety Board concludes that Boeing should have placed greater emphasis on the prohibition of takeoff if leading edge contamination is observed or even suspected. To accommodate those situations in which the flightcrew may be unable to detect small amounts of contamination, the Board concludes that more positive measures should have been taken by Boeing, such as those imposed by the CAA in its Airworthiness Directive 010-01-82.

Moreover, the Safety Board is aware that The Boeing Co. has been considering and evaluating modifications to the B-737 wing thermal anti-ice system which would permit that system to be used during ground operations to prevent the formation of ice on the wing leading edge devices. In view of the span of time over which the pitchup/rolloff incidents were reported, the Board believes that The Boeing Co. should have developed this modification and promulgated corresponding operational procedures more expeditiously. The Board believes that both the manufacturer and the FAA should move rapidly and before the next winter season to assure that wing thermal anti-ice system modifications and related operational procedures are implemented or takeoff speed margins are added to prevent further pitchup or rolloff occurrences of B-737 aircraft during cold weather conditions.

Washington National Airport.—The ideal situation during periods of precipitation conducive to ice accretion or snow accumulation is to deice the aircraft immediately before taxi and to receive takeoff clearance without delay. Unfortunately, this same type of weather is most apt to produce significant air traffic delays. In this context, the Safety Board examined the conditions at Washington National Airport. Although there was no attempt during this investigation to evaluate the airport's ability to cope with normal daily operations, it was evident that the airport's capacity affected the ground delays experienced on January 13. First, the airport operates with a single acceptable instrument runway. While most other major airports have multiple runways and snow can be removed from one runway while operations are conducted from another, at Washington National it is necessary to close the airport for snow removal. This necessarily produces a backlog of both arriving and departing traffic. Second, at many airports it is possible to implement a gate-hold procedure, permitting aircraft to remain at the gate where deicing equipment is accessible until takeoff can be made with minimum delay. At Washington National, however, both gate and ramp space are limited. On January 13, the imbalance between arriving and departing traffic resulted in more aircraft on the ground than the airport normally handles, making it necessary to clear aircraft for taxi in order to provide gate space and relieve the congestion of arriving traffic. Consequently, aircraft were lined up awaiting air traffic control's ability to fit them into the traffic flow. Third, the constrained taxi areas, particularly in periods of snowfall, provide for only limited movement and maneuvering of delayed aircraft. There is not sufficient room under most circumstances to get out of line and taxi to a designated area for deicing and then fall back in line for takeoff. The flightcrew's options are limited to continued waiting until they are able to takeoff, or returning to their deicing areas where they will probably be exposed to more waiting for space at the ramp. Thus, while the Safety Board believes that professional flightcrews must give paramount consideration to the hazards of takeoff with a contaminated aircraft, the practicality of returning to a deicing area only to encounter repeated delays awaiting takeoff might influence a flightcrew's decision to take off with an accumulation of ice or snow on the aircraft which a flightcrew might view as nonthreatening.

The Safety Board also analyzed the conditions of the runway and taxiways as they might have influenced the performance of Flight 90. Pilots who had landed following the airport's snow removal operation and others who landed about the time of the accident stated that the runway was snow covered at the approach and departure ends and that it was patchy with areas of asphalt visible through the snow in the center. None of the pilots reported problems in stopping their aircraft within the runway length. Indeed, most arriving aircraft turned off before the intersection with runway 33-15. The Safety Board's analysis of the takeoff performance of Flight 90 indicated that the actual acceleration of the aircraft during the takeoff roll correlated closely with the acceleration that a B-737 at the accident aircraft's weight would attain at an EPR setting of 1.70. Therefore, the Board concludes that the runway contaminant did not significantly affect the aircraft's takeoff performance. Undoubtedly, the braking coefficient which could have been achieved on the runway was less than that for a dry runway. However, the actual braking coefficient was not measured. Therefore, the Board cannot precisely assess the extent to which the runway condition might have become a factor if the takeoff had been rejected at high speed. However, assuming braking coefficients generally associated with icy runways, the aircraft should have stopped without difficulty if the takeoff had been rejected below 120 kns. Therefore, the Safety Board believes that the runway condition should not have been a factor in any decision to reject the takeoff when the instrument anomaly was noted.

Pilots using the airport at the time of the accident stated that the taxiways were covered with about 3 inches of snow and slippery conditions were encountered during taxi. While there is no evidence that Flight 90 encountered problems taxiing, the snow on the taxiway might have contributed to the accumulation of contaminant on the aircraft, particularly because of its proximity to the preceding aircraft. However, the Board believes it is likely that the continuing precipitation was the major source of wing contamination and that the snow on the taxiway contributed little to the contamination.

Although the Safety Board believes that the airport snow condition was a factor only insofar as it contributed to the flight's ground delay as it awaited takeoff clearance, the Board has been concerned about the problems of runway surface conditions as they affect aircraft, particularly air carrier operations. As a result of this accident and others, including a fatal accident which occurred only 10 days afterward, the Safety Board convened a 3-day public hearing on May 3, 1982, to receive evidence on the subject. Witnesses from Government and various segments of the aviation industry appeared to address five related issues: airport management requirements and maintenance procedures during inclement weather, the role of the airline, air traffic control, and the pilot in determining the operational adequacy of a runway, the effect of slippery runways on aircraft certification and operational regulations, the adequacy of present techniques for measuring runway friction and their value to a pilot, and the development of equipment or techniques to monitor aircraft acceleration. The findings of that hearing will be published by the Safety Board in a Special Investigation Report.

Runway 36 at Washington National Airport does not comply with current FAA design criteria for newly constructed airports for extended runway safety areas. While the Safety Board acknowledges that a longer safety area would have provided a greater margin of safety if Flight 90 had rejected its takeoff, it notes that the length of the hard surface of runway 36 exceeded the runway length required by regulations for Flight 90's takeoff. Furthermore, the total length afforded by runway 36 and its extended surface area exceeded the total length which would have been provided if Flight 90 had been operating from a minimum length runway having a currently prescribed extended safety area. Consequently, the Safety Board does not consider the fact that the runway does not meet the current FAA design criteria for new airports to be a factor in this accident.

Regardless of the relevance to this accident, the Safety Board has had a long-standing concern with the adequacy of runway safety areas. On April 20, 1977, the Safety Board recommended that the FAA amend 14 CFR 139.45 to require that extended runway safety area criteria be applied retroactively to all certified airports. At those airports which cannot meet the full criteria, the extended runway safety area should be as close to the full 1,000-foot length as possible. The FAA responded that the requirement for an extended runway safety area at all certificated airports would "be unacceptable due to the unreasonable burden placed on airport operators." However, the FAA is considering an amendment to 14 CFR 139 to require extended runway safety areas at new airports, or when new runways or major runway extentions are constructed at existing airports. The FAA has, however, rewritten Advisory Circular 150/5335-4 to place more emphasis on the design criteria for extended runway safety areas.

In view of the FAA's decision not to emphasize the construction of extended runway safety areas at certificated airports, the Safety Board urges voluntary action by airport owners and managers to upgrade those runways which fall short of the current design standards for extended runway safety areas.

Flow of Traffic Into Airport (Air Traffic Control).—The congestion of aircraft operations at Washington National Airport on January 13, 1982, as the cause of takeoff delays after aircraft had been deiced has been discussed. Certainly, the ability to handle large numbers of aircraft without difficulty even in good conditions is a recognized limitation of the airport. Therefore, the Safety Board believes that the FAA should have used all available means to prevent saturation of the airport and the air traffic control system during the weather conditions which existed. The FAA could have provided stricter control of the number of aircraft inbound to Washington National Airport through their Central Flow Control Facility (CFCF).

It is an accepted procedure that airport management notify the Air Route Traffic Control Center (ARTCC) and the CFCF when it anticipates closure of an airport. Such notification should be given at least 30 minutes before the airport is closed so that the affected ARTCC's and CFCF can take appropriate action to deal with aircraft destined for the airport. They must plan for holding or rerouting those aircraft which are airborne and scheduled to arrive during the period of closure. Action should also be taken to prevent an arrival backlog by notifying ARTCC's to hold those aircraft which are planning flights to the airport, but which have not yet taken off from their departure airports.

At 1300 on January 13, 1982, Washington National Airport personnel advised the Washington ARTCC and CFCF that the airport would be closed for snow removal operations between 1330 and 1430. The Washington ARTCC thus began to hold en route traffic inbound to the airport at 1320. Concurrent action was not taken by CFCF to hold aircraft at departure airports. Thus, the backlog of arrival traffic being placed into holding increased. The situation was compounded further when Washington National Airport personnel notified the ARTCC at 1425 that the airport would reopen at 1437, but then at 1437 revised the expected time for reopening to 1500. At that time, the Washington ARTCC was becoming saturated with holding inbound traffic and holding was extended to the adjacent ARTCC's. It was not until 1455 that the adjacent ARTCC's began to delay departures of aircraft destined for Washington from airports within their respective areas.

The Safety Board believes that the CFCF should be capable of adjusting rapidly to changing weather conditions to enable the system to hold traffic at the departure airports. The failure or inability to do so resulted in a flow of arrival traffic immediately after the airport reopened which saturated the airport. The Safety Board concludes that the FAA's CFCF did not anticipate the developing situation and take action to prevent it. The Safety Board believes that its failure to act may have been the result of inadequate communications between facilities—either the lack of timeliness of essential information or inaccurate information, such as the closing of the airport for 30 minutes longer than anticipated. The Safety Board thus believes that the FAA should review ATC coordination practices and modify them as necessary to require that facilities provide CFCF with current and accurate information and that CFCF acts on that information in a positive manner to minimize airport saturation and extensive traffic delays.

Traffic Separation.—A witness observation suggested and the Safety Board's evaluation of the ATC communications and radar data confirmed that Eastern Flight 1451, a B-727, touched down on the runway before Flight 90 became airborne from the same runway. The correlation of data showed that the minimum separation was no greater than 4,000 feet and might have been much less. The Safety Board concludes that the separation between Flight 1451 and Flight 90 was an unsafe condition which violated acceptable ATC procedures and established separation criteria.

As a result of the traffic backlog on the day of the accident, arrivals were being fed by approach control to the local controller in a continuous sequence and departures were being delayed. The local controller was placed under considerable pressure to expedite the traffic flow in order to reduce departure delays, and he was interspersing departure traffic between successive arrivals.

In this type of operation, the separation between departing and arriving aircraft depends upon the interval between successive arriving aircraft established by approach control. The local controller is responsible, however, for monitoring that interval so that he can provide the prescribed separation or departing traffic. He must decide whether the interval is sufficient to allow the departure. The controller's actions are guided by the limiting criteria set forth in FAA's Air Traffic Control Handbook 7110.65B--that is, under IFR conditions, a departing aircraft may be separated from an arriving aircraft on final approach by a minimum of 2 miles if separation will increase to a minimum of 3 miles within 1 minute after takeoff. The criteria are intended to assure that safe separation is maintained between departing and arriving aircraft in the event that an arriving aircraft executes a missed approach. However, both the local controller on duty at the time of the accident and the Washington National Airport Tower Chief stated at the Board's public hearing that the FAA's ATC Handbook criteria are widely interpreted to allow for the "accordion effect" of landing deceleration and takeoff acceleration. To the contrary, the ATC training manuals and controller tests clearly indicate that no such allowance is intended.

In making his operational decisions regarding the insertion of departure traffic, the controller must consider factors, such as the time required for a landing aircraft to clear the runway, the time required for a departing aircraft to taxi to the takeoff position and initiate takeoff and the acceleration of the departing traffic and its relationship with the closure rate (ground speed) of the landing traffic. Other factors, such as taxiway and runway conditions, must be considered as they affect the movement of aircraft. The assessment of these factors undoubtedly is more difficult on a day when aircraft holding for takeoff or those rolling out after landing cannot be seen from the tower. The controller must then base his judgment on radar displays, experience, and verbal communications with the aircraft. For example, based on all of the factors, the local controller might determine that he needs a minimum spacing of 6 miles between arriving aircraft. If he notes a separation of less than 6 miles, he must realize that he cannot insert a departure. His logical action would then be to notify the approach controller to provide more spacing between arrivals in order to accommodate departures. Based on the evidence, the Safety Board concludes that the local controller handling the departure of Flight 90 used poor judgment of these factors, compromising the required separation criteria. That he realized that the spacing interval was tight is evident by the ATC communications. Eastern 1451 reported "by the marker" 30 seconds before Flight 90 was told to taxi into "position and hold." The earlier landing traffic was asked to expedite its turnoff from the runway, Eastern 1451 was asked to maintain reduced speed, and Flight 90 was told to takeoff without delay. The last two transmissions were particularly poor practices. Restricting speed on short final is a dangerous practice and is specifically prohibited by the Air Traffic Control Handbook when inside the final approach fix. Expecting Flight 90 to takeoff without delay was improper since the controller did not verbally and could not visually verify that Flight 90 had reached the takeoff position at the time. Until Flight 90 was cleared for takeoff, the controller had the option of holding Flight 90 and issuing a missed approach to Eastern 1451. However, after Flight 90 was cleared, the situation became critical. The controller should have requested a rolling report from Flight 90 and continued to monitor the progress of Eastern 1451. Failing to receive a rolling report from Flight 90 as Eastern 1451 closed to within 3 miles, the controller could have issued a missed approach and vectors. Instead, the 2-mile separation criterion was probably compromised when Flight 90 started rolling, and the abnormally slow acceleration of Flight 90 further reduced the expected separation.

Since the controller could not see the aircraft because of poor visibility, he could not monitor Flight 90's takeoff progress visually and was completely dependent upon radar information and verbal communications in order to determine whether he should permit Eastern 1451 to continue its approach. Consequently, he may not have known if Flight 90 had rejected a takeoff in time to issue a missed approach clearance to Eastern 1451 which could be executed safely. Furthermore, action to issue a missed approach clearance to Eastern 1451 or even voluntary execution of a missed approach by Eastern 1451 after Flight 90 had commenced takeoff would have been equally hazardous since the two aircraft could have collided during departure.

The Safety Board has concluded that the proximity of Eastern 1451 should not have been a factor in the takeoff decision of the captain of Flight 90, and there is no evidence that it did influence his decision. Although the Safety Board does not believe that there is sufficient evidence to determine that the ATC's handling of Flight 1451 was a causal factor in the crash of Flight 90, the Board concludes that the local controller's overeagerness to expedite the traffic flow to relieve the departure backlog was contrary to established procedures and jeopardized safety. The Safety Board is concerned that no operational error was recorded although the local controller's handling of traffic in this case was clearly contrary to FAA procedure.

Takeoff Acceleration Monitor.—The Safety Board believes that this accident clearly illustrates fallacies in the takeoff field length criteria and decision speed concept employed by air carrier operators to assure an acceptable level of safety during takeoff. The minimum field length from which air carrier aircraft can takeoff is established so that an aircraft experiencing an engine failure during the takeoff roll can either stop safely within the runway length or continue to accelerate with power from the remaining engines and take off safely. In preparation for the takeoff, the flightcrew computes the decision speed (V_1), the speed above which the aircraft can continue the takeoff safely if an engine fails.

There are two significant fallacies in the takeoff criteria. One, the aircraft accelerate-stop-performance upon which the decision speed and runway length computations are based is determined during the aircraft type certification tests on a clean dry runway. The stopping performance is determined without the use of reverse thrust and is thus considered by the FAA and the airframe manufacturers to be conservative on a clean dry runway. However, this conservative margin is obviously degraded on runways having a braking coefficient reduced by snow, ice, or even liquid contamination. Thus, on a snow-covered runway, there are no assurances that the aircraft can be stopped from the V_1 speed within the limits of a minimum length runway. In fact, since stopping data on slippery runways are not provided in objective terms, the pilot is not able to determine the existing margin of safety for takeoff under conditions such as existed at Washington National Airport on January 13. However, data provided by the aircraft manufacturer during the investigation showed that runway 36 was longer than required for Flight 90 using the minimum field length criteria for a clean dry runway and that a B-737 aircraft at the accident aircraft weight performing normally should have been capable of accelerating to V_1 and stopping on runway 36 using reverse thrust even if the braking coefficient was reduced to 0.1--equivalent to that expected on clear ice.

The second fallacy in the takeoff criteria is, however, more significant to the circumstances of this accident. The accelerate-stop performance and thus the field length and decision speed computations are based upon the demonstrated and theoretical acceleration of the aircraft using normal takeoff power. If, for any reason, the aircraft aceleration is less than that used for the computation, the runway distance used to achieve V_1 will be increased and the length of runway available for stopping will be decreased. Thus, with subnormal acceleration, such as occurred during the takeoff of Flight 90, there is no assurance that the aircraft can stop from V_1 on the remaining runway even if the runway surface is clean and dry. Since a takeoff may have to be rejected at an airspeed much lower than V_1 when aircraft acceleration is subnormal to assure adequate stopping distance, the pilot must be able to recognize the subnormal acceleration rate early during the takeoff roll.

The Safety Board has investigated other accidents which have occurred after an aircraft failed to accelerate at a normal rate during takeoff. In its report of one such accident in November 1970, 19/ the Safety Board noted that a timely rejection of the takeoff might have been initiated effectively if the flightcrew had been able to assess the aircraft's acceleration rate more accurately under the given operating conditions. Consequently, the Safety Board recommended implementing takeoff procedures that will provide the flightcrew with time or distance references to enable the pilot-in-command to make a go-no-go judgment with regard to the aircraft acceleration rate to the V_1 speed, particularly for critical length runways and for runway surface conditions that may impede acceleration.

As a result of this recommendation, in early 1971, FAA asked the Air Transport Association of America (ATA) Flight Operations Committee to update its position on the use of distance-to-go runway markers as a means of supplying acceleration rate information to V_1 speed to flightcrews on takeoff. In addition, the airlines were also asked to explore the feasibility of developing an acceptable acceleration time check on aircraft having inertial navigation systems (INS) to determine if procedures could be developed that would enable flightcrews to make a go-no-go decision with regard to the airplane's acceleration to V_1 speed. The Flight Operations Committee reviewed this subject in detail and concluded that any attempt to use distance-to-go runway markers or

19/ Aircraft Accident Report: Capitol International Airways Inc., DC-8-63F, N4909C, Anchorage, Alaska, November 27, 1970 (NTSB-AAR-72-12).

to use the INS system for acceleration rate information to V_1 speed was not feasible for airline operations. Of more serious concern in using such techniques was the fear of increasing exposure to unnecessary high-speed aborts and subsequent overruns. The Flight Operations Committee believed, based on individual investigations and experience, that acceleration checks during takeoff roll could cause more accidents than they might prevent.

As a result of its investigation of another accident 20/ in May 1972, the Safety Board reiterated its recommendation that FAA "require the installation of runway distance markers at all civil airports where air carrier aircraft are authorized to operate." It also again urged the FAA to "require the use of takeoff procedures which will provide the flightcrew with time and distance reference to associate with acceleration to V_1 speed."

Nothwithstanding the views expressed by ATA's Flight Operations Committee in 1971, the Air Line Pilots Association (ALPA) appears to have recognized some merit in using time-to-distance checks. In late 1973, ALPA petitioned FAA to require distance-to-go markers at 1,000-foot intervals on runways used by turbine-powered aircraft. The petition did not, however, include a proposal to require the use of an operational procedure in connection with the proposed markers. In response to ALPA's proposal and the Safety Board's recommendations, FAA issued an Advance Notice of Proposed Rulemaking (ANPRM) on this subject in May 1973. But, as a result of industry-wide opposition to the proposal, FAA withdrew the ANPRM in May 1977.

The Safety Board acknowledges that the many variables affecting the acceleration rate of an aircraft present a difficult problem. First, the target acceleration rate for any set of conditions must be determined; second, a method of measuring and comparing the actual acceleration in terms of speed versus distance traveled with the target value must be established; and third, acceptable tolerances must be applied to prevent unnecessary takeoff rejections particularly at higher speeds where the hazard of overrun is greatest. Nonetheless, the Safety Board believes that some means of assessing takeoff progress could have alerted the flightcrew of Flight 90 to the fact that their aircraft was accelerating at a lower-than-normal rate and may have prompted a safe rejection of the takeoff. The monitoring of takeoff acceleration was also explored at the Safety Board's May 1982 public hearing.

At the hearing, the Safety Board queried representatives of a number of aviation organizations regarding the extent to which speed and distance checks are currently used in turbo jet operations to assess takeoff performance. Without exception, spokesmen from ALPA, ATA, Allied Pilots Association (APA), and several air carriers indicated they knew of no carrier which regularly used such checks. Similarly, General Aviation Manufacturers Association (GAMA) and Aerospace Industries of America (AIA) representatives indicated that to their knowledge none of their member companies use or advocate such techniques. Although some military operations still use runway markers to provide specific information on distance, time-to-speed and time-to-distance checks are used infrequently elsewhere in aviation operations. Furthermore, most of the hearing participants agreed that technology has surpassed the manual methods of using stop-watches or runway distance markers to monitor takeoff progress. Automatic systems to monitor distance which can then be compared with a computed theoretical distance for a given speed are receiving more industry attention. While those directly involved in the design of such equipment appear optimistic, much of industry, including

20/ Aircraft Accident Report: Pan American World Airways, Inc., B-747, July 30, 1971, San Francisco, California (NTSB- AAR-72-17).

FAA, is skeptical that the necessary state of development of such equipment -- particularly in definition of tolerances and in accurate and reliable measurements -- has been reached.

The Board believes that a concerted effort and support by various elements of the aviation community could overcome the technical hurdles involved and would lead to the implementation of a takeoff performance monitoring system that could contribute significantly to flight safety. The Board believes that such a concerted effort should be initiated by a joint government-industry task force at the earliest possible date. In, the interim, the Safety Board reiterates its Safety Recommendation A-72-3, issued January 3, 1972, that the FAA:

> Require the installation of runway distance markers at all airports where air carrier aircraft are authorized to operate.

Crash Dynamics and Injury Analyses.—The witness observations, the examination of damage to the vehicles struck by the aircraft, and the examination of the recovered aircraft wreckage were used to reconstruct the aircraft's impact sequence and to analyze the nature of the loads experienced by the aircraft structure and passengers. The reconstruction showed that the aircraft was descending along a flightpath of about 9° with a nose-high attitude of about 15° when the tail structure first contacted vehicles on the bridge. An analysis based on the estimated velocity change and the distance in which the structure decelerated showed that the initial impact vertical load experienced by the tail section averaged about 4g. The impact of the tail structure with the vehicles and bridge caused a downward acceleration of the aircraft's nose as it plunged toward the ice-covered river. The deformation of the nose structure of the aircraft showed that it hit first. The downward acceleration of the nose was abruptly reversed at impact and an analysis based on the crushing deformation showed that an average deceleration of 12g was experienced. However, the dynamic characteristics of impact as various structural elements collided during the progressive crushing of structure probably resulted in peak loads several times greater than the calculated average. The extensive breakup and numerous undefinable variables made a meaningful load analysis impossible. Nevertheless, the Safety Board believes that the average loads experienced in the cabin were within human tolerance for survivability, but that the extensive breakup of the fuselage, the impingement upon occupiable space, and the failure of the cabin floor with the consequent loss of occupant restraint resulted in secondary impact loads on the passengers which exceeded survivable tolerances.

All but 1 of the 74 occupants who were fatally injured suffered severe impact injuries which directly related to their deaths. The injuries to 54 of these occupants were of a nature to cause immediate death. The injuries to the other 19 were incapacitating to the extent that they could not have escaped from the aircraft without assistance. The injuries to some of these persons may have been survivable, but only under conditions where rescue personnel could have reached them to render immediate assistance and medical attention.

Therefore, the Safety Board concludes that the magnitude of peak impact loads exceeded rational limits for aircraft structure. The accident was classified as nonsurvivable for the cabin occupants because of the violation of occupiable space when the cabin collapsed and broke up and because of the high secondary impact forces following the loss of passenger restraint. The Board further concludes that the rescue effort following the crash was not a factor in the deaths of 73 of the aircraft's occupants.

The only occupiable area which remained relatively intact was that section of the aft cabin near the separation forward of the empennage. The one passenger who survived the crash but who drowned and the four passengers and one flight attendant who were rescued all were seated in this aft cabin area and managed to escape through the separation.

Rescue Efforts.--The obscured visibility as Flight 90 was taking off prevented the local controller from observing the aircraft as it proceeded toward the departure end of the runway. The local controller was depending upon his radar monitor and air/ground communications to track the aircraft's takeoff progress. The controller observed the aircraft to be airborne on his radar display, and at 1600:33 he advised Flight 90 to "contact departure control." He received no response from the flight, and at 1601:22, within about 20 seconds of the aircraft's contact with the bridge, he noted that the radar return from Flight 90 had disappeared. After an unsuccessful attempt to reestablish communications with the flight, the local controller, who was also the tower team supervisor, was relieved immediately by another controller so he could assume supervisory duties. He stated that he then notified Operations and Safety and called the Washington National Airport fire department to report a possible accident. The relieving controller continued the attempts to establish communications or determine the whereabouts of Flight 90 until the tower received a telephone call that an aircraft had crashed north of the 14th Street Bridge.

The evidence showed that the airport fire department became aware of the accident at 1603, about 2 1/2 minutes after the accident but was not officially notified until 1604. Although the notification of the fire department might have been expedited had the controller taken action to call them first immediately upon loss of the radar target, the Safety Board believes that, under the circumstances, the controller acted properly and promptly in attempting to ascertain the status of the aircraft and in notifying the fire department.

At 1606, 5 minutes after the crash, the Washington Metropolitan Area Communication Circuit of the Defense Civil Preparedness Agency was notified and it in turn alerted all circuits to an aircraft emergency. The notification included Arlington fire and police departments, U.S. Park Police, the District of Columbia fire and police departments, and the Fairfax and the Alexandria fire departments. All departments responded; however, none were properly equipped to perform a rescue operation in the ice-covered river. The Washington National Airport airboat was available for rescue efforts, but it had never been tested for performance on ice. It was launched from near the end of runway 36 at 1622, but experienced directional control difficulties and did not reach the rescue scene in time to be used to rescue the survivors. The distance traveled by the airboat was about three-quarters of a mile. The District of Columbia fire boat and harbor police boats were unable to break ice in order to reach the scene in time to be effective.

The U.S. Park Police was notified of the accident at 1606. The U.S. Park Police helicopter did reach the scene promptly and although not equipped nor required to be equipped for water rescue operations, it predominated in the rescue effort. Eagle 1, a jet-powered Bell Jet Ranger helicopter arrived on the scene at 1622. The pilot hovered the craft near the survivors while his crewman dropped make-shift rescue aids, ropes with loops and life rings to survivors in the water. The survivors were dragged to the shore in this manner. To accomplish one rescue, the crewman stood on the helicopter's skid and pulled one of the survivors from the water. The Safety Board commends the heroic actions of the helicopter pilot and crewman who participated in the rescue effort. The Board also commends the prompt and heroic actions of bystanders, one of whom disregarded personal safety and jumped into the frigid water to swim to the aid of a survivor. His action is deserving of and has met with, the highest praise and recognition. In addition, the Safety Board recognizes the unselfish act of the flight attendant who inflated the only available lifevest and gave it to one of the more severely injured passengers.

The lifevest was packaged in plastic and was difficult to open. The survivors had to chew on the package and tear it open with their teeth. The Safety Board had noted similar difficulties of opening lifevests were experienced by survivors of the National Airlines, Inc. B-727 aircraft accident near Pensacola, Florida, May 8, 1978. As a result, the Safety Board issued Safety Recommendation No. A 79-39. This recommendation specifically addressed standards for packaging along with other needed changes and asked that these changes be made in a revision of Technical Standard Order (TSO)-C-13d. However, a draft TSO on life preservers published by the FAA on November 16, 1981, had no provisions regarding packaging. The Safety Board on February 19, 1982, in responding to the draft, urged the FAA to include in the new TSO packaging standards that would assure that survivors of aircraft accidents could, under adverse conditions, easily unpack the life preserver.

FAA has not issued final TSO-C-13d, but expects to do so by the end of 1982. The Safety Board at this time does not know if the final TSO will contain standards for the proper packaging of the lifevest. The Safety Board is continuing to monitor the FAA's actions in this regard. The Safety Board again urges that the FAA include packaging standards in the TSO.

While recognizing the contribution of these individuals in rescuing the survivors of this accident, the Safety Board does not believe that the various emergency response organizations were adequately equipped for this emergency. Undoubtedly, had there been a large number of persons surviving the impact forces, many would have drowned in the icy water before they could have been rescued. The Safety Board has continually supported and advocated disaster planning and reciprocal agreements between airports and their surrounding communities. As recently as July 1981, the Washington National Airport plan was tested during a simulated ditching exercise in which the surrounding communities participated. The exercise effectively pointed out problems with equipment Also, apparently, little thought had been given to a situation involving conditions as they existed on January 13, 1982. The accident demonstrated the need for special equipment capable of being launched rapidly and of performing on ice. The Board further notes that there are no specific FAA requirements regarding the type of equipment to be maintained to accomplish rescue from waters surrounding any air carrier airports. In fact, Washington National had more equipment than was required by applicable regulations. The guidance provided in FAA Advisory Circular 150/5210-13, however, goes beyond regulatory requirements and suggests that the emergency plans, facilities, and equipment at airports include capability for water rescue for all conditions which might be encountered.

The Safety Board believes that the response capability at the Washington National Airport was not totally consistent with the guidance provided in the Advisory Circular. In that respect, there was a lack of adequate equipment and the apparent lack of planning to meet a situation of this magnitude, especially at an airport with the traffic density of Washington National.

The Board is aware of the extensive improvements which have been made at Washington National Airport since the accident. In addition to another airboat, the FAA has acquired a 22-ft Boston Wehaler boat equipped with firefighting equipment and a 40-ft steel-hull utility boat which has a limited ice breaking capability. Police and firemen have been trained in ice operations in the airboats, and have received formal CFR training in the Boston Whaler. The FAA has also purchased new rescue nets for use by helicopter crews in water operations. One net was provided to the U.S. Park Police for use in its helicopters. Finally, a diving team is being trained at Washington National Airport for use in underwater rescue and operations. The Board believes these measures are necessary at an airport with extensive water boundaries. We urge the FAA to use the same rationale for the bolstering of water rescue capability at Washington National to require additional equipment at certificated airports located next to large bodies of water.

Some of the rescue units from the District of Columbia and the surrounding communities were still en route to the Air Florida crash site when they were notified of an accident involving the Washington Metropolitan Area Transit Authority train at the Smithsonian Metro station which occurred about 1630 January 13. Several of these units were redirected to the scene of that accident. This action did not affect the rescue efforts at the aircraft accident site. However, the occurrence of two major accidents within a 30-minute period in the Washington Metropolitan area during weather conditions as they existed on January 13, 1982, placed a severe burden on the emergency response capability of those jurisdictions required to respond to both accidents. The concurrent emergencies, while unique, emphasized the need for the District of Columbia fire department to review its emergency response plans to assure that a residual rescue response capability is available at all times.

3. CONCLUSIONS

3.1 Findings

1. The aircraft was properly certificated, equipped, and maintained in accordance with existing regulations and approved procedures.

2. The flightcrew was certificated and qualified for the scheduled domestic passenger flight in accordance with existing regulations.

3. The weather before and at the time of the accident was characterized by subfreezing temperature and almost steady moderate-to-heavy snowfall with obscured visibility.

4. The aircraft was deiced by American Airlines personnel. The procedure used on the left side consisted of a single application of a heated ethylene glycol and water solution. No separate anti-icing overspray was applied. The right side was deiced using hot water and an anti-icing overspray of a heated ethylene glycol and water was applied. The procedures were not consistent with American Airlines own procedures for the existing ambient temperature and were thus deficient.

5. The replacement of the nozzle on the Trump deicing vehicle with a nonstandard part resulted in the application of a less concentrated ethylene glycol solution than intended.

6. There is no information available in regard to the effectiveness of anti-icing procedures in protecting aircraft from icing which relates to time and environmental conditions.

7. Contrary to Air Florida procedures, neither engine inlet plugs nor pitot/static covers were installed during deicing of Flight 90.

8. Neither the Air Florida maintenance representative who should have been responsible for proper accomplishment of the deicing/anti-icing operation, nor the captain of Flight 90, who was responsible for assuring that the aircraft was free from snow or ice at dispatch, verified that the aircraft was free of snow or ice contamination before pushback and taxi.

9. Contrary to flight manual guidance, the flightcrew used reverse thrust in an attempt to move the aircraft from the ramp. This resulted in blowing snow which might have adhered to the aircraft.

10. The flight was delayed awaiting clearance about 49 minutes between completion of the deicing/anti-icing operation and initiation of takeoff.

11. The flightcrew did not use engine anti-ice during ground operation or takeoff.

12. The engine inlet pressure probe (Pt_2) on both engines became blocked with ice before initiation of takeoff.

13. The flightcrew was aware of the adherence of snow or ice to the wings while on the ground awaiting takeoff clearance.

14. The crew attempted to deice the aircraft by intentionally positioning the aircraft near the exhaust of the aircraft ahead in line. This was contrary to flight manual guidance and may have contributed to the adherence of ice on the wing leading edges and to the blocking of the engine's Pt_2 probes.

15. Flight 90 was cleared to taxi into position and hold and then cleared to take off without delay 29 seconds later.

16. The flightcrew set takeoff thrust by reference to the EPR gauges to a target indicator of 2.04 EPR, but the EPR gauges were erroneous because of the ice-blocked Pt_2 probes.

17. Engine thrust actually produced by each engine during takeoff was equivalent to an EPR of 1.70 - about 3,750 pounds net thrust per engine less than that which would be produced at the actual takeoff EPR of 2.04.

18. The first officer was aware of an anomaly in engine instrument readings or throttle position after thrust was set and during the takeoff roll.

19. Although the first officer expressed concern that something was "not right" to the captain four times during the takeoff, the captain took no action to reject the takeoff.

20. The aircraft accelerated at a lower-than-normal rate during takeoff, requiring 45 seconds and nearly 5,400 feet of runway, 15 seconds and nearly 2,000 feet more than normal, to reach liftoff speed.

21. The aircraft's lower-than-normal acceleration rate during takeoff was caused by the lower-than-normal engine thrust settings.

22. Snow and/or ice contamination on the wing leading edges produced a noseup pitching moment as the aircraft was rotated for liftoff.

23. To counter the noseup pitching moment and prevent immediate loss of control, an abnormal forward force on the control column was required.

24. The aircraft initially achieved a climb, but failed to accelerate after liftoff.

25. The aircraft's stall warning stickshaker activated almost immediately after liftoff and continued until impact.

26. The aircraft encountered stall buffet and descended to impact at a high angle of attack.

27. The aircraft could not sustain flight because of the combined effects of airframe snow or ice contamination which degraded lift and increased drag and the lower than normal thrust set by reference to the erroneous EPR indications. Either condition alone should not have prevented continued flight.

28. Continuation of flight should have been possible immediately after stickshaker activation if appropriate pitch control had been used and maximum available thrust had been added. While the flightcrew did add appropriate pitch control, they did not add thrust in time to prevent impact.

29. The local controller erred in judgment and violated ATC procedures when he cleared Flight 90 to take off ahead of arriving Eastern Flight 1451 with less than the required separation and jeopardizing.

30. Eastern 1451 touched down on runway 36 before Flight 90 lifted off; the separation closed to less than 4,000 feet, in violation of the 2-mile preparation requirement in the Air Traffic Control Handbook.

31. Runway distance reference markers would have provided the flightcrew invaluable assistance in evaluating the aircraft's acceleration rate and in making a go-no-go decision.

32. The Federal Aviation Administration's failure to implement adequate flow control and the inability to use gate-hold procedures at Washington National Airport resulted in extensive delays between completion of aircraft deicing operations and issuance of takeoff clearances.

33. The average impact loads on the passengers were within human tolerance. However, the accident was not survivable because the complex dynamics of impact caused the destruction of the fuselage and cabin floor which in turn caused loss of occupant restraint. The survival of four passengers and one flight attendant was attributed to the relative integrity of the seating area where the tail section separated.

34. The crash/fire/ rescue capability of Washington National Airport meets the applicable regulations, which do not require water rescue equipment.

35. Washington National Airport had water rescue equipment available; however, it had not been tested for use in ice-covered waters and it proved ineffective.

36. The Washington National Airport crash/fire/rescue personnel were notified 3 minutes after the crash as tower personnel attempted to determine the aircraft's whereabouts.

37. Rescue of the survivors was due solely to the expeditious response of a U.S. Park Police helicopter, and the heroic actions of the helicopter crew and of one bystander.

3.2 Probable Cause

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.

4. RECOMMENDATIONS

As a result of this accident and several others involving operations in snow and icing conditions the National Transportation Safety Board issued the following recommendation to the FAA on January 28, 1982.

> Immediately notify all air carrier operators of the potential hazard associated with engine inlet pressure probe icing, and require that they provide flightcrews with information on how to recognize this hazard and requiring that flightcrews cross-check all engine instruments during the application of takeoff power. (Class I, Urgent Action) (A-82-6)
>
> Immediately review the predeparture deicing procedures used by all air carrier operators engaged in cold weather operations and the information provided to flightcrews to emphasize the inability of deicing fluid to protect against reicing resulting from precipitation following deicing. (Class I, Urgent Action) (A-82-7)

Immediately review the information provided by air carrier operators to flightcrews engaged in cold weather operations to ensure comprehensive coverage of all aspects of such operations, including the effects of a runway contaminated by snow or slush on takeoff, and methods to be used to obtain maximum effectiveness of engine anti-ice during ground operations and takeoffs. (Class I, Urgent Action) (A-82-8)

Immediately require flightcrews to visually inspect wing surfaces before takeoff if snow or freezing precipitation is in progress and the time elapsed since either deicing or the last confirmation that surfaces were clear exceeds 20 minutes to ensure compliance with 14 CFR 121.629(b) which prohibits takeoff if frost, snow or ice is adhering to the wings or control surfaces. (Class I, Urgent Action) (A-82-9)

Immediately issue a General Notice (GENOT) to all FAA tower and air carrier ground control personnel alerting them to the increased potential for aircraft icing during long delays before takeoff and when aircraft operate in proximity to each other during ground operations in inclement weather, and encouraging procedural changes where possible so that the controllers implement the gate-hold provisions of the Facilities Operations and Administration Manual 7210.3F, paragraph 1232. (Class I, Urgent Action) (A-82-10)

Document the effect of engine inlet pressure probe blockage on engine instrument readings and require that such information be added to approved aircraft flight manuals. (Class II, Priority Action) (A-82-11)

Amend Advisory Circulars 91-13c, "Cold Weather Operation of Aircraft," and 91-51, "Airplane Deice and Anti-Ice Systems," to discuss in detail the effects and hazards associated with engine inlet pressure probe icing. (Class II, Priority Action) (A-82-12)

Revise the air traffic control procedures with respect to aircraft taxiing for takeoff, holding in line for takeoff, and taking off to provide for increased ground separation between aircraft whenever freezing weather conditions and attendant aircraft icing problems exist. (Class II, Priority Action) (A-82-13)

Expand the training curricula for air traffic controllers and trainees to assure that instruction includes the hazards associated with structural and engine icing of aircraft. (Class II Priority Action) (A-82-14)

Immediately disseminate the contents of this safety recommendation letter to foreign operators involved in cold weather operations. (Class I, Urgent Action) (A-82-15)

The Safety Board has received the following response from the FAA regarding these safety recommendations:

A-82-6.--On March 11, 1982, the FAA issued Air Carrier Operations Bulletin (ACOB) No. 7-82-2, Cold Weather Procedures, emphasizing the problems associated with engine inlet icing and suggested operational procedures.

A-82-7 and 8.--These safety recommendations were provided to all air carriers via a telegraphic message on January 28, 1982. A telephone conference between FAA's Office of Flight Operations personnel and all regional Flight Standards Division Chiefs on January 29, 1982, tasked the regions to conduct a review of their operators. The request was for each principal operations inspector or appropriate aviation safety inspector to actively review the manuals and guidance on cold weather operations. The benchmarks for this review were pertinent Federal Aviation Regulations, advisory circulars, air carrier operation and maintenance bulletins, plus guidance in the January 29, 1982, telephone conference.

A-82-9.--Reference to a time such as 20 minutes since deicing or the last confirmation that the aircraft surfaces were clear is not considered in the best interest of flight safety. Under some atmospheric conditions ice may form in a much shorter period whether ground deicing has been performed or not. Flightcrews must use the "clear aircraft" concept specified by current rules without regard to specific time intervals. (The FAA response presented an extensive rationale for its position.)

As a result of the Air Florida, Flight 90, B-737 accident and the subject recommendation, the R&D effort has been accelerated. We do not anticipate that changes will be made to the existing clean aircraft concept. However, information resulting from R&D efforts is expected to emphasize improved procedures to assure that hazardous ice formation does not exist prior to takeoff.

A-82-10.--A copy of NTSB Recommendations A-82-6 through -15 was sent in its entirety to all air traffic facilities in GENOT form on January 28, 1982. The provisions of FAA Facilities Operations and Administration Manual 7210.3F, paragraph 1232, gate-hold procedures, adequately cover the handling of departure procedure delays. The GENOT of January 28 acts to remind facilities to review their application of these procedures.

A-82-11 and 12.--A new advisory circular (AC) is being developed which will include a complete discussion of the hazards of engine inlet icing; pressure probe icing and blockage, and methods a flightcrew can use to recognize these conditions and properly use the engine anti-ice system. In addition, a detailed technical analysis is being undertaken in order to include specific engine instrument reading impacts, cross-check procedures, and performance degradation parameters in this AC. Initial information from this study is being immediately disseminated to the field in the ACOB described in FAA's response to NTSB Safety Recommendation A-82-6. When completed, this AC will be forwarded to the Safety Board. Flight Manuals will be revised after the AC is completed, if such changes are deemed essential for flight safety.

In addition, the FAA will perform a detailed review of AC 91-13c and AC 91-51 in order to update them as required in areas other than that covered by the new AC on engine inlet icing.

A-82-13.--The following note was added to Handbook 7110.65C, paragraph 972b:

> Aircraft taxiing behind jet aircraft in freezing conditions may experience aggravated engine and airframe icing. For planning purposes, be alert to pilot advisories that increased taxi intervals may be used.

A-82-14.--In the meteorological portion of Phase II in the basic air traffic training program, indepth training is conducted to identify the forms of icing and its effects on aircraft performance.

Additionally, the FAA will advise the present work force via the Air Traffic Service Bulletin on the hazard associated with structure and engine icing of aircraft. The Bulletin will be published in September or October 1982.

A-82-15.--A telegraphic message was transmitted on January 28 to all FAA facilities; U.S. air carriers; U.S. owners, operators, aircraft and engine manufacturers; foreign authorities of known airplane registration; and other interested groups. This notice contained the verbatim contents of the Board's safety recommendation letter issued and transmitted to the FAA on January 28. The purpose of the transmittal to all air carrier operators and manufacturers was to ensure their awareness of the preliminary findings and recommendations as requested by the Board.

A telephone conference (telecon) was conducted on January 29 involving FAA headquarters and all FAA regional flight standards division personnel. The telecon was initiated to advise regional flight standards personnel to contact all air carriers, with the emphasis on operators of turbine-powered aircraft, to review the Board's safety recommendations and each operators' respective cold weather operational procedures, training programs, and contents of their operational manuals, as requested by the Board.

A survey report has been provided by each FAA region. This report indicates that all air carriers have been contacted and made aware of the safety recommendations and hazards associated with icing. The results of this survey indicate that there is a positive attitude on the part of industry concerning these safety recommendations.

As a part of its investigation, on May 10, 1982, the Safety Board requested the following information from the FAA:

(1) Data pertaining to, contemplated, or actual changes to the Boeing 737 (standard or advanced) FAA Approved Flight Manual.

(2) Data pertaining to the issuance or contemplated issuance of any Service Bulletins applicable to the Boeing 737 (standard or advanced) aircraft.

(3) Data pertaining to the issuance or contemplated issuance of any Operations Manual Bulletins applicable to the Boeing 737 (standard or advanced) aircraft.

(4) Data pertaining to the issuance or contemplated issuance of any revisions to the Boeing 737 Operations Manual.

(5) Data pertaining to the issuance or contemplated issuance of any revision to the Boeing 737 Maintenance or Structural Repair Manuals.

On July 27, 1982, the FAA replied that its Seattle, Washington, Area Aircraft Certification Office has requested that Boeing change appropriate Airplane Flight Manuals to more adequately cover the questions raised concerning B-737 and B-727 airplane icing of the engine inlet total pressure probe (Pt_2) and the use of engine anti-ice while on the ground. The Seattle Aircraft Certification Office has not as yet received any operational manual changes or bulletins from Boeing, and Boeing has not yet issued any B-737 service bulletins related to adverse weather operations since January 13, but that Boeing is developing a Service Bulletin which would permit the use of the wing anti-ice system on the ground.

Boeing has issued a "Telex" to all operators of B-737's and 727's on the subject of engine Pt_2 icing. Boeing is reviewing both the B-737 Operations Manual and Maintenance Manual. The review is not complete. Service letters have been sent to all B-737 and 727 airline representatives on the Pt_2 vent.

As a result of its analysis of the investigation of this accident, on August 11, 1982, the Safety Board issued the following additional recommendations to the Federal Aviation Administration:

> Issue a Maintenance Alert Bulletin to require Principal Maintenance Inspectors to emphasize to air carrier maintenance departments that proper maintenance of ground support equipment may be critical to flight operations and the importance of adhering to maintenance practices recommended by the manufacturers of such equipment. (Class II, Priority Action) (A-82-79)
>
> Issue a Maintenance Alert Bulletin to require Principal Maintenance Inspectors to review contract agreements between an air carrier operating into a facility at which another air carrier or maintenance contractor is providing maintenance services to assure that the responsibilities of both parties and key personnel are clearly defined and that the contractor providing the maintenance is thoroughly familiar with the maintenance of the type of aircraft involved. (Class II, Priority Action) (A-82-80)
>
> Issue an Operations Alert Bulletin to require Principal Operations Inspectors to require that air carrier training programs adequately cover the effects of aircraft leading edge contamination on aerodynamic performance, particularly as it affects the relationship between airspeed and angle of attack and those functions whose activation is dependent on the angle of attack, such as stall warning systems and autothrottle speed command systems. (Class II, Priority Action) (A-82-81)
>
> Require revision of the B-737 Approved Flight Manual to add "anti-ice" to the normal taxi and takeoff checklist. Review the checklists for all air carrier aircraft to ensure that all action items required for a successful takeoff are included on the appropriate checklist. Special consideration should be given to items whose functions may be affected by environmental conditions subject to change during ground delay periods. (Class II, Priority Action) (A-82-82)

Issue an Airworthiness Directive to implement the necessary airplane modifications and/or changes in operational procedures for B-737 aircraft takeoff operations during weather or runway conditions conducive to the formation of leading edge frost, snow, or ice contamination to require either: (1) that the leading edge is free of frozen contaminant through the pretakeoff use of a ground-operable wing thermal anti-ice system, or (2) an increased stall airspeed margin at liftoff which will provide adequate pitch and roll control to counter the effects of undetected leading edge contaminants by modification of takeoff flaps configuration and/or increased takeoff airspeed schedules. (Class II, Priority Action) (A-82-83)

Amend Air Traffic Control coordination procedures and practices to require that terminal and en route facilities provide the Central Flow Control Facility (CFCF) with current and accurate information regarding congestion and that CFCF act on that information in a positive manner to minimize airport saturation and extensive traffic delays. Review implementation of prescribed gate-hold procedures and require their use wherever possible. (Class II, Priority Action) (A-82-84)

Issue a General Notice to terminal area Air Traffic Control facilities to emphasize to controllers that the separation criteria set forth in FAA Air Traffic Control Handbook 7110.65C which require a minimum of 2 miles separation do not permit deviation based upon the anticipated acceleration differences between landing and departing traffic. (Class II, Priority Action) (A-82-85)

Evaluate the criteria and current practices of Air Traffic Control facilities regarding the declaration and reporting of operational errors to ensure that all such errors are reported and are investigated. (Class II, Priority Action) (A-82-86)

Provide for essential equipment and increased personnel training to improve the water rescue capabilities at the Washington National Airport in all anticipated weather conditions, and provide necessary funding for surrounding communities and jurisdictions which will be called on to support the airport's rescue response. (Class II, Priority Action) (A-82-87)

Survey all certificated airports having approach and departure flightpaths over water and evaluate the adequacy of their water rescue plans, facilities, and equipment according to the guidance contained in Advisory Circular 150/5210-13 and make recommendations for improvement as necessary to appropriate airport authorities. (Class II, Priority Action) (A-82-88)

Amend 14 CFR 139.55 to require adequate water rescue capabilities at airports having approach and departure flightpaths over water which are compatible with the range of weather conditions which can be expected. (Class II, Priority Action) (A-82-89)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ G.H. PATRICK BURSLEY
Member

/s/ DONALD D. ENGEN
Member

August 10, 1982

APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

Investigation

The Safety Board was notified of this accident about 1603 on January 13, 1982. An investigative team was dispatched immediately but full team activity was delayed for several hours because of severe weather conditions and local transportation emergencies. Working groups were established for operations, air traffic control, witnesses, aircraft records, human factors, weather, powerplants, systems, structures, flight data and cockpit voice recorders, aircraft performance and human performance.

Participants in the on-scene investigation included Air Florida Inc., Federal Aviation Administration, Air Florida Pilots Association, Airline Pilots Association, Allied Pilots Association, the Boeing Company, Pratt & Whitney Division of United Technologies, and the International Association of Machinists.

Public Hearings

A public hearing was convened on March 1, 1982, and completed on March 9, 1982.

Parties to the hearing included the Federal Aviation Administration, Air Florida Inc., Air Florida Pilots Association, Airline Pilots Association, Allied Pilots Association, the Boeing Company, and the Pratt & Whitney Division of United Technologies.

APPENDIX B

PERSONNEL INFORMATION

Mr. Larry Michael Wheaton - Captain

Captain Wheaton, age 34, was employed by Air Florida, Inc. in October, 1978. He qualified as a first officer in the DC-9 in October 1978 and qualified as a first officer in the B-737 in June of 1979. He was upgraded to captain in the B-737 on August 27, 1980. Captain Wheaton held airline transport pilot certificate No. 1669130, dated April 2, 1980, for airplane multiengine land with ratings in the DC-3 and B-737 aircraft and commercial privileges airplane single engine land. His Flight Instruction certificate, No. 16669130 CFI, dated June 29, 1974, for airplanes single and multiengine- instrument, had expired.

His current first class medical certificate, dated October 12, 1981, contained no limitations.

Captain Wheaton had approximately 8,300 flight hours, about 2,322 of which were accumulated with Air Florida, Inc. His commercial jet operating experience, all with Air Florida, Inc. consisted of the following: (times are approximate) DC-9 first officer 471, B-737 first officer 752, B-737 captain 1,100.

In the past 90 days, 30 days, and 24-hours, Captain Wheaton flew about 221 hours, 64 hours, and 2 hours 14 minutes respectively.

His duty time (flight and standby) the previous 24-hours was approximately 5 hours and 46 minutes. His rest time during the 24-hours prior was about 18 hours 14 minutes. Total duty time the previous 30, 60, and 90 days was approximately 177 hours, 372 hours and 642 hours respectively.

Mr. Roger Alan Pettit - First Officer

First Officer Pettit, age 31, was employed by Air Florida, Inc. on October 3, 1980. He became qualified as a first officer in the B-737 on November 23, 1980. First Officer Pettit held airline transport pilot certificate No. 1795470, dated June 14, 1979, for airplane multiengine land with a rating in the CE-500 and commerical privileges airplane single engine land.

His current first class medical certificate, dated September 15, 1981, contained no limitations.

First Officer Pettit had approximately 3,353 flight hours, about 992 of which were accumulated with Air Florida, Inc. - all in the B-737. Prior to being hired by Air Florida, Inc. First Officer Pettit was a fighter pilot in the United States Air Force. From October 1977 to October 1980 First Officer Pettit accumulated 669 flight hours as a flight examiner, instructor pilot, and ground instructor in an operational F-15 unit.

In the past 90 days, 30 days, and 24 hours, First Officer Pettit flew about 180 hours, 66 hours, and 2 hours 14 minutes respectively.

His duty time (flight and standby) the previous 24 hours was approximately 5 hours and 46 minutes. His rest time during the 24 hours prior was about 18 hours 14 minutes. Total duty time the previous 30, 60, and 90 days was approximately 179 hours, 390 hours and 505 hours respectively.

Cabin Crew

Ms. Kelly Duncan, age 22, had previously flown for Air Sunshine, an airline acquired by Air Florida. She completed initial training for Air Florida on September 15, 1979, and since then had completed recurrent training in February 1980 and in February 1981. Her January 1982 schedule was in B-737's. She had flown 26 hours and 25 minutes during January 1982.

Ms. Donna Adams, age 23, completed initial training for Air Florida on June 30, 1978, and had completed recurrent training in October 1978, October 1979, October 1980, and in October 1981. Her January 1982 schedule was in B737's. She had flown 26 hours and 25 minutes during January 1982.

Ms. Marilyn Nichols, age 25, completed initial training for Air Florida on November 16, 1979, and had completed recurrent training in July 1980 and in July 1981. Her January 1982 schedule was in B-737's. She had flown 26 hours and 25 minutes during January 1982.

APPENDIX C

AIRCRAFT INFORMATION

The aircraft was a Boeing 737-222. The aircraft, United States registry N62AF, serial No. 19556 was obtained by Air Florida from United Airlines on July 28, 1980, and had been operated continuously by Air Florida since that date. The aircraft total time as of January 1, 1982, was 23,608.44 at departure from Miami.

Statistical Data

Aircraft	
Date of Certification	February 25, 1969
Fuselage Number	P2600
Serial Number	19556
Registration Number	N62AF
Airframe Hours	23610:40 at departure DCA
Airframe Cycles	29549 at departure DCA

An original standard Airworthiness Certificate, Transport Category was issued February 20, 1969.

The aircraft was issued a valid Certificate of Registration dated October 2, 1980, in the name of Weiler, Alan G., Trustee, 1114 Avenue of the Americas, New York 10036.

Engines

Number 1 Engine		Number 2 Engine	
Type Pratt & Whitney	JT8D-9A	Type Pratt & Whitney	JT8D-9A
Date of Manufacture	4-14-68	Date of Manufacturer	7-2-71
Serial Number	P655929B	Serial Number	P674546[illegible]
Total Time	20,762:20	Total Time	17,091.3[illegible]
Time Since Overhaul	20,762:20	Time Since Overhaul	9,171:15
Total Cycles	26,955	Total Cycles	16,661
Date of Installation	7-29-81	Date of Installation	8-5-81

Under Letter of Agreement with American Airlines, signed by American Airlines, Inc., Director of Interline Service Agreements and Air Florida, Inc., Senior Vice President, American Airlines, Inc., provided the following services to Air Florida, Inc., at Washington National Airport:

Aircraft Loading and Unloading
Transportation of Passengers, Baggage, Mail & Cargo
Aircraft Cabin Cleaning
Weight and Balance Computation
Aircraft Marshall and Push Out
On Call Minor Emergency Aircraft Maintenance as defined by American Airlines (Air Florida's Technical Representative to provice guidance and sign aircraft log).

APPENDIX D

AIRPORT BULLETIN

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
METROPOLITAN WASHINGTON AIRPORTS

DCA 7/4J

Date: October 9, 1981

Cancellation
Date: April 1, 1982

SUBJ: CONTROL OF SNOW, SLUSH AND ICE EMERGENCIES

1. PURPOSE. This Airport Bulletin is issued to assign responsibilities and establish procedures to be followed in removing and controlling snow, slush, ice, sand or water at Washington National Airport.

2. REFERENCE.

a. FAA Advisory Circular 150/5200.23 dated November 1, 1976.

b. FAA Advisory Circular 150/5380-4, dated September 11, 1968.

3. GENERAL CONSIDERATIONS. Snow fall or icing conditions of sufficient proportions to create hazardous situations on the operating surfaces of the airport may be expected at Washington National Airport several times during each winter season and will require removal or control measures to be placed in effect. The primary objective is to preserve or restore the operational capability of the airport and to maintain sidewalks, streets and approach roads in a safe usable condition so that essential services will not be interrupted. In achieving this objective, procedures must be initiated promptly and conducted in a manner to cause the least interference possible with aircraft movements and other vital activities of the airport.

4. RESPONSIBILITIES. Effective and rapid prosecution of the snow clearance program will be accomplished only with close and continued coordination among all activities concerned, particularly the Operations Division, Engineering and Maintenance Division, airline committees, and Airport Control Tower. Specific responsibilities are assigned as follows:

a. The Chief, Operations Division is responsible for:

(1) Contacting the Snow Removal Activities Director, Engineering and Maintenance Division, when information reveals the possibility of snow or icing conditions in the Metropolitan Area.

(2) Deciding when snow removal and ice control operations shall begin based on his evaluation of the existing conditions, after a study of present and forecast weather, and normally after discussion with the Airport Manager, Chief, Air Traffic Controller, Snow Activities Director, and the Airline Snow Committee.

Distribution: DCA-3, All Tenants, Concessionaires and Air Carriers

Initiated By: AMA-120

(3) Determining after full evaluation which removal plan will be effected (Ref: Par. 6.a.(2)). This decision must be based on the character of precipitation, predicted winds, anticipated traffic, and an evaluation of the overall situation.

(4) Maintaining liaison with the Airport Manager and the Chief Air Traffic Controller on anticipated or planned snow clearance operation on the aircraft operating areas.

(5) Issuing NOTICE TO AIRMEN to report changing field conditions.

(6) Determining the condition of runways and taxiways whenever there is any question concerning the surfaces. This is normally to be done in coordination with, and using designated representatives of the Airlines Snow Committee and the others mentioned above, as appropriate.

(7) Requesting braking action measurement be made when conditions warrant such action.

b. The Chief, Engineering and Maintenance Division is responsible for:

(1) Providing and maintaining, in an operable condition, all heavy equipment and related servicing facilities expected to be required during the snow removal season.

(2) Training and qualifying snow controllers and equipment operators who will be completely familiar with radio control procedures, the layout of runways and taxiways, and the location of lighting fixtures, and other airport features subject to damage in the course of snow removal.

(3) Establishing procedures for assembling crews when existing or forecast conditions indicate a need for snow removal or sanding operations outside of regular working hours.

(4) Taking action to place sidewalks, streets and roadways in useable condition.

(5) Measuring the braking action of the runways when conditions indicate such measurement is needed.

5. GENERAL PROCEDURES. The following general procedures shall be followed unless circumstances clearly justify a deviation therefrom:

a. Actual plowing or sweeping shall be started at the discretion of the Chief, Operations Division, or following coordination specified in Paragraph 4.

b. Normally, Runway 18-36 will be cleared first to put the airport in the position to accept lower minimum instrument approaches.

c. Sanding operations shall be conducted on runways and taxiways at any time icing or slippery conditions make additional traction desirable. Sand of needed specification - as to grade or temperature, or both - will be used.

d. Runway deicer will be used on the runways whenever there is a condition of packed snow or ice that cannot be removed mechanically. The material will be distributed on the runways a minimum of 150 feet wide and full length if necessary. The use of the runway deicer must have the prior approval of the Airport Manager.

e. The use of shotted urea as a melting agent is authorized on sidewalks, passenger walkways, gate positions, ramps, aprons, taxiways, runup blocks, and runways.

f. Prompt attention will be given to correcting dangerous slush conditions.

g. When slippery conditions exist on any aircraft operating area, to the extent possible, operational tests shall be used to measure the degree of braking actions - taking pilot reports into primary account at all times. The results will be translated into appropriate terminology for use in the issuance of NOTAMS.

h. Control over all snow/sand equipment while it is on the airfield rests with the Snow Removal Activities Director in coordination with the Tower by means of a radio-equipped vehicle.

i. When a prolonged delay is encountered in crossing an active intersection, the Operations Officer will be notified of the condition. He will then request the Control Tower to suspend operations until equipment can cross.

j. The operators of snow equipment maneuvering on the airfield shall exercise extreme caution to avoid conflict with ground traffic or to otherwise create a hazard.

6. SPECIFIC PROCEDURES. The following procedures for snow removal operations at Washington National Airport will be strictly adhered to:

a. Pre-snow removal decisions will be limited to:

(1) Time airport will be closed.

(2) Effect either Plan A, B, C, or alternate Plan A, (with appropriate attendant procedures specified under Paragraphs 7. and 8.), in its entirety without deviation. Alternate Plan A will be effected only under an extremely heavy accumulation or continuing precipitation.

b. The announced time of airport closing will be firm and unchangeable, weather conditions permitting. All aircraft movements on the airport will cease at that time, and no takeoffs or landings will be permitted until the removal plan in effect is completed.

c. A NOTAM will be issued two (2) hours in advance of closing, when possible.

d. When the first designated removal operations Plan (A, B, or C) is completed, the airport will be opened thereby cancelling the NOTAM. The next designated removal plan will then be executed if the Snow Removal Activities Director in charge determines it feasible, depending on the conditions of equipment and employees.

7. SPECIFIC PLANS.

a. Plan A (Runway 18-36).

(1) All airfield snow removal equipment will be ready at the west end of Taxiway Alpha, north side of the Air Cargo Building, at the designated closing time of the airfield (Applicable to Plans A, B, and C).

(2) The equipment will proceed up vehicle traffic lane to Taxiway Bravo, plowing as they go. At this point, some equipment will continue cleaning vehicular lane, ramp (east of vehicular lane), and Taxiway Lima to Hangar 12 (Applicable to Plan A, B, and C).

(3) All other equipment will clean Taxiway Bravo to Taxiway Alpha, Taxiway Alpha east to Taxiway Charlie, and Taxiway Charlie from Runway 3/21 to Runway 18/36, Runway 18/36 to Taxiways Echo, Foxtrot, Hotel west 18/36, India between Runway 18/36 and Kilo, Juliet between Runway 15/33 and Runway 18/36; and 100 feet of Taxiways Hotel and Mike east of 18/36, then Runway 15/33 from 40 feet from intersection of 18/36 to 100 feet northwest of Taxiway Juliet, Taxiways Juliet from Runway 15/33 to ramp.

b. Alternate Plan A - Runway 18/36.

(1) See Paragraph (1) and (2) of Plan A.

(2) All other equipment will clean Taxiway Bravo to Taxiway Alpha, Taxiway Alpha east to Taxiway Charlie, and Taxiway Charlie from Runway 3/21 to Runway 18/36. Runway 18/36 (150 feet wide only), Runway 3/21 between Taxiway Delta and Runway 18/36, Taxiway Delta, Runway 15/33 between Runway 18/36 and Taxiway Juliet, and Taxiway Juliet from Runway 18/36 to ramp.

c. Plan B (Runway 15/33).

(1) See Paragraph (1) of Plan A.

(2) The equipment will proceed up vehicular traffic lane from Hangar 7 to the runup block of 15/33 plowing as they go. Ramp snow removal detail will continue cleaning Taxiway Lima and ramp from runup block of 15 to Hangar 7. All other equipment will clean Runway 15/33, Taxiway Kilo, Hotel and Foxtrot.

d. Plan C (Runway 3/21).

(1) See Paragraphs (1) and (2) of Plan A.

(2) Clean Taxiway Bravo, Runway 3/21, Taxiways Hotel, west of 3/21, Mike and Foxtrot, west of 18/36.

e. Other Snow Removal Procedures.

(1) Snow from Hangar 6 Ramp. The Hangar 6 tenant is responsible for clearing snow from his ramp. Snow shall be piled on each side of the ramp adjacent to the ramps of Hangars 5 and 7. Snow will be removed from these areas by the DCA Engineering and Maintenance Division as soon as practical.

(2) Snow from Gate Position. Once the plows have started plowing the vehicular lane and ramp, snow shall not be pushed from gate positions or from in front of Hangars on or across the vehicular lane. Any snow, west of the vehicular lane, shall be piled in designated areas by the tenants.

(3) Aircraft Parking on South Hangar Line, Southeast of Vehicular Lane. Aircraft shall be moved prior to the time airport is closed. This must be strictly adhered to because the plows and blowers will start at Hangar 7 in the vehicular lane and plow north. Snow from the blowers could cause heavy damage to any aircraft parked in this area.

(4) Cargo Building.

(a) Airport plows will clean the vehicular lane to the Post Office on the field side, and remove snow within 20 feet of the loading dock on the south side of the Cargo Building if area is clear of tenant equipment.

(b) All vehicles and cargo equipment under the jurisdiction of the tenant group, and all delivery vehicles shall be kept clear of these areas so that the plows can operate efficiently. The tenants shall be responsible for cleaning all other areas.

(c) Snow shall not be pushed from ramp side into vehicular traffic lane once the plows have started plowing vehicular lane.

(5) Levee Road, Landing Aid Sites, Radar, etc., Roads to Cargo Buildings, United Air Freight and Post Office for a width of 20 feet, and other Airport Public Roads plus Sidewalks and Stairways used by the General Public (including the Ramp from the GW Parkway to Route 233). The airport will effect removal operations in these areas in conjunction with runway cleaning. However, the runway cleaning will have priority over all other operations.

(6) Closed Areas. All taxiways not mentioned in Plans A, B, or C shall be closed until the equipment is checked and repaired.

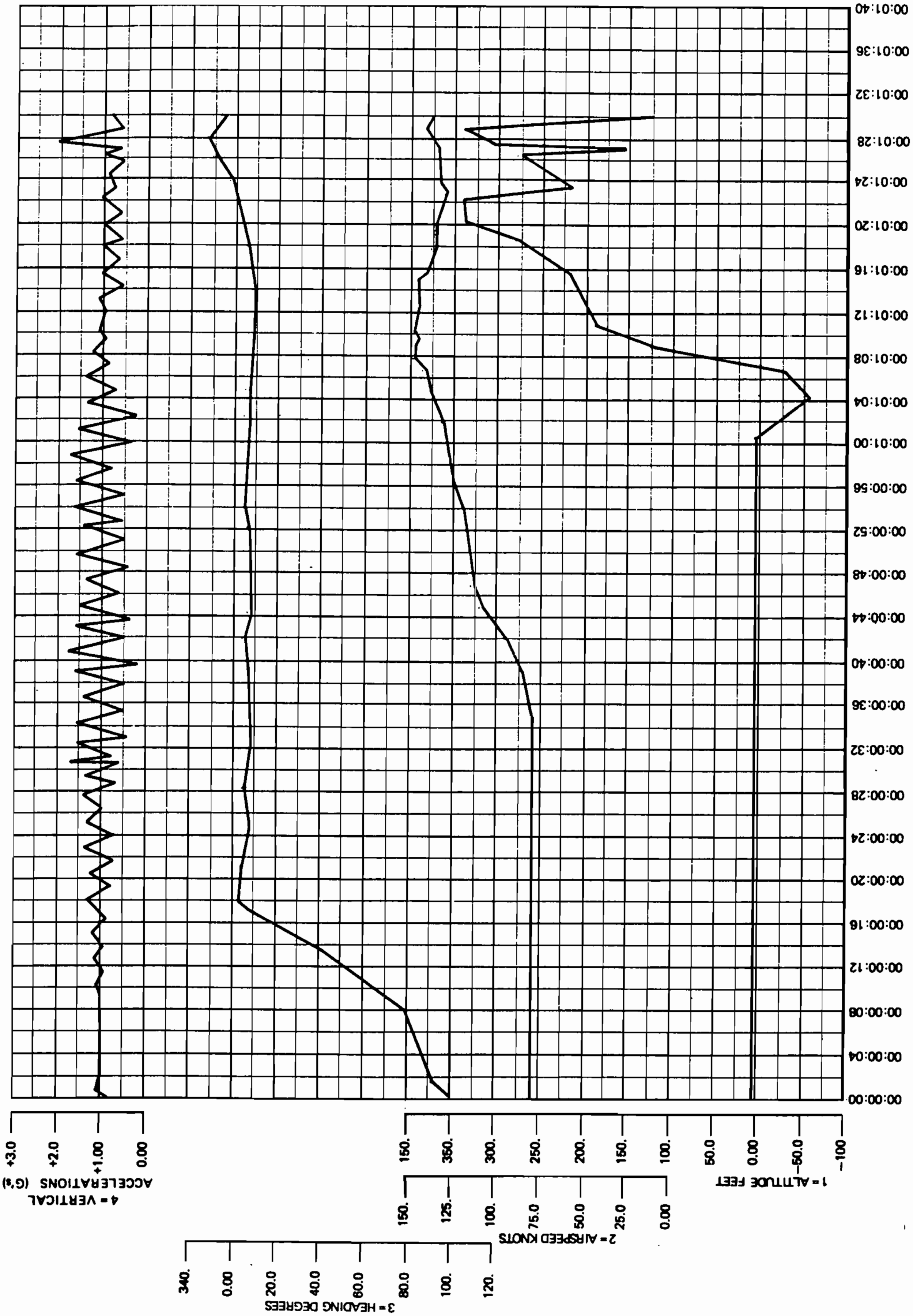
(7) Snow Dumping Areas. All tenants shall use designated snow dumping area at the north end of the field. The use of the north end will be restricted as follows: No more than two vehicles will be allowed in the area at any one time and no snow pile will exceed five (5) feet in height from the ground surface.

(8) Small Plane Parking (Taxiway Lima). Snow removal operations on Taxiway Lima will result in forming a windrow between Taxiway Lima and the small aircraft parking area. This will be removed when the required runway plan(s) are completed, except for entrance exit at north and south end, which will be cleaned in connection with Taxiway Lima.

NOTE: Past experience has indicated that the most effective, economical and overall time saving procedure in removing snow and providing maximum aircraft operational capability is to execute Plan A, B, and C in that order when permissible. However, Plan C will not be initiated without the express permission of the Airport Manager.

Augustus A. Melton, Jr.
Airport Manager, DCA

APPENDIX E



Flight Data Recorder Graph

APPENDIX F

TRANSCRIPT OF A SUNDSTRAND V-577 COCKPIT VOICE RECORDER S/N 2282 REMOVED FROM AN AIR FLORIDA B737 WHICH WAS INVOLVED IN AN ACCIDENT AT WASHINGTON, D. C., ON JANUARY 13, 1982

LEGEND

CAM	Cockpit area microphone voice or sound source
RDO	Radio transmission from accident aircraft
-1	Voice identified as Captain
-2	Voice identified as First Officer
-3	Voice identified as Head Stewardess
-4	Voice identified as Stewardess
-?	Voice unidentified
TUG	Tractor
INC	Intercom
AOPS	American Operations
LC	Tower (Local Control)
PA	Public address system
GND	Ground Control
E133	Eastern one three three
625	One six two five
NYA 58	New York Air fifty-eight
556	TWA five fifty-six
00J	Eight thousand juliet
451	Eastern fourteen fifty-one
41M	Four one mike
68G	Six eight gulf
*	Unintelligible word
#	Nonpertinent word
%	Break in continuity
( )	Questionable text
(( ))	Editorial insertion
---	Pause

Note: All times are expressed in local time based on the 24-hour clock.

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
CAM-2	* figure it out	1530:48 TUG	You have your brakes on right?
CAM-2	We're too heavy for the ice	INC-1	Yeah, brakes are on
CAM-2	They get a tractor with chains on it? They got one right over here		
	((PA announcement relative to pushback))		
		1531:33 AOPS	Palm ninety from American Operations
		1531:36 RDO-2	Palm ninety, go ahead
		1531:38 AOPS	Okay, your agent just called to tell me to tell you to amend your release showing nineteen twenty-five zulu per initial RH
		1531:51 RDO-2	Okay, nineteen twenty-five romeo hotel, thanks
CAM-1	That's not so # great	AOPS	Roger, how's it look for you, you gonna be departing soon, I hope
		1532:03 RDO-2	Well, we're working on it, what time does he say to do it, it's twenty thirty-five right now

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM-1	Ah we'll take that
1532:22 CAM-2	I hadn't called ground to tell 'em we didn't make it, do you want me to tell 'em?
CAM-?	* * call 'em and tell 'em * *
CAM-2	I'm surprised we couldn't power it out of here
CAM-1	Well we could of if he wanted me to pull some reverse
CAM-?	*
1532:59 CAM-1	I've done it in Minneapolis and I had to come up to one point four, one point five
1533:05 CAM-1	It had chains on it
1533:15 CAM-2	((Chuckle)) did you hear that guy, think he'll get a gate in a second, I don't see anybody pushing

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1532:07 AOPS	That's the interesting thing, he said nineteen twenty-five, let me give him a buzz back cause we think that maybe he meant twenty twenty-five, hang on
1532:18 RDO-2	Okay

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM-2	Want me to tell Ground that we're temporarily indisposed?
1533:25 CAM-2	He'll call us surely
CAM-2	Where are you guys?
CAM-?	* *
CAM-2	Huh
CAM-?	* *
1533:40 CAM-2	It's twenty-five, it's not too cold really
CAM-1	It's not really that cold
CAM-2	It's not that cold, cold, like ten with the wind blowing, you know
1534:09 CAM-2	People's going to deplane in the snow here
CAM-2	Piedmont's going to park it on the ramp
1534:24 CAM-1	Here comes the chain tractor

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT

- 4 -

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1535:14 CAM-2	Well that's a difference, do you want twenty-five (or start up)
CAM-2	Yeah
1535:40 CAM-2	I guess (I) never even thought about it being a little plane like this, figured they'ed push it out of there, you know but we're pretty heavy, we're a hundred and two thousand sittin' there
1536:13 CAM-2	Maybe we can taxi up side'a some seven two sittin' there runnin', blow off whatever (accumulated on the wings)

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1535:06 TUG	Ready to roll
INC-1	Ready to roll
TUG	Brakes off
INC-1	Brakes are off, "A" pumps are off, interconnects closed
TUG	Bet those vacuum cleaners would do wonders as a snow melter
INC-1	Sure do
1536:19 TUG	You can start engines if you want, I don't know whether you got 'em running or not

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1536:50 CAM-1	Checklist again, right
CAM-2	We did it and we're down to before start, that's all
CAM-2	Shoulder harness
CAM-1	On
CAM-2	Air conditioning pack
CAM-1	Off
CAM-2	Start pressure
CAM-1	Up

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1536:23 INC-1	I'll tell you what, I'm gonna wait till you disconnect before I start them up so I can get the buckets closed
1536:31 GND	Okay, parking brakes
1536:34 INC-1	Okay, brakes are set
TUG	Stand by for salute and we'll see ya later
1536:43 INC-1	Right'o, thanks a lot

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
CAM-2	Anti-collision		
CAM-1	On		
CAM-2	Starts complete		
		GND	%
1537:01 CAM-2	LaGuardia's not accepting anybody right now		
CAM-3/4	Is it raining in Tampa?		
CAM-2	Rainy and foggy		
CAM-3/4	How is the temperature?		
CAM-?	Fifty		
CAM-2	Sixty		
CAM-1	((Sound of laughter)) can they land here?		
1537:31 CAM-2	Drop		
CAM-2	Oil pressure		
1537:41 CAM	((Strange sound apparently associated with engine start))		
1537:46 CAM-2	(Eighty-seven) (bet it feels like a gas stove)		
CAM-1	Temperature		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1537:49 CAM-2	(Isn't that an artist though)
CAM-1	Huh -- oil pressure
1538:06 CAM	((Second strange sound apparently associated with engine start))
CAM	((Sound of igniters))
CAM-1	Stowed
CAM-2	Cut out
1538:16 CAM-1	After start
CAM-2	Electrical
CAM-1	Generators
CAM-2	Pitot heat
CAM-1	On
CAM-2	Anti-ice
CAM-1	(Off)
CAM-2	Air conditioning pressurization

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT

APPENDIX F

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM-1	Packs on flight
CAM-2	APU
CAM-1	Running
CAM-2	Start levers
CAM-1	Idle
CAM-2	Door warning lights
CAM-1	Out
CAM-2	You want me to hold the flaps till we get up closer?
CAM-1	He said something about Palm
CAM-2	Yeah
CAM-2	((Chuckle))

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1538:22 GHD	Can you get around that Palm on the pushback
1538:34 RDO-2	Ground Palm ninety, we're ready to taxi out of his way
1538:38 GND	Okay Palm ninety, roger, just pull up over, behind that, ah, TWA and hold right there, you'll be falling in line behind a, oh, Apple DC nine

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM	((Sound of takeoff warning))
1538:58 CAM-2	Behind that Apple, I guess
CAM-1	Behind what TWA?
1539:04 CAM-2	Over by the TWA to follow that Apple, apparently
CAM-2	((Whistling))
1539:29 CAM-2	Boy, this is shitty, it's probably the shittiest snow I've seen
CAM	((Sound of takeoff warning horn))
CAM	((Beginning of flight attendant P/A))
1540:15 CAM-1	* * go over to the hangar and get deiced
CAM-2	Yeah
CAM-2	Definitely

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1538:47 RDO-2	Palm one ninety

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
CAM-1	* * deiced * * ((laughter))		
CAM-2	Yeah, that's about it		
1540:42 CAM-2	It's been a while since we've been deiced		
CAM-1	Thank I'll go home and (play) * *		
1541:24 CAM-2	That Citation over there, that guy's about ankle deep in it		
CAM	((Sound of laughter))		
1541:47 CAM-2	Hello Donna		
CAM-3	I love it out here		
CAM-2	It fun		
CAM-3	I love it		
CAM-3	The neat way the tire tracks		
1541:52 CAM-2	See that Citation over there, looks like he's up to his knees		
CAM-4	Look at all the tire tracks in the snow		
CAM-3	Huh		

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
CAM-4	The tire tracks in the snow		
CAM-3/4	* * *		
1542:13 CAM-2	No that's a DC nine Apple New York Air		
CAM-4	Is that the way ours are, that low to the ground, too		
1542:21 CAM-2	I don't know, those are dash tens there, aren't they, DC nine dash tens, don't know what we had, thirties? Is that a thirty?		
CAM-4	It is *		
1542:29 CAM-1	Doesn't look like it, I can't see, I can't tell		
CAM-1	I need to see something other than what we're looking at		
1542:59 CAM-2	((Sound of whistling))		
CAM-1	* * snow * * snow		
1543:22 CAM-2	Pretty poky		
CAM-4	What does the "N" stand for on all the aircraft, before the number?		
CAM-1	U. S. registered		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM-2	U.S. United States see everyone of of them have an "N" on it see, then you see somebody else like. ah
CAM-4	(Like Bahamas)
1543:37 CAM-1	"C" is Canada, yeah I think, or is it "Y"?
CAM-2	I think, I think it is "C"
CAM-2	There's, ah, you know, Venezuela
CAM-2	Next time you have a weird one, you can look up
CAM-3/4	* * *
CAM-2	Stand by a second
1544:59 CAM-2	I never got back to Operations on the twenty twenty-five, we can put twenty-five, romeo hotel, just, just go for it
CAM-2	That's what time it is, awhile ago instead of nineteen twenty-five, I think the guy just * * he added four instead of five
CAM-1	That's why I said, that's why I gave the agent twenty-five so I wouldn't have to be concerned with that #

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
RDO	((Radio call pertaining to Palm))

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM-2	What's our release good for, one hour? one hour release
CAM-2	Ha, ha, god he said LaGuardia is not taking anybody, # it's early yet ((sound of laughter)) we may end up in Kennedy or somewhere, you never know ((sound of laughter))
1545:43 CAM-1	Bradley, Albany
CAM-2	Yeah
1545:51 CAM-2	There's PSA's Eastern jet coming in ((sound of laughter))
CAM-2	And they used to laugh at us for flying those green tails, you know
CAM-2	Whatever it was
1546:21 CAM-1	Tell you what, my windshield will be deiced, don't know about my wing
1546:27 CAM-2	Well all we really need is the inside of the wings anyway, the wing tips are gonna speed up by eighty anyway, they'll, they'll shuck all that other stuff ((sound of laughter))
1546:34 CAM-2	There's Palm thirty-five coming in

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1546:51 CAM	((Sound of takeoff warning))
1547:01 CAM-2	Yeah, Palm thirty-five's in the holding pattern right now
1547:32 CAM-1	(Gonna) get your wing now
1547:37 CAM-2	D'they get yours? can you see your wing tip over 'er?
CAM-1	I got a little on mine
CAM-2	A little
1547:46 CAM-2	This one's got about a quarter to half an inch on it all the way
1547:53 CAM-2	Look how the ice is just hanging on his, ah, back, back there, see that?
CAM-2	Side there
1548:06 CAM-2	W'its impressive that these big old planes get in here with the weather this bad you know, it's impressive

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
1548:13 CAM-2	It never ceases to amaze me when we break out of the clouds, there's the runway anyway, d'care how many times we do it. God, we did good! ((sound of laughter))		
1548:24 CAM-2	See all those icicles on the back there and everything		
CAM-1	Yeah		
1548:31 CAM-2	He's getting excited there, he got his flaps down, he thinks he's getting close ((sound of laughter))		
1548:59 CAM-2	See this difference in that left engine and right one		
CAM-1	Yeah		
CAM-2	Don't know why that's different		
1549:05 CAM-2	Less it's his hot air going into that right one, that must be it		
CAM-2	From his exhaust		
CAM-2	It was doing that in the chocks awhile ago but, ah		
		1549:42 GND	Okay, Palm ninety, cross runway three and if there's space and then monitor the tower on nineteen one, don't call him, he'll call you

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
		1549:49 RDO-2	Palm ninety
CAM-?	((Sound of whistling))		
1550:08 CAM-2	I'm certainly glad there's people taxiing on the same place I want to go cause I can't see the runway, taxiway without these flags ((sound of takeoff warning))		
1550:29 CAM-?	((Sound of whistling))		
1550:38 CAM-1	Where would I be if I were a holding line?		
CAM-2	I would think that would be about right here, agreed?		
1550:45 CAM-2	May be a little further up there, I don't know		
CAM-1	Ah, # he's barely off of it		
CAM-2	I know it		
1551:05 CAM-2	This thing's settled down a little bit, might'a been his hot air going over it		
1551:13 CAM	((Sound of takeoff warning))		

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
1551:23 CAM-4	We still fourth		
CAM-2	Yeah		
CAM-4	Fourth now		
1551:38 CAM-2	We're getting there, we used to be seventh		
1551:49 CAM-?	((Sound of whistling))		
1551:54 CAM-1	Don't do that Apple, I need to get the other wing done ((sound of laughter))		
		1552:04 LC	Now for Palm ninety, if you're with me you'll be going out after, ah, the red DC nine Apple type
		1552:09 RDO-2	Palm ninety
CAM	((Sound of laughter))		
		1552:30 RDO	((Tower gives direction to Eastern concerning CAT two line))
CAM-2	That guy shooting CAT two ILS's there says how come there was a small Lear on the runway when we ((sound of laughter))		
CAM-1	When we landed on the taxiway		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1552:42 CAM-1	You ought to talk to Rich Lussow, he landed on a --- landed on a closed runway in, ah, Chicago
1552:49 CAM-2	Accidently
1552:53 CAM-1	In about sixteen inches, a seven two seven, that # stopped just like that
CAM-2	I'll bet it did smooth deceleration, eh, ((sound of laughter)) mwaugh
1553:21 CAM-2	Boy, this is a, 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
CAM-1	That, ah, satisfies the Feds
CAM-2	Yeah
CAM-2	As good and crisp as the air is and no heavier than we are I'd
CAM-1	Right there is where the icing truck, they oughta have two of them, you pull right
CAM-2	Right out
1553:42 CAM-1	Like cattle, like cows right
CAM-1	Right in between these things and then

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM-2	Get your position back
CAM-1	Now you're cleared for takeoff
CAM-2	Yeah and you taxi through kinda like a car wash or something
CAM-1	Yeah
1553:51 CAM-1	Hit that thing with about eight billion gallons of glycol
1554:04 CAM-1	In Minneapolis, the truck they were deicing us with the heater didn't work on it, the # glycol was freezing the moment it hit
CAM-2	Especially that cold metal like that
CAM-1	Yeah
CAM-2	Well I haven't seen anybody go around yet, they're doing good
CAM-2	Boy I'll bet all the school kids are just # in their pants here. It's fun for them, no school tomorrow, ya hoo ((sound of laughter))
1555:00 CAM-1	What do think we should use for a takeoff alternate

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
CAM-2	Well, it must be within an hour, is that Stewart up there within an hour?		
1555:09 CAM-2	About thirty-five minutes up there isn't it, on one		
CAM-2	Dullas got a big old runway over there, probably about the same, probably about the same stuff as here, you know		
1555:36 CAM-1	Been into Stewart?		
CAM-2	No, I've overflown it several times, over by the water over there, kinda long, it looks like an Air Force base, use'ta be something		
CAM-1	Yeah		
CAM-2	Looks pretty good		
1555:44 CAM-1	Yeah, it's a nice airport		
CAM-2	Is it?		
CAM-2	You been there, haven't you		
CAM-2	Did you have to from White Plains		
1555:49 CAM-2	Yeah		
CAM-2	I heard, ah		

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	CONTENT
CAM-1	In the service too		
CAM-2	Yeah, we were in, we were into White Plains one time, we were in earlier in the day and then saw some guys at the bar late that night come straggling in there really bitching, where in the # you all been, we been to Stewart man, we drove a van over here		
CAM-2	Nice touchdown		
		1556:11 LC	Eastern one three three taxi into position and hold
CAM-1	Right on it		
CAM-2	Uh uh		
		1556:15 E133	Eastern's one three three, position and hold
1556:19 CAM	((Sound of laughter))		
1556:20 CAM-2	Got his wing tip		
		1556:24 LC	Grumman one six two five, turn left taxi clear and hold, ground point seven as you clear
		1556:28 625	One six two five

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1556:39 CAM-1	Sure glad I'm not taking off in that piece of #
1556:43 CAM-2	Yeah that thing right there, that gets your attention
1556:47 CAM-2	Hopefully, thats, ah, is that turbo charged or fuel injected?
1556:51 CAM-2	Hate to blast outta here with carburetor ice all over me
1556:54 CAM-2	Specially with the monument staring you in the face
1556:56 CAM-1	They call it the, ah, four twenty-one, Golden Eagle
1556:59 CAM-2	Yeah
1557:02 CAM-1	It's, ah, pretty fancy

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1556:39 LC	Eastern one thirty three cleared for takeoff
1556:42 E133	Cleared to go, Eastern's one thirty-three on the roll
1556:44 LC	Roger
1556:47 LC	Apple fifty-eight taxi into position and hold, be ready for an immediate
1556:50 NYA 58	Position and hold, Apple fifty eight
1556:53 556	TWA five fifty-six is inside Oxonn
1556:56 LC	Trans World five fifty-six roger, runway three six

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1557:05 CAM	((Sound similar to parking brake release))
CAM	((Sound of takeoff warning horn simultaneous with above))
1557:30 CAM-2	Where do you want to go?
1557:32 CAM-1	I just don't want to blast him
1557:34 CAM-1	CAT two line's right here
1557:35 CAM-1	I'm on it
1557:38 CAM-2	Yeah
1557:42 CAM-2	Do you want to run everything but the flaps?

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1557:06 LC	Trans World five fifty-six, the wind is zero one zero at one zero, you're cleared to land runway three six visual range is three thousand touchdown is at, ah, rollout is one thousand eight hundred
1557:31 LC	Apple fifty-eight cleared for takeoff traffic's three south for the runway
1557:34 NYA 58	Apple fifty-eight take off

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
1557:44 CAM-1	Yeah	1557:44 LC	Eastern one thirty-three contact departure control
1557:45 CAM-2	Start switches		
1557:46 CAM-1	They're on		
1557:46 CAM-1	Recall		
1557:47 CAM-1	Checked	1557:47 E133	Okay sir, good day
1557:47 CAM-1	Checked		
1557:48 CAM-2	Flight controls	1557:48 LC	Good day
CAM-1	Bottoms		
1557:49 CAM-2	Tops good		
1557:50 CAM-2	Let's check these tops again since we been setting here awhile		
1557:55 CAM-2	I think we get to go here in a minute		
		1557:56 OOJ	National tower eight thousand juliet approaching pisca

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1557:58 CAM-2	Ought to work		
1558:00 CAM-2	Flaps we don't have yet		
1558:01 CAM-2	Stab trim set at five point three		
1558:02 CAM-1	Set		
1558:03 CAM-2	Zero fuel weight, we corrected that up		
		1558:04 LC	Eight thousand juliet Washington tower report Oxonn
1558:05 CAM-2	Ought to be, ah, seventy-nine one now		
CAM-1	Sevety-seven	1558:07 OOJ	Eight thousand juliet
1558:08 CAM-2	Seventy-seven one		
1558:09 CAM-1	Set		
CAM-2	Okay		
1558:10 CAM-2	EPR all the way two oh four		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1558:12 CAM-2	Indicated airspeed bugs are a thirty-eight, forty, forty four
1558:20 CAM-1	Set
1558:21 CAM-2	Cockpit door
1558:22 CAM-1	Locked
1558:23 CAM-2	Takeoff briefing
1558:25 CAM-2	Air Florida standard
1558:26 CAM-2	Slushy runway, do you want me to do anything special for this or just go for it

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1558:16 556	TWA five fifty-six cleared to land?
1558:18 LC	Five fifty-six is cleared to land the wind is zero one zero at one zero
1558:22 556	Cleared to land TWA five fifty-six
1558:24 451	Eastern fourteen fifty-one by the marker
1558:26 LC	Eastern fourteen fifty-one runway three six
1558:29 451	Fourteen fifty-one

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1558:31 CAM-1	Unless you got anything special you'd like to do
1558:33 CAM-2	Unless just takeoff the nose wheel early like a soft field takeoff or something
1558:37 CAM-2	I'll take the nose wheel off and then we'll let it fly off
1558:39 CAM-2	Be out the three two six, climbing to five, I'll pull it back to about one point five five supposed to be about one six depending on how scared we are
1558:45 CAM	((Sound of laughter))
1558:47 CAM-2	Up to five, squawk set, departure is eighteen one, down to flaps ((sound of laughter))
1558:56 CAM-2	Oh, he pranged it on there

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1558:31 LC	Apple fifty-eight contact departure control
1558:33 NYA 58	Fifty-eight so long
1558:55 LC	Palm ninety taxi into positon and hold, be ready for an immediate

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1558:59 CAM	((Sound similar to parking brake being let off))
1559:00 CAM	((Sound of takeoff warning))
CAM	((Sound similar to flap lever activation))
1559:03 CAM	((Sound of takeoff warning ceases))
1559:06 PA	Ladies and gentlemen, we have just been cleared on the runway for takeoff, flight attendents please be seated
1559:15 CAM-2	Flight attendant alert
1559:16 CAM-1	Given
1559:16 CAM-2	Bleeds

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1558:58 RDO-2	Palm ninety positon and hold
1559:03 451	Eastern fourteen fifty-one, keep it at reduced speed, traffic's going to depart, Trans World five fifty-six left turn off if you can turn at the next taxiway, it would be appreciated nothing's been plowed

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
1559:17 CAM-1	They're off		
1559:18 CAM-2	Strobes, external lights	1559:18 LC	Okay contact ground point seven right there, thank you for your cooperation
CAM-1	On		
1559:19 CAM-2	Anti skid		
CAM-1	On		
1559:21 CAM-2	Transponder		
CAM-1	On		
1559:22 CAM-2	Takeoffs complete		
		1559:24 LC	Palm ninety cleared for takeoff
		1559:26 RDO-2	Palm ninety cleared for takeoff
		1559:28 LC	No delay on departure if you will, traffic's two and a half out for the runway
1559:32 CAM-1	Okay	1559:32 RDO-2	Okay
1559:45 CAM-1	Your throttles		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1559:46 CAM-2	Okay
1559:48 CAM	((Sound of engine spoolup))
1559:49 CAM-1	Hollar if you need the wipers
1559:51 CAM-1	It's spooled
1559:53 CAM-?	Ho
CAM-?	Whoo
1559:54 CAM-?	Really cold here
1559:55 CAM-2	Got 'em?
1559:56 CAM-1	Real cold
1559:57 CAM-1	Real cold
1559:58 CAM-2	God, look at that thing

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1559:56 41M	Ground four one mike, we behind the Piedmont?
1559:59 LC	Four one mike, you're behind the Piedmont

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1600:02 CAM-2	That don't seem right does it?
1600:05 CAM-2	Ah, that's not right
1600:07 CAM-2	(Well) ---
1600:09 CAM-1	Yes it is, there's eighty
1600:10 CAM-2	Naw, I don't think that's right
1600:19 CAM-2	Ah, maybe it is
1600:21 CAM-1	Hundred and twenty
1600:23 CAM-2	I don't know

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1600:03 LC	Eastern fourteen fifty-one, the wind is zero one zero at one one you're cleared to land runway three six, the visual range touchdown two thousand eight hundred rollout one thousand six hundred
1600:11 E451	Fourteen fifty-one cleared to land over the lights
1600:24 OOJ	Oxonn for eight thousand juliet

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
		1600:26 LC	Eight thousand juliet runway three six, you're cleared to land the wind is zero one zero at one two
		1600:28 00J	Eight thousand juliet cleared to land
1600:31 CAM-1	Vee one		
1600:33 CAM-1	Easy		
		1600:36 LC	Six eight gulf taxi into position and hold be ready
1600:37 CAM-1	Vee two		
		1600:38 68G	Position and hold six eight gulf
1600:39 CAM	((Sound of stickshaker starts and continues to impact))		
		1600:41 LC	Palm ninety, contact departure control
1600:45 CAM-1	Forward, forward		
1600:47 CAM-?	Easy		
1600:48 CAM-1	We only want five hundred		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1600:50 CAM-1	Come on, forward
1600:53 CAM-1	Forward
1600:55 CAM-1	Just barely climb
1600:59 CAM	(Stalling) we're (falling)
1601:00 CAM-2	Larry, we're going down, Larry
1601:01 CAM-1	I know it
1601:01	((Sound of impact))

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1600:52 172	Tower US Air one seven two with you ten out
1600:54 LC	US Air one seven two, roger
1600:56 LC	Eastern fourteen fifty-one, turn left at the next taxiway, advise when you clear the runway, no delay clearing

APPENDIX G

-258 (12-20-79)

REPORT
of the
FBI
TECHNICAL SERVICES DIVISION
FEDERAL BUREAU OF INVESTIGATION
WASHINGTON, D. C. 20535

To: Mr. Rudolf Kapustin
Investigator-in-Charge
National Transportation Safety Board
800 Independence Avenue, S.W.
Washington, D. C. 20594

April 7, 1982

FBI FILE NO. 95-247269

LAB. NO. 20316113 E QZ

YOUR NO.

Re: CRASH OF AIR FLORIDA
BOEING 737, FLIGHT 90,
WASHINGTON, D. C.
JANUARY 13, 1982

Examination requested by: Addressee

Reference: Letter dated March 11, 1982

Examination requested: Miscellaneous

Specimens received: January 25, 1982, personally delivered by Mr. Paul C. Turner, under Laboratory Number 20125005 E QZ.

Q15 One segment of 1/4-inch wide magnetic tape on a 5-inch reel.

Specimen received: March 15, 1982, personally delivered by Mr. Paul C. Turner, under Laboratory Number 20316113 E QZ.

Qc31 One Ampex 7-inch reel of 1/4-inch wide magnetic tape marked in part "Air Fla." on a red and white label.

ALSO SUBMITTED:

One transcription.

Result of examination:

An aural and electronic examination of the designated portion of specimen Q15 reveals that the recorded spoken word is "off."

No examination was conducted of specimen Qc31, since it is a copy of specimen Q15.

Continued Over

SA Bruce E. Koenig conducted the miscellaneous examination.

Specimen Q15 has previously been delivered to Mr. Daniel C. Beaudette of the Federal Aviation Administration, Washington, D. C. Specimen Qc31 will be forwarded to your office. The transcription will be retained by the Technical Services Division.

APPENDIX H

THERMAL ANTI-ICE SYSTEMS

ENGINE ANTI-ICE OPERATION

- Engine anti-icing should be turned on during all ground operations, takeoff and climb when icing conditions exist or are anticipated. Engine icing may occur when the following conditions exist simultaneously:

- The ambient temperature is below 8°C (46.4°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.

CAUTION: DO NOT OPERATE NACELLE ANTI-ICING CONTINUOUSLY ABOVE 80% N1 POWER WHEN THE TOTAL AIR TEMPERATURE (TAT) IS ABOVE 10°C (50°F) UNLESS VISIBLE MOISTURE IS PRESENT. PROLONGED OPERATION UNDER THESE CONDITIONS MAY REDUCE THE HAIL RESISTANCE OF THE ENGINE COWL INLET.

In the air, because of inlet pressure changes, the total air temperature indicator is not 100% accurate in determining the possibility of engine icing. However, the total air temperature indication and the presence of visible moisture or icing are the best criteria available. Icing may be expected with a TAT of 10°C or lower and visible moisture.

Two indicators of ice forming are the windshield wiper arm bolt and the EPR gages.

- Erratic EPR indications or abnormal EPR relative to N1 may be an indication of engine icing.

- The Pt2 EPR probe will ice up in icing conditions if anti-icing is not in use; therefore, the first noticeable indication could be an erratic EPR reading.

Engine Start Switches...............ON

Place start switches to LOW IGN. Start switches may be placed OFF after engine EPR is stabilized.

Engine Anti-Ice Switches............ON

Engine Anti-Ice Valve Open Lights - MONITOR
Check all VALVE OPEN lights illuminate brightly, then dim.
EPR Indicators - OBSERVE DECREASE
Reset thrust, accounting for anti-icing penalty.

- When engine anti-ice is no longer required:

Engine Anti-Ice Switches...........OFF

Engine Start Switches.............OFF

- EPR Indicators - OBSERVE INCREASE
Reset thrust as required.

During descent with engine anti-ice operation, maintain at least 55% N1.

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ENGINE ANTI-ICE VALVES FAIL IN THE CLOSED POSITION (AVOID ICING AREAS)

If the engine anti-ice switch is ON and any VALVE OPEN light remains illuminated bright, the respective valve has failed to open properly. Prolonged holding in moderate icing areas should be avoided. Use continuous ignition on the affected engine in icing conditions. Loss of left or right anti-ice valve should have little effect on inlet guide vane and dome anti-icing.

WING ANTI-ICE OPERATION

There are two methods recommended for operating the wing anti-ice system. The primary method is to use as a de-icer by allowing the ice to accumulate before turning wing anti-ice 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. 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, wing anti-icing can be activated to prevent ice accumulation on the wing leading edges. The windshield wiper arms or EPR give the first indication of ice forming on the airplane.

CAUTION: DO NOT OPERATE WING ANTI-ICING WITH TOTAL AIR TEMPERATURE ABOVE 10°C (50°F) UNLESS VISIBLE MOISTURE IS PRESENT. PROLONGED OPERATION UNDER THESE CONDITIONS WILL REDUCE THE HAIL RESISTANCE OF THE LEADING EDGE SKIN.

Wing Anti-Ice Switch................ON

- Wing Anti-Ice Valve Open Lights - MONITOR
  - Check both VALVE OPEN lights illuminate brightly, then dim. ●
- EPR Indicators - OBSERVE DECREASE
  - Reset thrust, accounting for anti-ice penalty.

When wing anti-ice is no longer required: ●

Wing Anti-Ice Switch...............OFF

- EPR Indicators - OBSERVE INCREASE ●
  - Reset thrust as required.

During descent with wing anti-ice or ● de-ice operation, maintain at least 55% N1.

Prolonged operation in icing conditions with the leading edge and trailing edge flaps extended is not recommended. After landing, trailing edge retraction to less than flaps 15 is not recommended until ice has been removed or a ground inspection can be made.

WING ANTI-ICE VALVES FAIL IN THE CLOSED POSITION (AVOID ICING AREAS)

If the wing anti-ice switch is ON and the VALVE OPEN light is illuminated bright, the wing anti-ice valve has failed to open properly. Asymmetrical wing icing has little effect on flight characteristics. Extended holding in moderate icing areas should be avoided.

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