PB82-910415

NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

WORLD AIRWAYS, INC., FLIGHT 30H
MCDONNELL DOUGLAS DC-10-30CF, N113WA,
BOSTON-LOGAN INTERNATIONAL AIRPORT
BOSTON, MASSACHUSETTS
JANUARY 23, 1982

NTSB-AAR-82-15

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UNITED STATES GOVERNMENT

SEE ALSO: NTSB Reporter - May '83, p. 12

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16. Abstract On January 23, 1982, World Airways, Inc., Flight 30H, a McDonnell Douglas DC-10-30, was a regularly scheduled passenger flight from Oakland, California, to Boston, Massachusetts, with an en route stop at Newark, New Jersev. Following a nonprecision instrument approach to runway 15R at Boston-Logan International Airport, the airplane touched down about 2,500 feet beyond the displaced threshold of the 9,191-foot usable part of the runway. About 1936:40, the airplane veered to avoid the approach light pier at the departure end of the runway and slid into the shallow water of Boston Harbor. The nose section separated from the forward fuselage in the impact after the airplane dropped from the shore embankment. Of the 212 persons on board, two are missing and presumed dead. The others evacuated the airplane safely, but with some injuries.

The weather was 800-foot overcast, 2 1/2-mile visibility, with light rain and fog. The temperature was 38° with the wind from 165° at 3 kns The surface of runway 15R was covered with rain, hard-packed snow, and glaze ice. At 1736, 2 hours before the accident, runway braking was reported by a ground vehicle as "fair to poor;" subsequently, several pilots had reported braking as poor, and one pilot had reported braking as "poor to nil" in the hour before the accident.

The National Transportation Safety Board determines that the probable cause of this accident was the pilot landed the airplane without sufficient information as to runway conditions on a slippery, ice-covered runway, the condition of which exceeded the airplane's stopping capability. The lack of adequate information with respect to the runway was due to the fact that (1) the FAA regulations did not provide guidance to airport

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Abstract continued

management regarding the measurement of runway slipperiness under adverse conditions; (2) the FAA regulations did not provide the flightcrew and other personnel with the means to correlate contaminated surfaces with airplane stopping distances; (3) the FAA regulations did not extend authorized minimum runway lengths to reflect reduced braking effectiveness on icy runways; (4) the Boston-Logan International Airport management failed to exercise maximum efforts to assess and improve the conditions of the ice-covered runways to assure continued safety of heavy jet airplane operations; and, (5) tower controllers failed to transmit available braking information to the pilot of Plight 30H.

Contributing to the accident was the failure of pilot reports on braking to convey the severity of the hazard to following pilots.

The pilot's decision to retain autothrottle speed control throughout the flare and the consequent extended touchdown point on the runway contributed to the severity of the accident.

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SYNOPSIS

On January 23, 1982, World Airways, Inc., Flight 30H, a McDonnell Douglas DC-10-30, was a regularly scheduled passenger flight from Oakland, California, to Boston, Massachusetts, with an en route stop at Newark, New Jersey. Following a nonprecision instrument approach to runway 15R at Boston-Logan International Airport, the airplane touched down about 2,500 feet beyond the displaced threshold of the 9,191-foot usable part of the runway. About 1936:40, the airplane veered to avoid the approach light pier at the departure end of the runway and slid into the shallow water of Boston Harbor. The nose section separated from the forward fuselage in the impact after the airplane dropped from the shore embankment. Of the 212 persons on board, two are missing and presumed dead. The others evacuated the airplane safely, but with some injuries.

The weather was 800-foot overcast, 2 1/2-mile visibility, with light rain and fog. The temperature was 38° with the wind from 165° at 3 kns. The surface of runway **15R** was covered with rain, hard-packed snow, and glaze ice. At 1736, 2 hours before the accident, runway braking was reported by a ground vehicle as "fair to poor;" subsequently, several pilots had reported braking as poor, and one pilot had reported braking as "poor to nil" in the hour before the accident.

The National Transportation Safety Board determines that the probable cause of this accident was the pilot landed the airplane without sufficient information as to runway conditions on a slippery, ice-covered runway, the condition of which exceeded the airplane's stopping capability. The lack of adequate information with respect to the runway was due to the fact that (1) the FAA regulations did not provide guidance to airport management regarding the measurement of runway slipperiness under adverse conditions; (2) the FAA regulations did not provide the flightcrew and other personnel with the means to correlate contaminated surfaces with airplane stopping distances; (3) the FAA regulations did not extend authorized minimum runway lengths to reflect reduced braking effectiveness on icy runways; (4) the Boston-Logan International Airport management failed to exercise maximum efforts to assess and improve the conditions of the ice-covered runways to assure continued safety of heavy jet airplane operations; and, (5) tower controllers failed to transmit available braking information to the pilot of Flight 30H.

Contributing to the accident was the failure of pilot reports on braking to convey the severity of the hazard to following pilots.

The pilot's decision to retain autothrottle speed control throughout the flare and the consequent extended touchdown point on the runway contributed to the severity of the accident.

1. FACTUAL INFORMATION

1.1 History of the Flight

On January 23, 1982, World Airways, Inc., Flight 30H, a McDonnell Douglas DC-10-30, was a regularly scheduled passenger flight from Oakland, California, to Boston, Massachusetts, with an en route stop at Newark, New Jersey.

During the en route flight to Newark, the captain of Flight 30H monitored the half-hourly weather broadcast of East Coast airports. Immediately before the landing at Newark International Airport, New Jersey, braking had been reported as "fair to poor" and taxiway braking as "nil." The DC-10-30 was landed on the 8,600-foot runway without incident. During his Newark layover, the captain checked the weather sequences and found that the weather was deteriorating at his previously selected flight plan alternate airports, Bradley and Newark. Accordingly, he refiled his flight release to change his alternate airports to New York (Kennedy) and Philadelphia. He also added 10,000 pounds of fuel and computed his revised weight and balance calculations. Flight 30H departed Newark Airport for Boston-Logan International Airport at 1848. 1/

At 1859, while en route at an altitude of 17,000 feet, Flight 30H made initial radio contact with the Boston Air Route Traffic Control Center (ARTCC). At 1903, Flight 30H was transferred to Boston approach control, where the controller vectored Flight 30H by radar from the Boston VOR 2/ to an outboard track parallel to the runway 15R VOR approach course and positioned the airplane for a left turn onto the final approach. (See appendix D.) The approach controller had been requested by Logan Tower to space inbound traffic at 7-mile intervals because of slippery runways and closed taxiways. The airport was to be closed for plowing of the intersection at runway 15R and runways 4R and 4L after Flight 30H landed. An approach controller asked the pilot of Flight 30H if he had received Automatic Terminal Information Services (ATIS) "X-Ray" and Field Condition Report 6. The pilot stated that he had received both reports. 3/

The captain noted as the airplane was descending to 6,000 feet m.s.l. that the ram air temperature was higher than the temperature which would require the use of anti-icing equipment, and he observed no ice accumulation on the airplane.

The captain continued to descend with the autothrottle/speed control (AT/SC) system engaged to control airspeed while using manual flight control without the autopilot. The captain used this technique frequently, a procedure suggested by the airplane manufacturer and accepted by World Airways. As the flight was cleared to descend to 4,000 feet, the captain ordered the trailing edge flaps extended to 22° and

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1/ All times herein are eastern standard time based on the 24-hour clock.

2/ Very high omni-directional range.

3/ The essential portion of the ATIS information stated, "...Boston weather measured ceiling eight hundred overcast; visibility two and one half miles and light rain and fog. Temperature three five, dewpoint two three, the wind is one eight zero at six... Braking action is fair to poor reported by a seven two seven on runway one five right. All field surfaces are covered with a thin layer of ice...." [The dewpoint was incorrect. Actual dewpoint was 33°.] Field Condition Report 6 stated, "...Runway one five right, three three left is open and plowed full length and width, surface sanded fifty three feet on either side of the centerline. Surfaces covered with up to one quarter inch hard packed snow with drifts up to one inch inside light lines at intersection of runway four right. The runway markings are obscured, the braking action is fair to poor, reported by a seven two seven. Use caution, some runway and taxiway markings are obscured...." (See appendixes E and F.)

selected a speed of 164 kns in the AT/SC system. This speed was obtained from appropriate flight manual data based upon the 22' flap configuration and the calculated airplane gross weight of 365,000 pounds to provide a 30-percent margin above the airplane's Power off Stall speed (1.3 V_{so}). However, the first officer saw that the AT/SC system would not accept the 164-kn command as indicated by the display of the word "ALPHA" on the flight mode annunciator. 4/ The first officer then increased the selected speed until the ALPHA display cleared. The selected speed was 174 kns and the airplane stabilized at 176 kns. The captain remarked to the other crewmembers that this was 10-kn higher than desired. (The captain accepted the higher speed in accordance with a World Airways bulletin which was prepared by McDonnell Douglas advising pilots to accept AT/SC speeds in lieu of flight manual speed if a disparity arises.)

The captain selected 35° flaps when on final approach. The captain stated that this flap selection was based on his assessment of the winds along the final approach path and the flight profile for a non-precision approach. Again the selection of the desired speed, 150 kns (V_{ref+5}), resulted in the ALPHA display on the flight mode annunciator. The selected speed was again increased to the minimum speed acceptable by the AT/SC, 158 kns. The airplane then stabilized at 160 kns.

At 1920, after an inquiry from the approach controller, Flight 30H reported that the inertial wind at 4,000 feet was from 226° and at a speed of 65 kns. Two minutes earlier, another inertial-equipped airplane landing ahead of Flight 30H on runway 15R had reported to the controller wind at 2,000 feet from 197° at 60 kns. Flight 30H did not encounter any significant turbulence. This wind report from the preceding airplane was relayed to the Flight 30H flightcrew by the approach controller, because Flight 30H was not on the controller's frequency when the pilot's report was given. Flight 30H did not directly hear any wind reports or braking action reports from preceding airplanes while on the approach control or tower frequencies, nor was Flight 30H given any pilot braking reports by the controllers.

At 1932, as Flight 30H was approaching 3,000 feet, the captain was maintaining a 14° right drift correction to hold the inbound VOR course. At this time, Flight 30H was cleared to contact Logan Tower, and the first officer reported to the tower controller that Flight 30H was approaching the final approach fix. The tower controller cleared the flight to land on runway 15R and informed the flight that the surface wind was 180' at 3 kns. After passing the final approach fix, the captain started the descent to 780 feet, the minimum descent altitude (MDA). One hundred feet above MDA, the first officer called "the ground in sight." The captain stated that near MDA, he sighted the airport lights off to the left and continued the descent to about 500 feet, where he stopped the descent and leveled the airplane. According to the first officer, when the airplane reached the MDA he could see the city lights but the forward visibility was poor. The first officer estimated that about 2 miles from the approach end of runway 15R, forward visibility improved and he saw the approach lights and runway lights. The first officer called the lighted glidepath of the visual approach slope indicator (VASI) as "red-red," indicating that the airplane had not intercepted, i.e. was below, the on-course descent path of the VASL (See appendix H.) As the airplane was flown into the center of the VASI glidepath, the captain continued the descent to the runway. The captain believed that the airplane touched down on the runway between 1,000 feet and 1,500 feet from the displaced threshold.

4/ The word ALPHA on the flight mode annunciator will appear when the speed selected on the AT/SC is below the 1.3 V_{so} speed computed from configuration, attitude and acceleration data in the AT/SC computer. This is the minimum speed which will be commanded by the AT/SC.

The airplane touched down at 1935:57. Immediately upon touchdown, the captain realized that the runway was very slippery. He recognized the slipperiness by the gentle, sliding contact of the landing gear with the runway, and he was aware that the ground spoilers, which automatically deploy on main wheel spinup, 5/ had not extended after the landing. However, as the nose wheel was lowered to the runway and the engines were put into the reverse thrust range, the ground spoilers deployed. Several seconds later, the captain applied full reverse thrust on all engines and fully depressed the brake pedals, where he held them throughout the landing roll. At 1936:08, about 11 seconds after touchdown, the captain called out "no braking," which was followed 14 seconds later by his second "no-braking" callout. He did not experience directional control problems, although he had little steering control About 9 seconds later, he remarked that the airplane was going to go off the end of the runway, and the first officer immediately notified the tower controller. When the captain realized that he could not stop the airplane on the runway, he steered' it to the left to avoid the runway 33L approach light pier. Four seconds later, at 1936:40, Flight 30H went over the sea wall and into Boston Harbor. (See figure 1.)

Because of the reduced visibility, traffic controllers in the Logan Tower lost sight of Flight 30H as it reached the end of runway 15R. After the first officer's last transmission, local and ground controllers radioed for confirmation of Flight 30H's location. Upon receiving no response, the tower supervisor activated the emergency alarm to the airport fire department, and the airport was closed to air traffic. The crash/fire/rescue facilities of the airport responded immediately.

The airplane had stopped in shallow water at the edge of the harbor, 110 feet left of the runway centerline and midway between the approach light pier and the large granite stone blocks which lined the top of an earthen embankment. The 30-foot gravel and mud slope dropped about 10 feet from the top of the embankment to the shoreline. Under the airplane, the muddy harbor bottom continued in a gradual 5° slope. As Flight 30H entered the water, the wing-mounted engines were flooded and stopped running; however, the centerline engine continued to run at full reverse thrust. At the time of the accident; the water was 4 feet deep at the bottom of the 4R exit door evacuation slide and 2 feet deep between the right wingtip and the shore. The airplane was canted to the right of the shoreline, and the distance between the right wingtip and the shore was less than 4 feet.

The accident occurred at 1936:40 during the hours of darkness at coordinates 42°21'3"N latitude and 70°59'6"W longitude.

1.2 Injuries to Persons

Injuries	Crew Cockpit	Crew Cabin	Passengers	Other
Fatal	0	0	2 (Presumed)	0
Serious	1	1	2	0
Minor	0	5	19	2 7/
None	2	3	174	0
Total	3	9	200 6/	2

5/ Ground spoiler extension spoils lift, thereby increasing braking efficiency. If upon touchdown, the spoiler handle does not move aft, World procedures call for the flight engineer to call out "no spoiler," and on the pilot's command, the flight engineer will manually activate the spoiler handle.
6/ Includes three unticketed infants.
7/ Rescue personnel

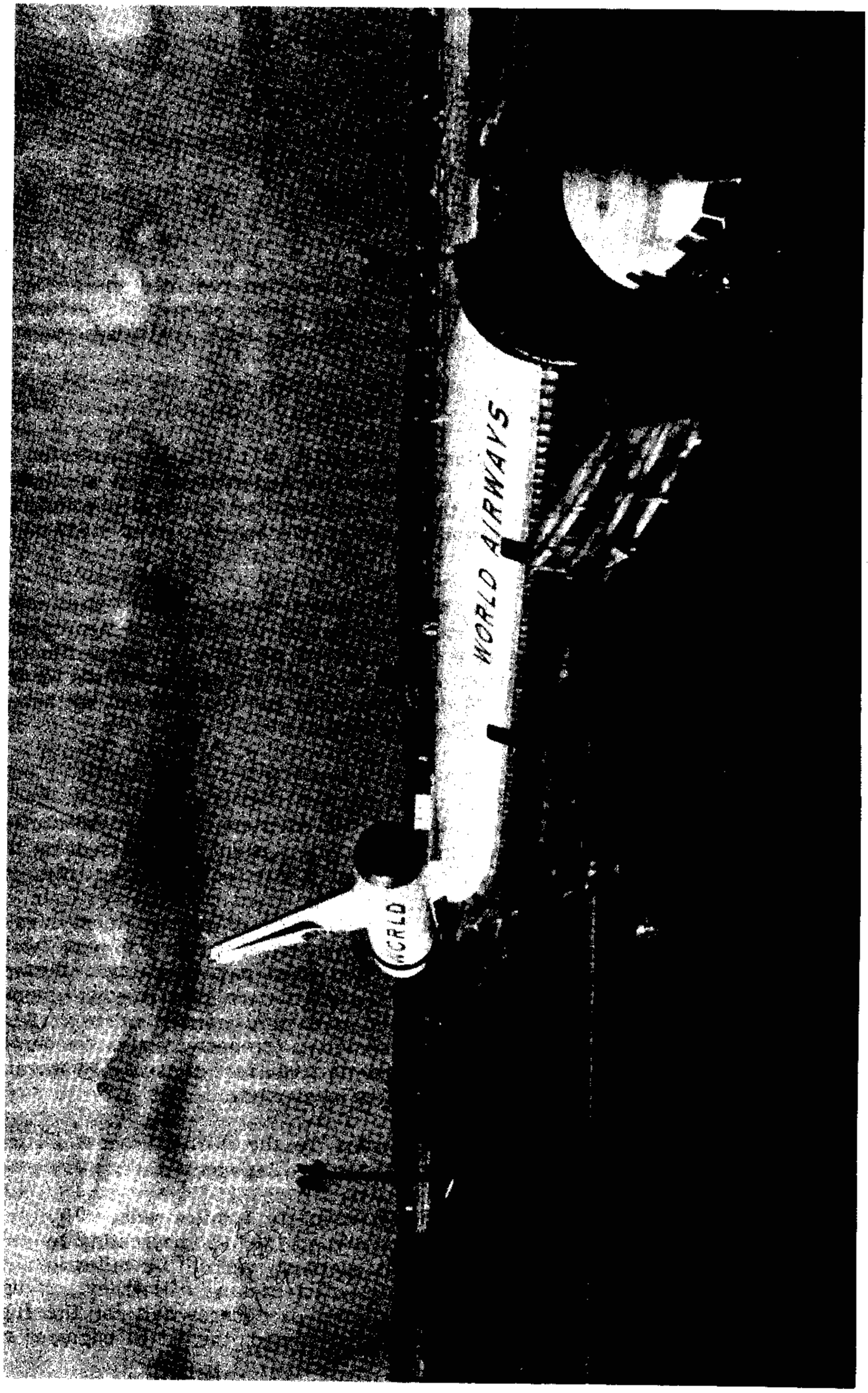

Figure 1.--Flight 30H as it rested in Boston Harbor.

13 Damage to Aircraft

The airplane was damaged substantially.

14 Other Damage

None.

15 Personnel Information

The flightcrew was qualified for the flight and had received the required training. All flightcrew members denied they were fatigued before the accident. Following the accident, the captain submitted to and passed a FAA first-class medical examination. (See appendix B.)

16 Aircraft Information

The airplane, a McDonnell Douglas DC-10-30CF, N113WA, was operated by World Airways, Inc. The airplane had been maintained in accordance with applicable regulations. At the time of the accident, the No. 1 system of the dual autothrottle system and the auxiliary power unit were inoperative; N113WA had had about 6,327 hours in service since new.

The flihtcrew estimated that the airplane's gross weight was about 365,000 pounds at the time of landing and used this weight to determine appropriate approach and landing speeds. The airplane was powered by three General Electric CF6-50C2 high-bypass-ratio turbofan engines. A review of the inspection records for the engines and the airplane's logbook for the 90 days preceding the accident did not reveal any significant deferred maintenance items. (See appendix C.)

1.1 Meteorological Information

The 1900 hours National Weather Service (NWS) environmental analysis showed that there was a large low pressure area north of Lake Huron which was influencing the weather over the eastern United States. At the surface, there were troughs extending south through Virginia and east through Massachusetts. The freezing level was near the surface in northern New England and sloped to 8,000 feet over southwestern Pennsylvania. Surface conditions in the vicinity of Boston-Logan International Airport were characterized by southerly winds, overcast skies, and liiht rain and fog. Surface temperatures were slightly above freezing. The surface winds were light; however, above the surface, lower level wind speed increased rapidly. A significant weather advisory (SIGMET), in effect for the area at the time of the accident, forecast frequent moderate or severe turbulence below 10,000 feet, especially within 3,000 feet above rough terrain. Low level windshear was possible because of strong low level winds.

The Boston-Logan terminal forecast, issued by the NWS Forecast Office, Boston, at 1640, valid from 1700, January 23, to 1700, January 24, was in part:

> **Boston:** Ceiling 400 feet obscured, visibility 1 mile, reduced by light snow, light ice pellets, and fog. Wind 120° 15 kns gusting to 25 kns, variable to ceiling 500 feet overcast, visibility 2 miles in light freezing rain, liiht rain, and fog.

The 1900 upper air sounding taken by the NWS at Chatham, Massachusetts, showed a surface temperature of 37' F. and an inversion from the surface to 2,700 feet where the temperature was 43° F. The freezing level was 8,400 feet.

Based upon information from the radar log and radar overlays from the NWS radar at Chatham at 1830, Boston Logan was on the western edge of an area of 7/10 coverage of light rain, light freezing rain, and snow. The tops of precipitation echoes were uniform at 15,000 feet. There was no evidence **of** convective activity. At 1930, the precipitation area, which was reported as 7/10 coverage, light rain and snow, tops uniform at 15,000 feet, was to the east of Boston.

Wind information reported by the NWS at 1900 for Atlantic City, New Jersey, and Portland, Maine: (These represent the nearest wind reports available from NWS.)

Altitude (feet above sea level)	Wind direction (degrees true)	Wind speed (knots)
Atlantic City Surface	240	12
923	233	32
1,836	240	48
2,841	244	50
3,828	242	48
4,801	237	52
5,744	234	55
Portland Surface	350	6
989	133	23
1,920	142	37
2,851	148	42
3,769	163	52
4,647	172	60
5,575	msng	msng

There were two reports from pilots of other airplanes of winds over Boston near the time of the accident. At 1906, Northwest Flight 42, a DC-10-40, reported the wind at 4,000 feet as 220' 60 kns and at 1,400 feet as 180' 20 kns. At 1918, Delta Flight 1025, a Lockheed L-1011, reported the wind at 2,000 feet as 197°, 60 kns.

From 1900 to 2000, the wind gust recorder at Boston-Logan International Airport showed a maximum wind speed of 8 kns and a minimum of 2 kns. From 1930 to 1940, the maximum speed was 6 kns at 1940 and the minimum was 2 kns at 1930 and 1935. The wind speed at 1936 was 3 kns.

The surface weather observations before and after the time of the accident, taken by the NWS Forecast Office at Boston-Logan Airport were as follows:

Time -- 1850: type -- surface aviation; ceiling -- measured 800 feet overcast; visibility 2 1/2 miles; weather -- light rain and fog; barometer -- 1000.9 millibars; temperature -- 35° F; dewpoint -- 33° F; wind -- 120' 8 kns; altimeter -- 29.55 inches; remarks -- pressure falling rapidly.

Time -- 1945: type -- special; ceiling -- measured 600 feet overcast; visibility -- 1 1/2 miles; weather--light rain and fog; wind -- 120' 4 kns; altimeter-29.49 inches.

Time -- 1951: type -- record special; ceiling -- measured 600 feet overcast; visibility -- 1 1/2 miles; weather -- light rain and fog; barometer -- 998.3 millibars; temperature -- 38° F; dewpoint -- 36° F.; wind -- 130° 4 kns; altimeter -- 29.48 inches; remarks -- (aircraft mishap) pressure falling rapidly.

At Boston-Logan Airport on January 21, the maximum temperature was 20° F, the minimum was 7° F; on January 22, the maximum temperature was 15° F., the minimum was 2° F; and on January 23, the maximum temperature was 38° F, the minimum was 6° F.

The following are precipitation records for January 23 from Boston-Logan Airport considered pertinent to the accident:

Period	Precipitation (water equivalent) (inches)	Snow Amount (inches)	Total Snow Depth (inches)
0049-0649	0	0	7
0649-1250	0.19	2.4	9
1250-1850	0.09	0.6	10
1850-0049	0.14	0	9
Total	0.42	3.0	35

Period	Type of Precipitation
0424-1615	light snow
1040-continuous	fog
1536-1630	ice pellets
1630-1725	light drizzle
1720-2020	light rain
2020-2304	light drizzle

Pilot braking reports.--About 1 hour 46 minutes before the accident, the pilot of a Piedmont Airlines B-727 reported that the braking was "fair to poor." He was the first pilot to land after the runway had been reopened at 1736. At [illegible]49, a Northwest B-747 pilot landed and reported braking as "fair to Door." Nine minutes later, however, a Delta DC-8 pilot reported braking as "poor to nil." In a written statement submitted after the accident, he said that he landed in the normal touchdown zone, applied full reverse thrust, and minimized brakes applications for controllability. He recalled that the last 1,000 feet of the runway was very slippery, and he found wheel braking ineffective. At [illegible]03, a British Airways Lockheed L-1011 pilot reported to the tower that, because of runway slipperiness, he was having trouble aligning the airplane with the runway for takeoff. At [illegible]15, a Republic Airlines B-727 landed and the pilot [illegible]d not report braking conditions to the tower. He later told investigators that he was [illegible] he Delta DC-8 "poor to nil" braking report, and he found that braking was worse than poor at the end of the rollout. Four minutes later, a Delta Lockheed L-1011 pilot, who had received the "poor to nil" braking report from his airline's local operations center, landed without making his own braking report. He found the runway slippery and stopping the airplane difficult.

At [illegible]21, an American B-727 pilot landed on runway 15R, but he did not report the braking conditions. He found upon landing that ". . .the runway was very slick." Four minutes later, a Northwest B-727 landed and the pilot reported the braking as "poor." This pilot recalled that he landed 1,000 feet to 1,500 feet from the displaced threshold, and he applied two-thirds of the maximum available brake pressure and full reverse engine thrust immediately upon touchdown. He applied full brake pressure when one–half of the runway remained. He said that he could not stop at his intended turnoff point on runway 27. At 1928, a Northwest Airlines DC-10 landed and reported the braking as "poor." This pilot stated later that after landing he activated reverse thrust on all three engines as quickly as possible and the engines spooled up evenly. When he applied wheel braking, he did not feel any deceleration. He stated that he would have normally started out of reverse thrust at 80 kns indicated airspeed (KIAS), but because of noticeably high rollout speed when 3,000 feet of runway remained, he left the three engines in the reverse thrust range. As the airplane slowed, the No. 3 engine compressor stalled and the engine temperatures exceeded limits. He recalled braking and steering difficulty as he turned the airplane onto the taxiway at the end of the runway. At 1933, an American Airlines B-727 pilot landed but did not report the runway conditions. He stated later that wheel braking was largely ineffective because the runway was extremely slippery.., Reverse thrust was used to stop the airplane as he proceeded on the taxiways to 'the terminal area.

During the hour before the accident, four pilots had executed missed approaches. At 1847, a Piedmont Airlines B-727-200 made a missed approach to runway 15R when the airplane was not in position to make a normal descent to the runway. At that time, the ceiling was reported to be a measured 800 feet, with visibility at 2 miles. At 1854, a Republic Airlines B-727-200 made a missed approach to runway 15R when the airplane broke out of the overcast at a point from which the pilot could not complete the landing. At 1906, a Northwest Airlines DC–10 pilot found the ceiling ragged at MDA, with visible precipitation. He saw the runway at about 2 miles and made a missed approach. These three airplanes completed their second approach successfully.

At 1909, the fourth airplane, an American B–727–100, which did not have the runway in sight at 780 feet (MDA), was directed to make a missed approach when a British Airways L–1011 had difficulty taking position for departure on runway 15R. His second descent to MDA was similar to the first. He did not have runway contact upon first reaching 780 feet; however, he subsequently sighted the runway and was able to complete his landing.

1.8 Aids to Navigation

A VOR distance measuring equipment (DME) instrument approach procedure serves runway 15R at the Boston–Logan International Airport. The procedure begins at an altitude of 4,000 feet, a distance of 15–mile DME from the VOR site, and an inbound heading of 147°. An altitude profile positions the landing airplane at 1,400 feet when passing the 5–mile DME fix, where the pilot is authorized to descend to the MDA of 780 feet. The required visibility for class–D type airplanes (such as the DC–10) is 2 1/2 miles. The missed approached point is over the runway 15R threshold, which is 1.4-mile DME from the VOR site. The touchdown zone altitude is 18 feet m.s.l.

At Boston–Logan, runway 15R has a 2–bar visual approach slope indicator (VASI) system installed adjacent to the left side of the runway. On runway 15R, the glidepath intersect distance is 1,183.3 feet from the displaced threshold. The system consists of lights arranged to provide visual descent guidance information and safe obstruction clearance during the approach to a runway. During darkness these lights can be visibile up to 20 miles or more. The light units are arranged so that the pilot using the VASI during an approach will see a combination of lights. When on the proper glidepath of a 2–bar VASI, the pilot will see the near bar as white and the far bar as red. From a position below the glidepath, the pilot will see both bars as red, and from a position above the glidepath the pilot will see both bars as white. From other glide slope positions, the pilot will see a combination of pink and red or white lights.

The 2-bar VASI system can be used in establishing the desired initial approach flightpath, but must be disregarded by pilots of wide-bodied aircraft, such as the DC-10, in sufficient time to make corrections that will afford adequate threshold crossing height and normal touchdown points. The 2-bar VASI cannot be used by pilots of these airplanes to provide guidance all the way to touchdown because of the position of the landing gear relative to the pilot's sight reference. In the case of the DC-10, the landing gear are 33 feet below and 94 feet behind the pilot's sight reference when the airplane is in the approach attitude. Consequently, it is recommended that DC-10 pilots disregard visual cues from 2-bar VASI installations at a minimum height of 200 feet above the runway threshold.

A 3-bar VASI system is installed at some airports. With this system, the third bar, located farther down the runway, is used in combination with the middle bar by the pilot of widebodied airplanes to maintain a glidepath having adequate threshold crossing height (TCH) and runway touchdown safety margin.

1.9 Communications

There were no known communications problems.

1.10 Aerodrome Information

Facilities--General Edward Lawrence Logan International Airport is located at an elevation of 20 feet m.s.l. The landing surfaces include four main runways, which are provided with several instrument landing facilities. Runway 15R is 10,081 feet long and 150 feet wide. The usable length from the displaced threshold is 9,191 feet. The runway is grooved and is equipped with high intensity runway lights, centerline lights, touchdown zone lights, and a medium intensity approach light system. (See appendix D.) On July 13, 1981, the runway 15R instrument landing system (ILS) DME facility was taken out of service to relocate the localizer and DME equipment on a centerline runway location. However, electronic problems were encountered at the new site and the restoration date could not be met. Therefore, the original offset location was reestablished to provide instrument approach capability to runway 15R during the winter. Restoration of full ILS/DME service was planned for February 4, 1982. The airport has available a mu-meter, but uses it only for runway maintenance evaluation.

Snow removal.--By management directive of the Massachusetts Port Authority, the overall responsibility and conduct of snow removal operations at Logan International Airport, including sanding of active airplane areas, is assigned to the Director of Aviation. The FAA-approved Massport Snow Plan also directs that the Manager of Public Safety, Operations Manager, Field Maintenance Manager, or Building Maintenance Manager be physically present on the airport during major snow removal operations ,when crews are working on either of the primary instrument runways or associated taxiways. The snow plan had been in effect for 2 days before the accident. At the time of the accident, these personnel were present at the airport, except for an Operations Manager. This position was vacant at the time of the accident; however, coverage of the duties of the position was assigned to the Operations Supervisor on duty. The responsibility of the Operations Manager is to insure that weather forecasts are maintained, braking action vehicle checks of ground surfaces are made, airfield condition reports (AIRAD's) which outline actual airfield conditions are issued, snow removal plans are implemented as necessary, and snow removal and sanding operations are coordinated with the FAA for planning purposes AIRAD information is incorporated into the FAA's ATIS and Field Condition Reports. Massachusetts Port Authority management had used chemicals on contaminated runways in the past, but found that the use of sand was the most effective means of providing acceptable airplane braking. Urea and glycol are normally used on runway surfaces since they are noncorrosive; however, they have the disadvantages of being slow acting and or losing effectiveness. Also, puddling and refreezing can occur. Accordingly, Boston-Logan airport management discontinued the use of urea. However, it is considering combinations of sand and chemicals.

The Logan Snow Plan provides for a Snow Watch Committee, which is headed by the Manager of Public Safety and is comprised of airport personnel, an FAA representative, and airline representatives, During snow removal operations, a member of the Snow Committee, preferably an airline chief pilot, will accompany the Operations Supervisor during his inspection of the airfield. Inspections are begun as soon as snow begins to accumulate, surface ice occurs, or when pilot reports indicate **poor** braking. Committee members on duty are directed to make continuous inspections of the field surfaces whenever there are changes in snow, slush, or ice accumulations. The inspections are conducted by a 4-wheel-drive vehicle in order to obtain braking action, and a report of these inspections is published on the teleprinter.

The snow plan was put into effect the day before the accident. On the day of the accident, runway 15R was opened at 1405 after the runway had been plowed full length and width and sanded 50 feet on each side of the centerline. Numerous scattered bare patches were reported; however, runway markings were obscured. Braking action, determined by a vehicle inspection, was fair. At 1440, runway 9/27 was reopened after plowing was completed. Braking action on this runway also was reported to be fair. At 1630, runway 15R-33L was closed for snow removal, and 9 minutes later, an AIRAD was issued to expect the closing of runway 4R-22L at 1730 for snow removal. At 2715, the tower issued a report via teleprinter that a B-737 and a DC-8 had reported braking action "nil" on runway 4R. At 1736, runway 4R-22L was closed for snow removal.

Runway 15R was reopened at 1736 by the Operations Supervisor. Prior to opening the runway, the Operations Supervisor, accompanied by the airline pilot representative on the Snow Committee, had driven a 4-wheel-drive vehicle down runway 15R to evaluate the braking conditions. The braking was reported by the Duty Operations Supervisor to be "fair to poor" following the test drive. At the time, all the runway markings were obscured by snow and a light rain was falling. The Operations Supervisor stated that pilot reports of braking on the FAA ground control frequency are monitored, and if the supervisor hears a pilot reporting "poor" braking, he will listen for the type of airplane, the airline which is reporting, and the pilot's description of the runway condition so that he can form a subjective opinion of the validity of the report. If he receives more than one "poor" report, he reinspects the runway. On the day of the accident, he did not reinspect runway 15R after it was reopened. He also stated that the exchange of information between the Operations Supervisor and the tower facility consisted of informal conversation on the ground control frequency and information exchanges sent via teleprinter from the tower to the operations control center at the north terminal. He also stated that there was no formal system for ensuring that all braking action reports would be conveyed to the Operations Supervisor. He had made the decision to close runway 15R before Fliiht 30H had reported to Boston approach control. The decision to close runway 15R was not related to the condition of the runway, but was related to the need to plow through the intersection of runway 4R and runway 15R so that runway 4R could be opened as the primary runway. No further sanding was considered for runway 15R. The Operations Supervisor had coordinated the runway closure with the tower facilities chief by telephone.

Crash/Fire/Rescue Capability.--Immediate response capability for water rescue is provided at Boston-Logan Airport by two crash-rescue boats operated by crewmen of the Logan Fire Department. One of these boats, an 80-foot fire boat, is located on the south side of the airport and it is manned 24 hours a day. This vessel carries flotation gear and a secondary 13-foot craft. The other, a 22-foot crash rescue boat, is housed adjacent to runway 27. It is cradled on a wheeled dolly with an electric winch to launch the vessel down inclined rails. In most cases, this vessel would be used as an auxiliary craft for the deployment of rafts and life preservers in shallow water operations. The FAA control tower is responsible for notifying the fire department of a water emergency. A direct line between the two is provided.

The FAA control tower also notifies the United States Coast Guard Boston Search and Rescue (SAR) Operations Center, which has the capability to direct Coast Guard vessels and helicopters to the waters adjacent to the airport to augment the immediate response capability of the airport. The Massachusetts Port Authority Emergency Plan estimates that Coast Guard surface vessels will arrive on the scene no later than 30 minutes after notification. Navy helicopter support is planned to arrive within 15 minutes from South Weymouth Naval Air Station and Coast Guard helicopter support within 30 minutes from Cape Cod Coast Guard Station. As soon as Coast Guard vessels arrive on scene, the Coast Guard assumes command of the accident area. Underwater search and rescue capability is provided by diving units from the Coast Guard, the Quincy Police Department, and the Massachusetts State Police.

1.11 Flight Recorders

The airplane was equipped with a Lockheed Air Services 209E digital flight data recorder (DFDR), serial No. 448. An examination of the DFDR revealed that it had been submerged in water. The tape medium was removed and dried shortly after arriving in the National Transportation Safety Board's laboratory in Washington, D.C. All data parameters relevant *to* the accident were examined and printed. Three plots of selected parameters were made, each 00:34:12 to 00:36:30 Greenwich Mean Time (19:34:12 to 19:36:30 e.s.t). The plots end at the time of impact.

The airplane was also equipped with a Fairchild A-100 cockpit voice recorder (CVR), serial No. 748. The CVR recorder had been submerged in water and the tape was wet upon arrival in the Safety Board's laboratory. The tape was removed from the reel, dried, respooled, and copied. A time coded channel was put on one copy for timing. The CVR transcript begins when Flight 30H descended to 6,000 feet. Extraneous radio transmissions were omitted. There were no discrepancies of the electrical or recording systems. (See appendix G.)

Following the accident, the Safety Board's laboratory examined the flight recorders from the last three wide-bodied airplanes to land at Boston-Logan before Flight 30H. However, the tapes from only two, Northwest Airlines Flight 43, a Boeing B-747, and Northwest Airlines Flight 42, a McDonnell Douglas DC-10, were read out successfully. The tape from Delta Flight 1025, a Lockheed L-1011, was read out, but the information of interest had been recorded over and was lost.

1.12 Wreckage and Impact Information

The airplane came to rest immersed in water up to the wings at high tide and in a slightly nosedown attitude. The nose section, which included the cockpit area and first row of main cabin passenger seats, separated from the fuselage along a fracture line from fuselage station (FS) 370 to 475. The nose section remained attached to the main fuselage structure by control cables and electrical wire bundles. The pressure bulkhead at FS 275 had been crushed aft at the fuselage bottom centerline. The main cabin floor beams from FS 392 to FS 475 failed with a progressively downward disglacement of each floor beam. The aft edge of this floor section was hanging down at a 45 angle. The cabin seat tracks in this area had fractured into short sections. The fractures were clean and bright, with the fractured surfaces about 45° to the local surface. There was no evidence of compression buckling or previous cracking. The first row of passenger seats, which consisted of a left side module of three seats, a center seat module of two seats, and a right module of three seats, had separated from the floor structure as the result of the seat track fragmentation. The three seat modules were installed in the immediate area of the nose-sectionlmain-fuselage separation. The pressure bulkhead at the forward end of the nose wheel landing gear well had been crushed inward and aft. The shear web on the fore and aft nose landing gear support beams contained a 2-foot vertical fracture at the nose gear drag link support fittings. The fuselage attach fittings for the nose gear drag braces were torn from the fore and aft nose gear support beams, and the gear had folded aft while pivoting about the strut trunnion axis.

The wing leading edge slats were in the fully extended position and the wing trailing edge flaps were extended to the 35° position. The wing structures showed no evidence of damage from ground contact.

The main landing gear assemblies were not heavily damaged. All main shock struts were extended. Examination of the tires and the brake assemblies disclosed that all tires were inflated to the proper pressures, the tire treads were worn only slightly and there was no evidence, such as cutting, rubber reversion, or flat-spotting, to indicate sliding or locked wheels. All brake linings were above the minimum allowable wear limit. The inspection and testing of the main wheel transducers, the four brake manifolds, and the main electronic antiskid control unit revealed salt water corrosion from prolonged immersion. The wheel spin transducers, which generate signal voltage for automatic spoiler deployment and antiskid modulation, were tested. All transducers operated normally except No. 6, which failed to operate because of corrosion and a broken wire. The Safety Board could not determine whether the wire was broken before or during the accident. The four antiskid manifolds were tested. One unit had an inoperative solenoid, which had been saturated with salt water. The Safety Board concluded that the cap of the solenoid unit had leaked after being immersed in water, rendering the solenoid inoperative.

The main antiskid control unit could not be tested because the electrical components had been corroded extensively by salt water. The circuit cards for each of the 10 wheels were removed from the control unit, cleared of corrosion and individually tested. Only 1 of the 10 cards failed the tests; the failed card was found to have a bad transistor, which could have caused low brake pressure to its associated brake assembly.

The accident aircraft's three engines remained attached to their respective pylons although the right rear link of the No. 3 engine rear mount was broken through the center of the link at the turbine rear frame attachment clevis. A furrow was found in the bed of the bay behind the No. 3 engine. The furrow was about 1 foot deep, 4 to 5 feet wide, and 15 feet long. There was no visible evidence of a furrow behind the No. 1 engine.

The No. 1 engine was about 80 percent submerged and the No. 3 engine was completely submerged during high tide. The No. 1 engine was completely exposed at low tide, while about 20 percent of the bottom of No. 3 engine, including the major portion of the accessory gearbox, was buried in the mud and sand. The Nos. 1 and 3 engines were removed from the airplane for on-site evaluation and documentation. Neither engine had substantial mechanical damage.

The No. 2 engine continued to run at full power with reversers extended for about 30 minutes after the airplane entered the water. The No. 2 engine was not removed from the airplane because of inaccessibility. Therefore, inspection of the No. 2 engine and nacelle area was limited. The inlet and cowling appeared to be undamaged and all latches were securely fastened. The fan rotor moved freely and visible internal parts of the engine were not damaged except for the effects of salt water corrosion. Significantly, the fan thrust reverser translating cowls and blocker doors of both wing-mounted engines were in the fully deployed position.

The airplane was equipped with the required number and capacity of life rafts, life preservers and survival equipment for water survival. The seat cushions were a nonfloatable type. The normal DC-10 life raft capacity is 398 persons, with a overload capacity to accommodate 494 people. This provides for malfunctioning or inaccessibility of some rafts, such as was the case in this accident where the two forward rafts were lost when the nose section broke off and the rear rafts were unusable because of the high winds created by the centerline engine.

1.13 Medical and Pathological Information

One flight attendant was treated for hypothermia following immersion in the 30° F salt water of the harbor. Five flight attendants, 19 passengers, and 2 firemen were treated for minor injuries at hospitals and released. The captain was admitted to the hospital and treated for shock. One passenger was hospitalized for a possible anginal attack. One passenger suffered a depressed cervical fracture. Two male passengers, who reportedly occupied seats 1B and 1C, have not been found and are presumed dead.

1.14 Fire

There was no fire.

1.15 Swival Aspects

Emergency Plan Notification and Initial Response.--In accordance with the Massachusetts Port Authority Emergency Plan, the Logan Air Traffic Control Tower notified the Logan Fire Department at 1937 and the Coast Guard Operations Center at 1940 that the DC-10 airplane was in the water off the end of runway 15R. The Logan Fire Department responded immediately dispatching emergency vehicles to the shoreline. The first firemen arrived at the site within 4 minutes after the crash alarm sounded. Vehicles were positioned on shore to provide illumination of the scene, and firemen discharged fire extinguishing agents into the No. 2 centerline engine intake in an unsuccessful attempt to stop the engine as the occupants began to evacuate the airplane. Since the accident site was accessible from the shore, the decision was made not to launch the two crash boats.

Evacuation.--The cabin area, which were configured to seat 354 persons, was divided into three passenger zones. There were four floor-level exits on each side of the airplane: forward of zone A (exits 1 L and R), between zones A and B (exits 2 L and R), between zones B and C (exits 3 L and R), and the aft floor-level exits (4 L and R) between the last seat row and the aft lavatory area. All exits were equipped with slidehaft combinations.

When the airplane came to a stop, the flightcrew, the forward cabin flight attendants, and the forward cabin passengers were immediately aware that the airplane's nose section had separated from the fuselage. The forward passenger seat row, which was adjacent to the fuselage break, and the flight attendant jump seats in the nose section had been thrown in the water. Passenger seat row one, comprised of two triple seat units and a double seat unit, had been occupied by three passengers. Two of these passengers are those presumed to have drowned. The third passenger was able to climb back into the main cabin.

Throughout the passenger cabin, the flight attendants directed the passengers to remain calm and to stay seated until the situation was assessed. When electrical power was lost, the emergency lights illuminated. The flight attendants at exit doors could not see outside through the moisture-covered windows. The rear cabin flight attendants did not immediately realize that the airplane had stopped because the loud noise and high vibrations of the No. 2 engine camouflaged the impact. Even after she became aware that the airplane had stopped, the senior flight attendant in the rear hesitated to order the evacuation because she knew that an engine was still running, and she was not aware of any structural damage, heavy smoke or flames, or other crewmembers' having started any evacuation. Additionally, she had not received orders to evacuate from the captain. The flight attendant in the forward cabin went aft to advise the senior attendant that the fuselage had broken and the passenger evacuation had begun. All emergency exits, except for the foremost exits which separated with the nose section, opened easily and the slidehafts inflated. When opened, exit L-4 was not usable because the airflow created by the, reverse thrust of the centerline (No. 2) engine was blowing debris into the cabin and had blown the slidehaft against the fuselage. Evacuation was also hindered at exits R-4 and L-2 when the wind twisted the slidehafts. The majority of persons left the airplane through the R-3 exit, which was over the right wing. Except for the area immediately adjacent to the separation, the cabin furnishings remained generally in place.

The captain stated that, as the airplane left the hard surface adjacent to the runway, he felt a jarring bump and the cockpit was suddenly immersed in water. He stated that as sea water and debris flooded in the nose section, the three crewmembers released themselves from their seatbelt/shoulder harnesses and left the nose section through the open fuselage break. The first officer and the flight engineer swam around the left wing to the shore where they were helped up the embankment by firemen. Both men had trouble staying clear of debris near the airplane and heavy ice floes along the shore. The flight engineer estimated that they were in the water for about 10 minutes before reaching the shore. As the first officer climbed the bank, he was shaking uncontrollably and he fell on the ice-covered ground several times before he was taken in a waiting vehicle.

When the captain swam from the cockpit section, he saw two flight attendants and the two other cockpit crewmembers in the water with him. When he saw the gaping hole in the forward fuselage, he swam to the fuselage and climbed into the cabin. The two flight attendants and a passenger who were in the water also climbed up to the cabin with help from several other passengers. At that time, passengers were continuing to evacuate the airplane through cabin doors and emergency exits. That majority of the passengers who departed through the R-3 overwing exit was able to proceed over the wing until they were about 10 feet from shore then wade through the 2- to 3-foot deep water and up the snow and ice-covered bank. About 30 passengers departed the cabin through the R-4 exit into the slidehaft. These persons had to wade about 15 to 20 feet through waist to chest deep water as they made their way to shore. Those few passengers who departed from the left side of the cabin were either helped back into the cabin or swam to shore. The captain exited through the left overwing exit. After aiding several passengers who had fallen in the water, he also made his way to shore and was carried to an ambulance.

The No. 2 engine had continued to run throughout the evacuation, and in addition to the problems created as the reverse thrust twisted the rafts, the engine noise hampered verbal communications. At the request of a fireman, the flight engineer returned to the airplane over the right wing, reentered the fuselage through the overwing hatch, and proceeded. to the forward cabin in an attempt to identify the No. 2 engine control cables. However, at that time, the engine began to surge and it stopped running. The flight engineer then returned to shore. The engine had run for 30 to **40** minutes after the airplane entered the water.

By **1948,** all passengers known to have evacuated the airplane were on the shore and by **1954,** those passengers started arriving at the firehouse. The rescue operation was terminated at **0100** on January **24,** and officials believed that all persons aboard the accident airplane had been accounted for. Several days passed before World Airways, Inc., officials acknowledged that two men were missing. **A** review of the World Airways, Inc., passenger service system revealed that the original passenger manifest **is** derived from the reservations computers; however, since some booked passengers never actually board, the most accurate count is based on the flight coupons lifted when the passengers board the airplane. Down-line stations are advised of the numbers of passengers boarded, the number deplaning at the following station, and the number continuing through. The Boston airport office of World Airways had been advised that there were **196** passengers deplaning from World **30H** in Boston. In this instance, the actual passenger count should have been **197** ticketed passengers because one passenger did not have his flight coupon lifted when he boarded. Further, a Massport employee injured at the accident scene was admitted to the hospital, and he was inadvertently reported as a passenger, Therefore, rescue and airline personnel were satisfied that all persons on World **30H** had been accounted for.

At the Safety Board's request, about **25** percent of the passengers submitted written statements regarding the evacuation and rescue. The context of the passengers' comments varied from a calm and orderly evacuation to a slightly hysterical one. The differences appear to depend on where the passenger was located and his/her proximity to a flight attendant who had the responsibility to determine the safest course of action. Several passengers commented that they had encountered difficulties in their use of the airplanes underseat life vests. A few passengers commented that they had problems retrieving the vests from under their seats. Several commented that they had difficulty opening the plastic packing of the vests. One flight attendant stated that she had to use her teeth.. Some of the passengers believed mistakenly that the seat cushions were buoyant and threw cushions to those in the water. The cushions, however, were not designed to provide flotation.

The most stressing element to the survivors was the cold water, **30° F,** and ambient air temperature, 35° F. Most of the passengers were only partially immersed for a short time period as they made their way from the wing or slide/raft to the shore. One flight attendant however who exited the left side of the airplane required hospitalization for hypothermia after having been in the water for about **10** minutes. All of the passengers were exposed to the cold air temperature and the 4-kn wind after reaching the shore. Several complained about the lack of timely and suitable transportation from the accident site to the fire station and terminal area and the lack of a warm, comfortable holding area to accommodate all survivors, especially those survivors who were not injured. About **20** passengers were driven in an open-stake truck to the fire station **25** minutes after they reached the shore. Passengers stated that they had to stand for over an hour on a cold, cement floor of the open fire station until they were released. One survivor, a physician, commented on the delays incurred assigning priority to the injured passengers. While the majority of the survivors were complimentary of the rescue efforts, they also commented on the lack of effective organization within the rescue' group.

Response by Other Public Service Agencies--Other public service agencies responding to the accident were Metropolitan District Police, Boston City Fire Department, Boston City Police Department, Boston Department of Health, local hospitals, 8/ and the United States Coast Guard.

After being notified at 1940 that a DC-10 airplane with about 190 persons on board was in the water off of the end of runway 15R, the Coast Guard Operations Center took immediate action to launch three cutters, four utility boats, one Coast Guard helicopter, and two Navy helicopters to the scene to augment rescue operations and secure the accident site. None arrived in time to assist in the evacuation of the airplane. The first Coast Guard vessel arrived on scene at 2020. The cutter PENDANT which was underway at 1956 arrived on scene at 2110, at which time it was designated as on-scene commander. The Coast Guard helicopter was airborne at 2058 from Cape Cod Air Station and the Naval helicopters were airborne from South Weymouth at 2103 and 2210, respectively. However, the three aircraft were forced to return to their bases because of poor weather in the area.

At 2058, the Coast Guard established a safety zone around the accident area. This order, issued by authority of 33 CFR 165, stated that all vessels were to remain outside of a 2,000-yard radius of the accident site and could not enter or remain in the safety zone without the permission of the Captain of the Port. The message was broadcast every hour on maritime radio.

At 2110, State police divers entered the water from the shore and examined the nose section and fuselage to determine if survivors remained in the airplane. Having boarded the Coast Guard patrol boat No. 44307 at 2110, Quincy police divers entered the water at 2202.

During the 4-hour period following the accident, while awaiting verification that all persons on board the accident airplane had been accounted for, Coast Guard units treated the situation as if the possibility remained that persons were in the water. However, by 2250, all floating units had been released from the scene except the Coast Guard cutter PENDANT and a utility boat which remained to maintain the established safety zone.

1.16 Tests and Research

1.16.1 Correlation of Approach Profile, Touchdown, and Subsequent Events To The Airplane's Position

Pertinent information and data from the airplane's DFDR and CVR were used along with DC 10-30 aerodynamic data supplied by the McDonnell Douglas Corporation to describe the approach descent profile of Flight 30H and to correlate significant events during the approach, touchdown, and landing roll to the airplane's position at the time of each.

The airplane's descent profile was derived by examining data from the en route ATC radar computer, the DFDR, the CVR, and weather records. The approach was examined from an altitude of 4,100 feet to touchdown. The radar data, which were available until the airplane descended to 500 feet were compared with the flightpath derived from the airspeed and altitude data recorded on the DFDR and estimated winds. The wind data were varied to achieve a match between the radar- and DFDR-derived

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8/ Hospitals included Boston City Hospital, New England Medical Center, Winthrop Community Hospital, and Massachusetts General Hospital.

profiles. The airplane's position in space as it descended below **500** feet was then compared with the glidepath indication which would have been viewed on the **VASI** system using the specifications for the installation of the 2-bar system on runway 15.

This examination of data showed that the airplane descended to **510** feet and leveled until the VASI glidepath was intercepted. (See appendix **I.**) The airplane then descended maintaining an average 800-fpm descent path which would have provided the pilot with an "on glidepath" indication to a height above the ground of about 120 feet. The airplane then deviated from the VASI glidepath so that the pilot would have observed a "slightly above glidepath" indication. 9/ The airplane passed over the displaced threshold at a height of about **45** feet with an indicated airspeed of **160** kns, **15** kns above the calculated reference speed (V_{ref}) for a gross weight of **365,000** pounds. The landing flare began when the airplane **was about** 40 feet above the runway and both airspeed and rate of descent were reduced. The pitch attitude was increased about 2° during the flare. The data analysis showed that the airplane touched down with a rate of descent of about **200** fpm and an indicated airspeed **of** 147 kns. About **6,690** feet of runway was available for stopping the airplane.

The touchdown position on runway 15R was established using the airspeed and three axes acceleration data recorded on the airplane's DFDR and the reported wind at the time of touchdown. The perturbations of DFDR-measured parameters corresponding to the airplane's touchdown and passage over the seawall were identified to establish the timing relationship of these events to each other and to the DFDR measurements. The groundspeed at touchdown and a double integration of the component of acceleration parallel to the runway centerline yielded the distance which the airplane traveled between touchdown, other occurrences, and passage over the seawall The known geographic position of the seawall provided the correlation between the events indicated by DFDR-parameters and the position of the airplane with respect to the runway. This analysis showed that the airplane touched down about **2,500** feet beyond the runway displaced threshold.

The ground spoiler actuation system had been armed during the approach so that the spoilers would extend automatically after touchdown when the main landing gear wheels spun up to a speed equivalent to about **60** kns. Based on crew statements and confirmed by DFDR data, the spoilers began to deploy about **2** seconds after main gear touchdown and were fully extended about **2** seconds later. The DFDR indicated that the thrust reversers were fully deployed about **2** seconds after nose gear touchdown. Since the reversers nominally take 2 seconds to deploy, it is assumed that the captain initiated reverse thrust at nose gear touchdown and idle reverse thrust was achieved **2** seconds later. The reverse thrust level increased during the next **11** seconds to reach **90** percent **N**, the maximum available reverse thrust. The positions of the airplane along the runway when the thrust reversers were actuated and deployed, and the subsequent levels of thrust which were attained, are shown in appendix **H.**

The DFDR indicated that wheel braking began about **2** seconds after the main gear touched down, when the airplane's groundspeed was about **135** kns. The brake system pressure was steadily increased and reached the maximum recorded pressure of 2,500 pounds per square inch after about **14** seconds. This pressure was maintained until about **2** seconds before the airplane went over the seawall and coincident with DFDR termination.

9/ For larger airplanes, such as the DC-10, the pilot is directed to disregard 2-bar VASI guidance information below an altitude of **200** feet above the runway.

The CVR indicated that the captain stated there was no effective braking twice after the main gear touched down. First, about **13** seconds and 3,000 feet after main gear touchdown **(3,700** feet from the departure end of the runway) at a groundspeed of **116** kns. By this time, the captain had applied about **95** percent of the World Airways normal limit reverse thrust level and about **32** percent of the peak DFDR value of brake pedal pressure. The captain's second "no braking.. ." comment was made about **27** seconds and **5,300** feet after main gear touchdown **(1,400** feet from the departure. end of the runway) at a groundspeed of 79 kns. By this time, about **105** percent of the World Airways normal limit reverse thrust level and **100** percent of the peak DFDR value of brake pedal pressure had been applied.

For about **3,600** feet after the main gear touched down, the airplane's ground track was essentially along the centerline of the runway with deviations of no more than about **6** feet, although the .airplane fishtailed several times. However, 3,600 feet past the main **gear** touchdown point, the airplane started to gradually turn or drift to the left side of the runway. The left turn or drift stopped about 5,000 feet from main gear touchdown, with the airplane about 35 feet to the left of the runway centerline. Then, about 6,100 feet from main gear touchdown, or about **600** feet from the end of the runway, a gradual but definite left turn began. The airplane continued to turn left, departed the end of the runway at the left corner, and then traversed the seawall, **200** feet past the end **of** the runway and **111** feet to the left of the runway centerline. The airplane's groundspeed **was** about **47** kns when it reached the seawall and the elapsed time from touchdown to the crossing of the seawall was **43** seconds.

1.16.2 Deceleration of Airplane During Landing Roll and Determination of Achieved Braking Coefficients

The three axes acceleration data recorded on the airplane's DFDR were corrected for biases and resolved to provide the component aligned with the airplane's decelerative forces. The total decelerative energy required was then determined using the estimated gross weight of the airplane. Dissipation of this total kinetic energy was then attributed to the airplane's aerodynamic drag, the added drag produced by ground spoilers, reverse thrust, tire rolling resistance, and wheel brakes. **DC-10-30** aerodynamic and performance data were used to determine the contribution to deceleration of basic airplane and ground spoiler drag and reverse thrust based upon the airplane's airspeed, attitude, and thrust levels recorded on the DFDR. The remaining decelerative forces were then attributed to rolling resistance and wheel brakes and were used as the basis for determining the braking effectiveness on runway 15R when Flight **30H** landed.

The airframe aerodynamic drag and the added aerodynamic drag produced by extension of the ground spoilers vary during the landing roll as a function of airspeed; drag decreases significantly as speed decreases. The effectiveness of the thrust reversers and thus the decelerative force produced by reverse thrust at a constant engine power setting is also reduced as the airplane slows. The rolling resistance of an unbraked tire is related to the frictional characteristics of the tire and the runway surface and produces a decelerative force of little significance. Therefore, the primary force to decelerate an airplane during normal landings on dry runways is that produced by the ,wheel brakes.

Contrary to the percentages of the decelerative energy normally developed from reverse thrust, drag, and wheel brakes, the calculated percentage which was generated by each of the contributing components during the landing roll of Flight **30H** is shown for decreasing airspeeds on Table **1.** The actual forces produced are shown in Table **2.**

Table 1.--Contribution of Drag, Reverse Thrust, and Wheel Brakes to Deceleration During Flight 30H Landing. */

Gross Weight	Decelerative Force Component (Percent)	Groundspeed (kns) 140	130	120	110	100	90	80	70	60	50
365,000	Airframe Drag	44	41	41	30	25	20	17	17	12	10
	Spoiler Drag	38	34	27	25	22	17	15	14	10	8
	Reverse Thrust	17	21	29	34	33	28	26	26	20	18
	Brakes	1	4	13	11	20	35	42	43	58	64

*/ Source: McDonnell Douglas/Safety Board Performance Group.

The torque applied to the airplane's wheel and tire assemblies through the brakes will retard the rotational speed of the wheels and cause the tires to stretch and scrub slightly on the runway surface. This scrubbing action increases the frictional force between the tire and the runway surface. However, the magnitude of the frictional force which is developed depends upon the characteristics of the runway surface and the amount of scrubbing between the tire and the runway surface. Tests have shown that optimum braking force is achieved when the airplane's wheels are rotating at a speed about 8 to 10 percent slower than a free wheeling tire would rotate. If the braking torque applied to the wheels exceeds the balancing frictional force which can be transmitted between the tires and the runway surface, the wheel rotation will slow excessively or the wheels will lock completely and the braking force will diminish greatly. The airplane antiskid system is designed to maintain a wheel braking torque which will produce the optimum amount of slip between the tire and runway surface to achieve the maximum braking force which can be generated for a given runway surface condition.

The frictional force which can be developed on a runway surface is described in terms of the runway coefficient of friction. 10/ For a braking airplane, the maximum retarding force that can be transmitted between a runway surface and the airplane tires is the runway coefficient of friction times the airplane's total gross weight. After the airplane lands, however, the aerodynamic surfaces continue to produce some lift, which balances a percentage of the weight and thus reduces the braking force. The extension of ground spoilers, the application of reverse thrust, and subsequent deceleration of the airplane will reduce the lift and increase the effective weight of the airplane acting through the tire to the runway, thus increasing the braking force which can be generated. Furthermore, in addition to the runway surface characteristics, other factors such as antiskid System efficiency affect braking force; therefore, the total braking effectiveness of the airplane for any particular condition is expressed as a coefficient of braking. This is the proportion of the airplane's weight which is distributed on the braked wheels and can be converted to a longitudinal retarding force through the tire-to-runway surface contact. The weight on the braked wheels depends upon both the amount of lift being developed and the weight distribution between the braked wheels and the unbraked nose wheels. Thus, if the braking coefficient remains constant throughout the landing roll, the braking force developed as the airplane slows would change as lift decreases and weight

10/ The force required to slide one surface along another is a function of the surface characteristics and the normal force pressing the surfaces together. The coefficient of friction relates the sliding force to the normal force as a percentage of the normal force.

MODEL DC-10
INFORMATION ON WORLD ACCIDENT 1/23/82 AT LOGAN 1/

CONDITIONS USED:

AIRPORT PRESSURE ALTITUDE = 360 FT

TEMPERATURE = 37°F

WEIGHT = 365,000 LBS CG = 18%

WIND = 2 KTS HEADWIND ON RUNWAY FLAPS = 35° EXCEPT AS NOTED

ITM 1 AND 2:

SPEED (KTS TGS)	140	130	120	110	110	90	80	70	60	50
DRAG (AIRFRAME WITHOUT SPOILERS LB)	25996	22476	19186	16180	13409	10917	8681	6886	4964	3486
GROUND SPOILER DRAG (LB)	22034	19027	16267	13699	11373	9244	7335	5662	4192	2954
REVERSE THRUST (LB)	10246	11805	17512	18364	17082	15094	12905	10716	8527	6337
BRAKING FORCE (INCLUDES ROLLING u') (LB)	377	2312	8278	5967	10490	18615	20984	17838	24531	23350
BRAKING COEFFICIENT u'	.0007	.0064	.0235	.0168	.0299	.0535	.0607	.0519	.0726	.0693
TOTAL DECELERATION (FT/SEC^2)	5.170	4.903	5.399	4.779	4.615	4.749	4.399	3.606	3.721	3.185
TOTAL DECELERATION FORCE (LB)	58653	55620	61243	54210	52354	53870	49905	41102	42214	36127

TABLE 2

1/ Source Safety Board Performance Group.

distribution changes. However, tests have shown that the braking coefficient does not remain constant, but changes as the airplane slows. On dry runway surfaces, the effective braking coefficients for DC-10-30 airplanes can range from 0.2 at high speed to 0.53 at low speed.

The runway coefficient of friction and thus the braking coefficient which an airplane can develop after landing are significantly reduced if the runway surface is covered with standing water, snow, ice, or any combination of such contaminants. Typical braking coefficients that are encountered by a DC-10-30 airplane at 100 kns on various runway surfaces are shown in Table 3 below.

Table 3.--Runway Condition Versus Effective Braking Coefficient.

Runway Condition		Approximate Effective Braking Coefficient (at 100 kns)
Dry Concrete		0.43
Wet Concrete		0.10
Ice		0.07
Wet Ice	Less Than	0.07

As shown in Table 3, the braking coefficient, and thus the decelerative force from the wheel brakes, developed by an airplane on an ice-covered runway can be less than 16 percent of that which can be developed by the same airplane on a dry runway at the same speed. While the braking coefficient normally increases as the airplane slows, the increase is considerably less on a runway covered with ice. Tests have shown that braking coefficient can begin to decrease as an airplane slows to speeds below 20 kns on slippery runways. Therefore, as speed decreases, the disparity between dry runway performance and contaminated runway performance can become even greater. As a measure of the relative magnitude of the low braking coefficients developed on ice, the rolling resistance of an airplane with unbraked tires on a dry runway equates to a braking coefficient of 0.015 to 0.02. The wheel brake decelerative forces which were calculated for Flight 30H during its landing at Boston-Logan were used with aerodynamic analysis of lift and weight distribution to determine braking coefficients for 10-kn intervals as the airplane's groundspeed decreased. The braking coefficients ranged from nearly zero at 140 kns to 0.07 when the airplane's speed slowed below 60 kns. (See table 4.)

Since the Safety Board was not able to determine the efficiency of the braking control provided by the airplane's antiskid system throughout the landing roll, it was not possible to relate the calculated braking coefficients to a runway surface coefficient of friction.

1.16.3 Deceleration of Northwest Orient Flight 42, DC-10-40

Northwest Flight 42 landed 8 minutes before Flight 30H, and its pilot reported the braking as "poor." He maintained reverse thrust throughout the landing roll and had difficulty turning of€ the runway at the end. The Safety Board obtained the DFDR from that airplane and examined the parameters recorded during the landing. The braking coefficients were calculated in the manner described above for the calculation of braking coefficients for Flight 30H. The braking coefficients attained by Flight 42 were similar to those attained by Flight 30H, ranging from 0.025 at 140 kns, 0.04 at 100 kns, 0.08 between 70 kns and 45 kns, and decreasing to 0.05 as the airplane slowed below 40 kns.

WORLD AIRWAYS FLIGHT 30H
MODEL DC-10-30
CALCULATED STOPPING DISTANCFS

AIRPORT PRESSURE ALTITUDE = 360 FT
TEMPERATURE = 37°F

WIND = 2 KTS HEADWIND ON RUNWAY
CG = 18%

ACTUAL CONTROL APPLICATIONS
TIME FROM TOUCHDOWN

SPOILERS (SECS)	BRAKES (SECS)	REVERSERS (SECS)
2 ACTUATION	7 INITIATION	2 UNLOCK
4 DEPLOYED	19 FULL	4 DEPLOYED
		17 SPOOL UP

WEIGHT (LBS)	FLAP (°)	TOUCHWWN GROUNDSPEED (KNOTS)	DISTANCE TO STOP (FT) u' 1	u' 2	u' 3	u' 4
365000	35	147.5	8392	8189	7364	7554
	50	144.9	7864	7665	6862	7096

OPTIMAL CONTROL APPLICATIONS
TIME FROM TOUCHDOWN

SPOILERS (SECS)	BRAKES (SECS)	REVERSERS (SECS)
2 ACTUATION	1.5 INITIATION	2 UNLOCK
4 DEPLOYED	3.5 FULL	4 DEPLOYED
		8 SPOOL UP

WEIGHT (LBS)	FLAP (°)	TOUCHDOWN GROUNDSPEED (KNOTS)	DISTANCE TO STOP (FT) u' 1	u' 2	u' 3	u' 4
365000	35	135.6	7464	7182	6308	6682
	50	130.8	6918	6642	5794	6137
	35	147.5	8128	7847	6973	7382
	50	144.9	7660	7383	6535	6910

LEGEND: u' = notation for mu, braking coefficient

u'1, u'2 and u'3 assume effective braking coefficients derived from the analysis of Flight 30H DFDR data during landing until the airplane decelerates to 55 kns

u'1 - u' extrapolated from 55 kns to 0 kn linearly from 0.0802 to 0.0200 and constant from 25 kns to 0 kn at 0.0200.

u'2 - u' extrapolated from 55 kns to 25 kns linearly from 0.0802 to 0.0200 and extrapolated from 25 kns to 0 kn linearly from 0.0200 to 0.0600

u'3 - u' constant from 55 kns to 0 kn at 0.0802

u'4 - u' assumes effective braking coefficient derived from analysis of Northwest Flight 42 as that airplane decelerated after touchdown.

TABLE 4

The Northwest DC-10-40 weighed about 340,000 pounds when it landed. The engines of Northwest DC-10-40 develop greater thrust than the engines of the World DC 10-30 and develop about 5 percent greater reverse thrust decelerative forces. Thus, the stopping distances between Flight 42 and Flight 30H cannot be directly related by the achievable braking coefficients.

1.16.4 Theoretical Landing and Stopping Distances Based Upon Calculated and Estimated Braking Coefficients

The total distance required to land a DC-10-30 weighing 365,000 pounds and bring it to a full stop under described conditions of abnormally low braking coefficients was calculated theoretically for two configurations and compared with the length of runway 15R at Boston-Logan International Airport. The calculations considered flap configurations of 35° and 50° and approach airspeeds consistent with the evident autothrottle performance on the accident airplane. The appropriate DC-10-30 aerodynamic and performance data were used to determine lift, drag, and reverse thrust as they related to the decelerative forces developed during landing roll. Several conditions which would affect the deceleration of the airplane were examined. Both the DFDR-measured time increments and the minimal reasonable time increments between touchdown and ground spoiler actuation, thrust reverser deployment, thrust buildup, and brake application were considered. The braking coefficients which were assumed were varied as the groundspeed changed during the landing roll. The braking coefficient groundspeed relationship determined from analysis of the accident airplane's DFDR parameters was used to a groundspeed of 55 kns. Three braking coefficient/groundspeed variations were considered below 55 kns. One calculation assumed a constant braking coefficient as the airplane decelerated from 55 kns to a stop. The other calculated distances assumed decreasing variations in the values for braking coefficient as the airplane decelerated. These latter assumptions were based upon braking coefficient data obtained during actual test demonstrations of airplane operations on low friction coefficient runways which were conducted by the Aeronautical Research Institute of Sweden and the Scandinavian Airline System. 11/ The values for braking coefficient determined for the landing roll of Flight 42 were also used to calculate stopping distances for Flight 30H, adjusting for the additional weight of Flight 30H and the various considerations for flap configurations, approach speeds, and post-touchdown control applications. The stopping distances calculated and the corresponding conditions and assumptions used are shown on Table 4.

The calculations showed that Flight 30H would have required between 7,364 feet and 8,392 feet in which to stop, with the actual configuration and application of controls as indicated by the DFDR, depending upon the assumptions for the variation of braking coefficient used as the airplane decelerated below 55 kns. The stopping distance using optimum deceleration techniques--50° flaps with rapid ground spoiler, reverse thrust, and wheel brake application--would have been reduced to between 6,535 feet and 7,660 feet. The required stopping distances calculated using the braking coefficient values obtained from the analysis of the Flight 42's DFDR were of similar magnitude, about 6,900 feet assuming a 50° flap configuration and optimum application of decelerative devices, and 7,550 feet assuming a 35° flap configuration and the application of decelerative devices as indicated on the Flight 30H's DFDR.

11/ McDonnell Douglas Corporation Report No. 57444. The DC-9-20 Mark IIIA Antiskid 1973-1974 Winter Service Braking Tests, October 13, 1977.

1.17 Additional Information

1.17.1 Certification Landing Distances and Approved Field Lengths

Under the airplane type certification provisions of 14 CFR 25.125, manufacturers are required to demonstrate the stopping distance capability of their airplanes. The dry runway landing distances are derived from the sum of the demonstrated air distance (air run) from the 50-foot height and the ground stopping distances, which are determined without the use of reverse thrust. These values represent minimum landing distances for dry runway surfaces when the airplane is operated near its maximum performance capability and structural limits. The techniques used during the certification flights are not those techniques used in routine airline operations where environmental factors influence landing operations. 12/ Further, under the provisions of 14 CFR 121.195 (Transport Category Airplanes: Turbine Engine Powered: Landing Limitations; Destination Airports), an FAA-approved field length must provide a distance that will allow a full stop within 60 percent of the effective length of each approved runway from a point 50 feet above the intersection of the obstruction clearance path and the runway.

Actual landing distances for wet runway stopping capability are not demonstrated during certification tests. Therefore, FAA-approved landing field lengths for wet runways are based on estimates obtained by increasing the dry runway landing field length by a factor of 15 percent. Since the air distance is not affected by runway conditions, the applied factor increases the wet stopping distance about 22 percent for the DC-10-30.

Landing distances determined during FAA certification of the DC-10-30 in accordance with 14 CFR 25.125 and 14 CFR 121.195 are also shown in Table 5. This table provides landing distance and field length data for the estimated 365,000-pound gross weight of Flight 30H with 35° trailing edge flaps and 50° trailing edge flaps. Data for the structural-limit gross weight of 421,000 pounds are provided for comparison. The FAA-approved landing field lengths for wet runways at the structural-limit gross weight of 421,000 pounds are 7,622 feet and 7,089 feet for 35° and 50° trailing edge flap settings, respectively.

FAA certification procedures also establish maximum landing gross weights limited solely by the performance capabilities of the airplane. The DC-10-30 performance-limited landing gross weight for Boston-Logan runway 15R when dry is 596,000 pounds and when wet is 522,700 pounds (World Airways Planning and Performance Manual).

To meet the provisions of 14 CFR 121.195, air carriers prepare airport analysis charts to describe factors affecting takeoff and landing limitations. The runway landing charts list the actual runway length, effective runway length, maximum structural weight limit, dry runway maximum weight limit, and wet runway maximum weight limit. Wind, inoperative antiskid, critical temperatures, and flap configuration are listed as factors affecting authorized gross landing weight, and when applicable, the maximum allowable gross weight must be adjusted for these factors. The charts do not include a basic certification stopping distance. The charts, which are weight-related and not distance-related, refer to dry and wet runways. Part 14 CFR 121.195 does not require operational field length data relating to stopping distances on snow- or ice-covered

12/ Aircraft Accident Report--"McDonnell Douglas Corporation DC-9-80, N980DC, Edwards Air Force Base, California, May 2, 1980" (NTSB-AAR-82-2).

FAA CERTIFICATION LANDING GISTANCES 1/

RIRPLANE GROSS WEIGHT LBS	TE FLAP SETTING GEGREES	RUNWAY CONDITION	AIR RUN SEGMENT-FEET ACTUAL	AIR RUN SEGMENT-FEET ACTUAL/0.6	STOPPING SEGMENT-FEET ACTUAL	STOPPING SEGMENT-FEET ACTUAL/0.6	TOTAL-FEET ACTUAL GIST.	TOTAL-FEET FAA AF'PROVEG FIELD LENGTH
365,000	35	DRY	1,131	1,885	2,392	3,987	3,523	5,872
		WET	-	1,885	-	4,868	-	6,753
	50	GRY	1,049	1,748	2,231	3,719	3,280	5,467
		WET	-	1,748	-	4,539	-	6,287
421,000 (Structural Limit)	35	DRY	1,211	2,018	2,766	4,610	3,977	6,628
		WET	-	2,018	-	5,604	-	7,622
	50	GRY	1,132	1,887	2,566	4,277	3,698	6,164
		WET	-	1,887	-	5,202	-	7,089

TABLE 5

1/ Derived by Safety Board Accident Investigation Performance Group using McDonnell-Douglas Corporation data from the FAA-approved Flight Manual.

runways where braking friction is less than those friction values normally associated with wet runways. Moreover, manufacturers are not required to provide such data to operators. Therefore, a flightcrew does not have an easily accessible reference to the landing distances required on contaminated runways, particularly to landing distances on extremely slippery surfaces. Currently, the certification standards and operating rules prescribed by the FAR do not provide methods by which flightcrews can assess the risks associated with flight operations on runways covered with various forms of snow, slush or ice, or when rain is freezing on the runway surfaces. However, the McDonnell Douglas Corporation's performance engineering manual contains charts which estimate stopping distances on wet and icy runways and the effects of varied threshold height and speed on stopping distances. The applicable data are not required to be and had not been transformed into meaningful information in the pilot's Operations Manual.

1.17.2 World Airways, Inc., Landing Procedures

The World Airways, Inc., DC-10 Training Guide prescribes that during the final approach the pilot will maintain the programmed airspeed and control the approach path so as to cross the runway threshold at 50 feet while establishing a sink rate no greater than 800 fpm. Since the main gear on the DC-10-30 is located about 94 feet behind and 33 feet below the pilot's position in the flare attitude, the pilot must not attempt to place the airplane on the forward end of the runway, but must touch down 1,000 feet to 1,500 feet beyond the runway threshold. The optimum threshold airspeed is reference speed plus 5 kns (V_{Ref} +5), with no variation. The pilot is directed not to hold the airplane off the runway during the flare since deceleration on a dry runway is about three times greater than in the air. Therefore, the pilot is directed to get the wheels on the runway even if the speed is slightly higher than desired. The Training Guide cautions the pilot that flying over the end of the runway at 100 feet altitude rather than at 50 feet could increase the total landing distance by about 900 feet on a 3° glidepath. As reverse thrust indicating lights illuminate, pilots are told to use reverse thrust on engines Nos. 1 and 3, reversing at idle thrust. However, if runway conditions require more than reverse idle on Nos, 1 and 3, thrust should be limited to 80 percent N_1 compressor speed. In an emergency, all three engines may be reversed to maximum continuous thrust, as required. Pilots are also directed to utilize the full length of the runway on rollout and to avoid any unnecessary wheel braking.

In World Airways, Inc., Flight Operations Policy and Procedures Manual, pilots are advised that landing on icy runways will be made at the pilot's discretion; however, if the braking coefficient is reported as "nil," based on a vehicle decelerometer, 13/ the flight will proceed to the alternate landing field. Pilots are directed to exercise good judgment when landing under hazardous conditions. They are advised to consider wind direction and speed, runway length, reported braking coefficient, and prevailing weather conditions. For pilot guidance, the manual quotes the International Civil Aviation Organization (ICAO) runway surface standards as *good* (dry surface) braking coefficient 0.30; medium or fair (wet) braking coefficient 0.15; and poor (icy) braking coefficient 0.08. The ICAO standards do not include a braking coefficient for no (nil) braking.

The World Airways DC-10 Flightcrew Operating Manual included the note that "final selection is normally 35°. Use 50° flaps on short or contaminated runways (wet or covered by snow, ice, or slush), or when, in the opinion of the captain, the landing distance will be adversely affected." A management letter, on the subject of fuel savings, dated December 1, 1981, addressed to all cockpit crewmembers stated: "Our established procedure of landing with 35° versus 50° flaps adds 5 knots to approach speed and 240 feet to landing distance yet saves an average of 145 pounds of fuel per landing."

13/ Boston-Logan International Airport does not have a vehicle decelerometer.

1.17.3 DC-10 Autothrottle/Speed Control System

The DC-10 airplane is equipped with a dual integrated AT/SC system which incorporates two independent circuits and the associated modules to provide total redundancy. Each of the two circuits may be engaged independently to automatically position the throttles to maintain either a selected airspeed or a specific thrust level schedule. Both circuits must be operable and engaged to provide the required degree of redundancy when the airplane's autopilot/autothrottle systems are being used for fully automatic landing operations.

The heart of the AT/SC system is the AT/SC computers which accept signals from the central air data computer, the thrust rating computer, engine speed sensors, airplane attitude and acceleration sensors, control surface position sensors, and other significant parameter transducers. The AT/SC computer then provides the proper output signal to an electrical servo which positions the throttle. Thus, when operated in the speed-select mode, the electrical servo will move the throttles as required to correct any error between the selected airspeed and the airplane's instantaneous airspeed as measured through the central air data computer.

The AT/SC system also incorporates circuitry to prevent the pilot from selecting a speed which would result in an unsafe stall margin. To determine and maintain a safe stall margin, the AT/SC computer uses the measured airspeed, attitude, and acceleration data to compute continually the airplane's flightpath angle, angle of attack, and the airplane weight which corresponds to the instantaneous airspeed and the computed angle of attack. The minimum airspeed acceptable to the AT/SC system is also computed for the computed weight. If the pilot selects a lower speed, the AT/SC flight mode annunciator will display ALPHA speeds and the throttles will be positioned to decelerate the airplane to and then maintain the computed minimum airspeed. Since the ALPHA speed computation is continuous, the ALPHA speed mode will be displayed when the speed is selected regardless of the airplane's actual airspeed at the time. The AT/SC design criteria specify an acceptable tolerance of ±7 kns for computed ALPHA speed when trailing edge flaps are extended to 35° or 50°.

The AT/SC system will also limit the maximum throttle position so that neither engine limits nor airplane structural limit speeds for the given configuration will be exceeded. However, there is no corresponding display to indicate that the pilot has selected too high an airspeed.

The AT/SC system includes logic to retard the throttles during landing. The RETARD mode will be automatically selected and displayed on the flight mode annunciator panel during a landing when the airplane descends through about *50* feet as measured by the radio altimeter. The throttles will then retard at a programmed rate to bleedoff speed as required for flare and landing. When the main gear wheels spin up after touchdown, the throttles will retard rapidly from their existing position to the idle stop.

The pilot may manually override the AT/SC system at any time by moving the AT/SC levers on the instrument panel to OFF, depressing disengage buttons on the outboard side of the No. 1 or No. *3* throttles, or by positioning the throttles to reverse thrust.

The autothrottle system tolerances could not be checked after the accident because the AT/SC computers were damaged from salt water immersion. The McDonnell Douglas Corporation issued literature regarding the usage of the AT/SC during normal operations. World Airways, Inc., distributed this literature to its DC-10 flightcrews. The literature described procedures to be used when AT/SC system would not accept the' approach speeds selected or when a disparity was evident between ALPHA speeds of the No. 1 and No. 2 system. The literature did not address what a crew should do with one system inoperative. (See appendix N.)

1.17.4 Antiskid System

The antiskid system is a fully automatic, pressure modulating wheel braking system which is controlled by individual wheel speed transducers, an antiskid control box, and individual antiskid control valves for each main and center wheel brake. The antiskid function does not operate until the main wheels of the airplane spin. To function properly, the wheel speed and the airplane's groundspeed must be synchronized. For efficient antiskid operation on a wet landing field-length-limited runway, a firm touchdown should be made to ensure prompt wheel spinup.

The brake pedal should not be relaxed or modulated during the landing roll. If the modulation sequence is interrupted by a release of pedal pressure, a new control level must be established, increasing landing distance. In another publication, 14/ McDonnell Douglas Corporation has noted that the coefficient of friction, which affects braking effectiveness, varies with airplane velocity. As the airplane slows down, braking force normally will increase. At high speeds where the coefficient of friction is lowest, skidding problems are most likely to occur.

On October 13, 1977, the McDonnell Douglas Corporation published a study as part of a cooperative research program into airplane operation on runways having low coefficients of friction. The test program was conducted by the Aeronautical Research Institute of Sweden (FFA) and the Scandinavian Airline System (SAS). The purpose of the program was to obtain airplane performance and braking system operational information on snow-, slush-, and ice-covered runways. The test program found that the best airplane stopping performance at a given measured frictional value was obtained for loose snow and icy runway conditions. The worst stopping performance was produced on compacted snow and ice and wet, rain-covered runways. The results indicated the critical importance of flying the correct threshold speeds to ensure safe stopping in extreme environmental conditions. When on the ground, proper braking technique is important to obtain braking performance consistent with optimum stopping distance.

The tests disclosed that a firm brake application (within 0.4 seconds after touchdown to full brake pressure) produced the most efficient control. However, slow applications as long as pressure was constantly increasing were handled well. There appeared to be no degradation in antiskid control when partial pedal depression was used. However, if pedal position is not held steady, which can easily happen in slippery conditions where rudder must be used for directional control, braking effectiveness is lost during antiskid readjustment to a new reference pressure. The only technique to be avoided is a rapid application followed by release and reapplication of brake pressure. However, during one landing in the SAS program on sanded ice, the pilot observed that poorer braking was evident during the last portion of the rollout. His comment was consistent with the recorded distance versus velocity plot which showed the braking effectiveness degrading at the slower speeds. This trend was checked on three other runs under similar conditions and found to be the same. The study based on these tests concluded that the loss of braking effectiveness may have been caused by an increase in localized surface melting as the tires moved over the surface at a slower rate. It also concluded that sanding was not as effective on the portion of the runway used by the airplane during the end of the landing rollout.

14/ Op. cit. McDonnell Douglas Corporation Report No. 5744, pg. 22.

1.17.5 Cornering Effect of Tires

The January 1977 DC-10 Flight Crew Newsletter published by McDonnell **Douglas** Corporation stated that during the landing roll the coefficient of friction is the most important parameter in stopping. The newsletter noted the pilot has a choice of how to use the available friction to his best advantage when a very small amount of friction **is** available. If wind is not a factor and there are no lateral control problems and he is interested in longitudinal deceleration, the use of the full brake application is the best procedure. If the airplane **is** drifting on the runway and the pilot wishes to change his ground track, the best procedure is to reduce braking and use aerodynamic forces generated by rudder application and nose wheel steering to corner the airplane. However, cornering the airplane requires friction. Therefore, on surfaces with low coefficients of friction, attempts to brake the airplane will reduce cornering ability. Conversely, attempts to correct directional control problems will reduce braking effectiveness. The manufacturer also noted that the effective braking coefficient varies with airplane velocity. That **is,** as the airplane slows down, braking force normally will increase, which points out the fact that at high speeds where the effective braking coefficient **is** lowest, skidding problems are most likely to occur.

1.17.6 Timely Information of Airport Conditions

Airport traffic controllers in a terminal area are required to issue airport condition advisories necessary for an airplane's safe operation in time for the information to be useful to the pilot. 15/ This requirement includes information concerning braking conditions as affected by ice, snow, slush, or water and factual information reported by the airport management concerning the condition of the runway. The controller is required to furnish to all airplanes the quality of braking action reports as received from pilots or the airport management. The quality of the braking action shall be described in terms "good," "fair," "poor," "nil," or a combination of these terms. The term "nil" is used to indicate bad or no braking action. The controller's report is to include the type of airplane or vehicle from which the report is received. Local and ground controllers are directed to exchange information as necessary for the safe and efficient use of airport runways and movement areas.

From the time that runway 15R was opened to landing traffic until the time that Flight 30H slid off the runway, 14 air carrier airplanes had landed. Only five flightcrews made voluntary braking action reports. Air traffic controllers, in the tower and ground control positions, moreover, had asked only one of the other nine flightcrews for braking action reports. The ground controllers had given two flightcrews the reports **of** braking conditions that they had received from other landing pilots. Three of the pilot braking action reports described stopping conditions which were more hazardous than those conditions described in the ATIS X-Ray report and Field Condition Report **6.** Both reports had been prepared by tower facility personnel.

The following messages are the complete record of communications on the airport interagency teleprinter circuit. Users of the airport teleprinter include airport management, the control tower, tenant airlines, FAA maintenance officer at the airport, and the National Weather Service office. The originator is shown in parenthesis following the message.

> 1715. Attention **all** users: Runway 4R. Braking action nil. B737 and DC 8. (TOWER)

15/ FAA Handbook: Air Traffic Control 7110.65C, Section 940(c) Chapter 5, dated January 21, 1982.

(No time). Tower visibility 2 1/2 miles. (TOWER)

1736. Boston–Logan field condition report. Runway 15R–33L open. Plowed full length and width. Surface sanded 50 feet either side of centerline. Surface covered with up to 1/4 inch of hard packed snow with drifts up to 1 inch inside the light lines. Part of intersection 4R runway markings obscured. Braking action fair by vehicle. (MASSPORT OPERATION)

1740. Boston–Logan AIRAD. Runway 4R–22L closed for snow removal (MASSPORT OPERATION)

1745. Boston–Logan field condition report. Caution advised. Thin layer of ice on all plowed surfaces. (MASSPORT OPERATION)

(No time). Runway 15R. Breaking action fair to poor. DC 9. (TOWER)

1845. Boston–Logan AIRAD. Charlie taxiway open. Plowed full **length** and width. Surface mostly covered with 1/4 inch hard packed snow, also covered with skim coat of ice. (MASSPORT OPERATION)

1858. Braking action poor to nil by DC 8 on runway 15R. (TOWER)

1925. Boston–Logan AIRAD. All plowed surfaces wet, mostly covered with a 1/4 inch layer of plowed snow and ice with wet scattered thin slush patches less than 1/4 inch. (MASSPORT OPERATION)

1938. Boston–Logan AIRAD. Runway 15R–33L closed. Disabled aircraft. (MASSPORT OPERATION)

1942. Boston–Logan AIRAD. Airport closed until further notice. (MASSPORT OPERATION)

2. ANALYSIS

2.1 The Flightcrew

The flightcrew was properly certificated and qualified in accordance with existing regulations; there was no evidence that medical or physiological problems affected their performance. They had received the required rest period before beginning the flight and they stated that fatigue did not affect their performance.

2.2 The Aircraft

The airplane was properly certificated, equipped, and maintained in accordance with existing regulations and approved procedures. Two uncorrected system, discrepancies were noted in the airplane's maintenance log. One, an inoperative auxiliary power unit was not significant to this accident; the other, an inoperative No. 1 AT/SC system was significant.. The No. 2 AT/SC system was functioning, and the airplane was capable of being operated using that system for autothrottle control in all regimes of flight except the total automatic landing mode. However, with the No. 1 AT/SC system inoperative, there was no redundancy of equipment by which the flightcrew could have checked the speed control function of the No. 2 system during the landing approach at the Boston–Logan International Airport.

23 The Accident

The investigation revealed that the landing approach was conducted in weather characterized by a low ceiling, low visibility, and light rain and fog. Although the ground level ambient temperature was slightly above freezing at the time of Flight 30H's landing, earlier subfreezing temperatures and precipitation had resulted in cold, wet ground surfaces, covered with hard-packed snow topped with a layer of glazed ice.

Fliightcrew accounts and the CVR conversations indicated that the approach was flown using 35' trailing edge flaps at an airspeed controlled by the airplane's AT/SC system which was 10 kns higher than the desirable approach airspeed. The airplane's DFDR parameters and the ATC radar data provided evidence that the airplane after intercepting the VASI glidepath achieved and maintained a stabilized descent and crossed the displaced threshold of runway 15R at a normal height. The data showed, however, that as airspeed dissipated the air run was extended and that after the flare the airplane touched down about 2,500 feet beyond the displaced threshold with about 6,690 feet of runway remaining on which to stop. The evidence showed that all decelerative devices were used, but that the total decelerative force attained was sufficient only to slow the airplane to 49 kns by the time it reached the end of the runway. The analysis of DFDR data and DC-10-30 performance parameters determined with certainty that the subnormal decelerative force was attributable to an extremely low effective braking coefficient between the airplane's tires and the runway surface.

In analyzing factors significant to the accident, the Safety Board considered:

- The condition of the runway 15R surface and the informational sources and judgments involved in the continuation of flight operations on that runway;
- The informational sources and judgment of the Flight 30H flightcrew in deciding to land on runway 15R and the extent to which flightcrew performance may have contributed to a longer stopping distance; and
- The adequacy of Federal Aviation Standards pertaining to airport runway conditions, airplane landing distance certification, and air carrier operating rules which relate airplane performance to airport runway capacity.

Runway Condition and Flight Operations--The Boston area had been exposed to subfreezing temperatures ranging from 2° F to 20° F throughout the 2 days before the accident. On January 23, the temperature had risen from 6° F at midnight to 38° F at the time of the accident. Light snow had fallen in the morning hours and had changed to light rain in the late afternoon. The runway surfaces, taxiways, and ramp areas were covered with hardpacked snow, and although the ambient temperature had risen above freezing, the continuing precipitation was freezing on contact with the surface to form a coating of glaze ice on top of the hard-packed snow. The conditions had been viewed as hazardous to the safe movement of vehicular and aircraft traffic, and consequently, the Massachusetts Port Authority had implemented its snow plan the day before the accident.

In accordance with the snow plan; runway 15R had been closed periodically during the day of the accident for plowing and sanding. After completing such an operation about 1700, the duty operations supervisor and an airline pilot representative of the Snow Committee had driven a 4-wheel-drive vehicle down the runway and had evaluated braking conditions to be "fair to poor." At that time, according to the information provided to update the ATIS report, the surface was covered with up to 1/4 inch of hard-packed snow to which sand had been applied 50 feet on both sides of the centerline. The Operations Supervisor noted that the runway markings at the crossing with runway 4 were obscured by snow and that a light rain was falling. The runway was reopened for flight operations at 1736--2 hours before the accident. Drizzle and light rain continued to fall throughout the 2-hour period as the 14 airplanes landed on runway 15R before Flight 30H.

The pilots' role.--Only 5 of the 14 flightcrews voluntarily provided braking action reports to the tower or ground controllers. The first flight to land after the runway was reopened was a Piedmont B-727, and the crew reported braking as "fair to poor." Nearly an hour later, at 1849, the pilot of a landing B-747 also reported the braking to be "fair to poor." Thereafter, at 1858, the pilot of a landing DC-8 reported braking as "poor to nil;" at 1903, the pilot of a departing L-1011 reported difficulties in achieving runway alignment because of the slippery conditions; at 1925, the pilot of a landing B-727 reported braking action as "poor;" and 3 minutes later, the pilot of a landing DC-10 reported "poor" braking action. This last report was made only 8 minutes before Flight 30H landed.

While the Safety Board acknowledges that the evaluation of braking action by a pilot is subjective and contingent upon such variables as pilot technique and airplane ctiaracteristics, pilot reports remain the primary source of useful information to both airport management as well as other pilots. Therefore, the Safety Board believes that pilots should report if they believe that safety is in jeopardy when runway conditions have deteriorated as they had on January 23. However, nine pilots failed to make reports although several later stated that the runway was very slippery or that they had encountered difficulty stopping their airplanes. Eight of the 14 landing airplanes were able to turn off the landing runway onto taxi runway 27, about 1,900 feet from the departure end of runway 15R. While this rollout distance may have far exceeded a normal acceptable landing distance for those particular airplanes, the fact that these airplanes had landed and slowed to turn off the runway and the pilots did not report stopping difficulties,' could have misled controllers and airport management to underestimate the criticai condition of the runway. The Board, therefore, believes that had more pilots reported their assessment of braking action, these parties may have placed more significance on the severe degradation of runway condition and taken more positive action. Moreover, the Safety Board believes that, if additional and more descriptive pilot reports had been made, the landing might not have been attempted.

The controllers' role.--When flightcrews which have landed airplanes and who are best able to assess runway surface conditions file adverse reports, the tower controllers must undertake to disseminate the reported braking conditions to those who need the information to formulate safety decisions--particularly pilots of arriving airplanes and airport management. The Safety Board believes that tower controllers should take the initiative to request braking action reports if they are not volunteered when runway conditions are subject to deterioration during continuing precipitation. The controllers should assure that all braking action reports particularly those indicating "poor" or "nil" conditions are disseminated promptly. Furthermore, the Safety Board believes that controllers should recognize that braking action evaluations are subjective and that they would vary with the type of airplane flown. They should be particularly aware that a heavy airplane that has less stopping margin on the runway than lighter airplanes which have landed previously may be subject to a greater hazard. The pilots of these heavy airplanes should be provided all available information with suitable cautions if no information is available from comparable airplanes.

In examining the circumstances preceding the landing of Flight 30H, the Safety Board noted that the tower controllers requested a braking action report from only one of the nine airplanes which did not volunteer reports during the 2-hour interval after the runway reopened. The Safety Board believes that the weather and runway conditions should have prompted the controllers to seek periodic runway surface information from pilots. Furthermore, there was only limited effort by the controllers to disseminate the limited pertinent information which was provided by flightcrews. The "poor to nil" report from the DC-8 was distributed through the airport interagency teleprinter circuit (AIRAD), but only the next two landing flights were advised of the "poor to nil" braking conditions report. That the departing L-1011 pilot reported difficulty in achieving runway alignment just 5 minutes after the DC-8 report should have further alerted the controllers to the hazardous runway condition. Yet, they made no further effort to ascertain braking actions, to assure that airport management was aware of the deteriorating condition, or even to continue the transmission of the braking action reports that had been received to later arrivals. Two of three airplanes landing within 11 minutes before Flight 30H volunteered reports of "poor" braking action. The pilot of a DC-10 had reported encountering compressor stalls as he used reverse thrust to lower-than-normal speed and that he still had difficulty stopping within the runway length. However, no action was taken by the controllers to pass these reports on to airport management or to Flight 30H.

The Safety Board views the failure of the controllers to transmit a braking action report to several landing flights including Flight 30H as a deviation from the procedures prescribed in the Air Traffic Controllers Handbook (FAA Order 7110.85C) which require controllers to furnish quality of braking action as received from pilots to all aircraft. While controllers may have considered the pilot's confirmation of receipt of the ATIS broadcast as constituting compliance with the braking action transmittal requirement, the ATIS X-Ray broadcast was last updated 2 hours before the accident and was based on previously reported "fair to poor" braking conditions. Even though revising the ATIS report is an optional action on the part of the terminal facility supervisor and he may have been reluctant to do so based on a single pilot report, later reports of worsening braking action should have prompted him to amend the report to reflect current, actual conditions, or. to direct the controllers to pass the later reports to flightcrews of arriving airplanes. Action to update the ATIS broadcast should have been taken no later than 1928 after successive reports of poor braking action, and especially after the second report provided by a DC-10 pilot who stated that he had difficulty stopping. At this point, however, the ATIS would probably could not have been amended in time to be helpful to Flight 30H.

The failure to issue an advisory to the flightcrew of Flight 30H that the reported braking action was poorer than that contained in the then-current ATIS report resulted in a critical gap in the information upon which the flightcrew of Flight 30H had to base its decisions. While the manner in which the flightcrew of Flight 30H would have used this information had it been available is only conjecture, the Safety Board concludes that the controllers denied the Flight 30H crew essential information and that this contributed to the accident. Had Flight 30H been alerted that one flight had reported braking action "poor to nil" and that the two flights landing immediately ahead of them had both voluntarily reported "poor" braking action. and that the DC-10 had difficulty stopping on the runway, the flightcrew may have decided to go to an alternate airport or to have employed more cautious landing procedures.

Airport management's role.--Airport management should have the benefit of current information .regarding runway conditions developed in airport communications between pilots and controllers, since management is ultimately responsible for assuring that the runway condition provides for safe flight operations. While both pilots and controllers should have been more active in providing essential information, the airport duty Operations Supervisor and key representatives of the airport snow committee were well aware that the weather conditions throughout the afternoon of January 23 were causing rapidly deteriorating runway braking action. The evidence shows that the airport snow removal and sanding crews had been busy the entire afternoon. As plowing and sanding of one runway was completed, that runway was inspected and reopened for flight operations and another runway was closed, and the surface was plowed and sanded.

The full length and width of runway 15R had been plowed and sanded earlier in the day and reopened for flight operations at 1405. At that time, some bare patches were visible and braking action was reported to be fair. At 1440, runway 9/27 was reopened after it had been plowed and braking action was reported as fair. At 1630, flight operations were continued using runway 4R/22L while runway 15R/33L was closed for plowing. At 1715, a message sent to the airport operations office via teleprinter indicated that two flightcrews had reported braking action "nil" after landing on runway 4R. The Board believes that these reports may have prompted the airport management to reopen runway 15R without further improvement even though the runway inspection disclosed only "fair to poor" braking action conditions. Runway 15R was opened to flight operations at 1736 and runway 4R was closed. The snow plows and sanding equipment were then moved to commence work at runway 4R. It was apparently the intention of airport management to continue this pace of activity to avoid closing the airport entirely to flight operations. The plowing and sanding operation of runway 4R was nearly completed and that runway was about to be reopened when the accident occurred. While Flight 30H was on approach, airport management had decided to close runway 15R when Flight 30H completed its landing and switch operations to runway 4R.

Although the duty Operations Supervisor stated that his normal policy is to reinspect the operational runway after he is made aware of successive reports of "poor" braking action, the evidence indicates that he took no such action to close or to reinspect the operational runways even after the reported "nil" or "poor" reports on January 23. Since they were transmitted via teleprinter, the Safety Board must assume that he was aware of these reports. The Safety Board believes that while his stated policy was a prudent one, in actual practice there was a willingness on the part of the Operations Supervisor immediately before the accident to accept the risks associated with continued operations to buy time to improve another runway in order to avoid closing the airport.

The Safety Board did not determine that there were any overt pressures placed on airport management by either airport tenants or air traffic control to keep the airport open. However, the consequences of closing an airport even for a short period -- the disruption to schedules, the rerouting of arrival traffic, the inconvenience to passengers, and other economic factors -- undoubtedly influence airport management decisions. The Safety Board, however, believes that the risk of an accident increases rapidly when heavy jet transport operations are involved and that abating this risk must override other considerations. The Board, therefore, concludes that the operational runway should have been closed and reinspected following the "poor to nil" braking action report even though it would have resulted in closing of Logan Airport to flight operations until a runway was deemed safe for landing.

In summary, the Safety Board believes that assuring the safety of continued operations on runways during inclement weather depends upon coordination between pilots, controllers, and airport management. Pilot braking action reports must be regularly made; they must be passed through the controllers to the airport management so that intelligent decisions regarding runway inspection or cessation of operations can be made and implemented by airport management. Timely decisions must be made to close a runway, and the airport if necessary, to eliminate unsafe operations. That airport management did not take such action on January 23 is a contributing cause of this accident.

Flightcrew Judgment and Performance.--While pilots expect airport personnel to maintain runways to an acceptable condition, those experienced in winter inclement weather operations must realize the difficulties in maintaining conditions which provide pressure for acceptable airplane stopping performance. Consequently, pilots must expect some degradation of braking. Since the final decision to land rests solely with the pilot, he must consider the reported braking action along with the other factors pertinent to his particular operation -- landing performance of his airplane, runway length, prevailing wind, and effects of decelerative devices. The Safety Board explored all of these factors as they were known to the flightcrew of Flight 30H as they prepared for the landing at Boston-Logan, and analyzed the role of each in the approach and landing. The Safety Board found no evidence that there were any overt pressures placed on them to continue the landing.

Continuation of the approach.--The flightcrew was aware of the prevailing weather in the Boston area and knew that the operational runway was contaminated with snow and ice. They had operated their airplane in similar conditions during the landing and takeoff at Newark International Airport, and they had checked the weather sequences during the layover for Boston-Logan and alternate airports. In fact, the pilot had changed his alternate airports from Bradley Field and Newark to New York (Kennedy) and Philadelphia because of prevailing weather and had taken on additional fuel.

Flightcrews rely on the appropriate airport analysis charts and other information contained in the Operations Manual to verify that the lengths of the operational runways at the destination airport are compatible with the stopping performance of the airplane at its estimated landing gross weight. The analysis charts in the World Airways Planning and Performance Manual provide the maximum gross weight at which the DC-10-30 can be landed on the various runways using either 35° flaps or 50° flaps. Wind factor is considered and gross weight data are provided for both dry and wet runway conditions. The maximum weight given is that at which the airplane can land and stop within the criteria defined in 14 CFR 121.195. Neither the World Airways Planning and Performance Manual nor the World Airways DC-10 Operations Manual contains landing data in terms of actual stopping distance requirements for a given airplane weight and configuration on either dry or wet surfaces. Rather, a flightcrew must estimate the margin of safety on a slippery runway by comparing the airplane's estimated landing gross weight with the maximum gross weight allowed for the landing runway in the airport analysis chart. The World Airways Airport Analysis Chart for runway 15R at Boston-Logan shows that the DC-10-30 can be landed on that runway when wet at a gross weight of 522,700 pounds with 35° flaps or a gross weight of 557,200 pounds with 50° flaps. 16/ The Safety Board believes that this flightcrew, having estimated the actual landing weight as 365,000 pounds, might have been misled by the apparent safety margin that the heavier allowable landing weights indicate.

As the flight approached the Boston-Logan Airport, the flightcrew received ATIS information and Field Condition Report No. 6, which indicated that braking action was "fair to poor" as reported by a B-727 flight. The braking action condition was not amplified further by either the approach controller or the local controller as the flight continued on the approach, and the Safety Board believes that this lack of amplification and the knowledge that airplanes were landing regularly probably lessened the flightcrew's

16/ In these cases. the actual maximum gross weight allowable for landing is limited by structural limitations of the airplane at 421,000 pounds.

concern about the hazardous runway conditions. The Safety Board concludes that without benefit of information indicating degradation of braking action and with the minimal landing performance data provided to it, the flightcrew had no apparent cause to discontinue the approach. However, the Board believes that the flightcrew did have sufficient knowledge of general airport conditions to prompt them to conduct the approach and landing in a precise manner to minimize the required stopping distance.

Conduct of approach and landing.--Examination of the ATC radar data, the airplane's DFDR data, and the CVR indicated that no special measures were discussed or taken by the Flight 30H flightcrew during the approach or the landing. The pilot conducted the approach and elected to land with 35° flaps. The selection was based on the pilot's assessment of a possible windshear encounter along the flihtpath and the descent profile of the nonprecision approach, both of which in his opinion required the use of 35' flaps. The use of 50° flaps as recommended by World Airways procedures for landing on contaminated runways would have permitted a slower approach airspeed and would have produced more deceleration from aerodynamic drag, thus shortening the airplane's total landing distance. The incremental landing distance between the 35° flap configuration and the 50° flap configuration is relatively small — between 300 to 500 feet for the DC-10-30 under dry runway conditions. While this distance may be insignificant during routine operations, on a contaminated runway, this distance can increase and become more significant.

The data analysis showed that the approach profile had been stabilized and that the airplane had crossed the threshold at a proper height. The airspeed, however, was about 10 kns higher than the normal World Airways approach speed, and 15 kns higher than the optimum reference speed for the airplane's estimated gross weight. This speed increment was accepted by the flightcrew when it was determined to be the minimum airspeed which could be selected using the AT/SC system. Again, the Safety Board notes that the World Airways recommended procedure is to use the AT/SC system, and its pilots are advised to accept the minimum speed attainable with the AT/SC if there is a disparity between the AT/SC speed and the approach reference speed indicated in the Operations Manual, unless the disparity can be resolved by comparison between the No. 1 and No. 2 AT/SC systems. In this case, the No. 1 AT/SC system was inoperable, denying the flightcrew the necessary system redundancy to make the comparison.

The Safety Board could not identify the reason why the No. 2 AT/SC system reference speed computation was high; however, this factor was most significant since the higher-than-normal speed extended the air run of the airplane between threshold crossing and touchdown and reduced the length of runway available for stopping. Two possibilities for 'the AT/SC disparity were considered; first, that the airplane weighed about 35,000 pounds more than estimated by the flightcrew, or second, that the airplane had accumulated an ice buildup on its aerodynamic surfaces which affected aerodynamic efficiency. There is no evidence, however, to support either possibility. In fact, these conditions may have caused the airplane to touch down sooner, but at a higher speed than the analysis of the actual flightpath showed. Rather, the approach profile and landing analysis showed that the flightcrew began a normal flare maneuver and the AT/SC retarded the throttles properly. There is no evidence that the captain increased the nose attitude excessively in a deliberate attempt to achieve a smooth touchdown; however, dissipation of the excessive airspeed and the increased aerodynamic efficiency of the airplane with resultant reduced drag as it approached the ground combined to decrease the rate of descent and extend the flare distance. The airplane also touched down at a slightly higher-than-normal speed, which further affected its landing roll deceleration profile.

The Safety Board also considered the possible effect of a low level wind shear on the final approach profile of the airplane. The analysis of the DFDR data correlated with other wind information and showed that the airplane encountered a decreasing headwind shear from about 20 kns at 600 feet to 2 kns at the surface. Normally, such a shear would cause the airplane to lose airspeed and fall below the desirable descent path. If thrust is not added, an airplane encountering decreasing headwind may touch down short of the pilot's aiming point. However, if sufficient thrust is added to inertially accelerate the airplane — increase its groundspeed as the headwind decreases -- the airplane will maintain the desired airspeed and descent path. As Flight 30H descended below 600 feet, the AT/SC added thrust, thus maintaining airspeed and increasing groundspeed. Thus, the Safety Board concludes that the wind change as Flight 30H descended had no direct effect on the airplane's flightpath or touchdown point.

The Safety Board concurs that the acceptance of AT/SC speed computation and use of that system under normal circumstances provides an increment of safety by assuring a safe stall margin if landing weight is miscalculated or if the airplane's aerodynamic surfaces are contaminated. Additionally, the AT/SC system can compensate for a low level wind shear condition on final approach better than a pilot might and perhaps prevent a short-landing-type accident. The Safety Board believes, however, that when a disparity of more than a few knots exists between the AT/SC system acceptable speed and the calculated reference speed, the flightcrew must make itself aware of the consequences of the high approach speed.

The Safety Board considered actions which the pilot might have taken to minimize the stopping distance. First, he could have disengaged the AT/SC system when he approached the flare and modified the thrust retard schedule to permit more rapid dissipation of airspeed. Second, he could have accepted an aiming point nearer to the displaced threshold. The Safety Board notes that the threshold of runway 15R is displaced about 890 feet beyond the actual end of the runway to provide required obstruction clearance for normal glidepath descent. The 2-bar VASI system is installed to provide a runway intersect distance 1,183 feet beyond the displaced threshold or 2,073 feet beyond the actual end of the runway. The 2-bar VASI is designed and installed to provide vertical approach guidance which ensures safe obstruction clearance and touchdown runway margins to conventional airplanes. However, the cockpit of wide-bodied airplanes is so far above and so far ahead of the wheels that, in landing attitude, the adherence to the VASI glideslope until touchdown will place the airplane's wheels on the runway several hundred feet short of the normal aim point. Consequently, pilots of DC-10 and L-1011 airplanes are advised to disregard the 2-bar VASI at 200 feet above the runway elevation 17/ and the captain of Flight 30H adhered to this procedure. The airplane rose slightly above the VASI glideslope as the pilot selected a safe aiming point. In retrospect, because of the displacement of the runway threshold, the Safety Board believes that the pilot of Flight 30H could have safely selected a shortened aiming point to compensate for the possible flare extension resulting from excess speed. In assessing the pilot's performance, however, the Board considered that the visibility was marginal and that this was the pilot's first landing on runway 15R at Logan. Therefore, the pilot's adhering to normal safe and prescribed 2-bar VASI procedures cannot be criticized. Furthermore, the Board concludes that the pilot's decision to accept the AT/SC system speed computation and his use of that system for airspeed control was not improper. However, when the use of the AT/SC system was going to result in higher speed which would lengthen the airplane's landing distance, the pilot should have been more alert to the situation associated with the icy runway. In this case, the pilot should have anticipated the

17/ B-747's are advised to disregard the 2-bar VASI at 300 feet above the runway.

possibility of a longer-than-normal flare distance or slightly high touchdown speed and should have been concerned about the additional problems of stopping on a runway with less than optimum braking condition.

The extended flare resulted in the touchdown about 2,500 feet beyond the displaced threshold. While this was about 1,300 feet beyond the VASI glideslope intersect point, it was only 600 feet beyond the nominal distance allotted for the air run segment considered in the development of the airplane certification landing distances which are the basis for information provided in the operator's airport analysis charts. The Board notes that the actual certification stopping segment for a 365,000-pound DC-10 landing on a dry runway is given as 2,392 feet. This distance presumes that the airplane touched down at an airspeed about 12 kns less than the Flight 30H touchdown speed. The stopping distance would nominally be increased about 440 feet as a result of the excess speed. 18/ That the flightcrew believed that the airplane touched down "about 1,500 feet" beyond the displaced threshold may be attributable to the night reduced visibility and the absence of good runway distance measuring references. Even had there been references, the crew would probably have believed that the 6,690 feet runway remaining at the point of touchdown was adequate for stopping the airplane since it was more than twice that which would be required to stop the airplane on a dry runway.

There was no indication that the flightcrew considered aborting the landing at touchdown, and the Board does not believe that the information and cues should have prompted such action. However, the Board believes that the conditions and good operational practices did indicate the need to apply all deceleration devices as rapidly as possible. This includes the deployment of ground spoilers, the application and use of maximum reverse thrust, and the initiation of the maximum obtainable wheel braking. The evidence showed that the automatic deployment of spoilers probably commenced as the airplane's wheels spun up about 2 seconds after main gear touchdown and full extension occurred about 2 seconds later. The captain initiated deployment of the reverse thrusters at nose gear touchdown and the reversers were fully deployed 2 seconds later. The thrust level was then increased to the maximum available level during the next 13 seconds. Wheel braking was initiated about 7 seconds after main gear touchdown, and the pilot steadily increased brake pressure reaching the maximum pressure about 12 seconds after the initial application.

To assess whether these actions were reasonable, ideal control application times were measured during tests by the McDonnell Douglas Corporation. These tests indicated that full reverse thrust application may be accomplished within 8 seconds following main gear touchdown on a dry runway and maximum braking pressure can be achieved within 4 seconds of main gear touchdown. The Safety Board does not believe, however, that a direct comparison between the actual control application times for Flight 30H and the ideal times demonstrated during tests is appropriate because the tests were conducted without consideration for the directional control problems which can be encountered on slippery runways. The DFDR heading data indicate that directional control was marginal and that the pilot probably anticipated problems during the application of reverse thrust. Prudent practice under such conditions requires that the pilot assure that all thrust reversers are fully deployed before adding thrust, and that the engines spool up symmetrically, and that directional control can be maintained as thrust is added and brakes are used. Under the circumstances, the Safety Board believes that the elapsed time for application of reverse thrust by the pilot was not excessive.

18/ The stopping distance increase can be nominally expressed as a function of the square of the speed.

The Safety Board also examined the time taken by the captain to initiate wheel braking and achieve full brake pressure. The procedure contained in the World Flightcrew Operating Manual specifies a smooth application of constant brake pressure to full pedal on short or slippery runways. The airplane's antiskid system is designed to provide optimum brake efficiency with constant full brake pressure. However, on a slippery runway, the actual brake toque required to cause the wheel to lock up and the tire to skid on the surface may be developed at lower-than-maximum brake pressures. The exact pressure which would have caused the antiskid to function during Flight 30H's landing was not determined, and the Safety Board is not aware of any engineering or test data to quantify the difference in obtainable brake efficiency with partial or full pressure under these conditions. Although the possible adverse effect of the pilot's delayed application of full pedal on airplane deceleration could not be determined, the Board believes that it was minimal.

In order to further examine the extent to which the flightcrews' performance may have contributed to this accident, the Safety Board analyzed the pertinent data to determine the effective braking coefficients obtained on runway 15R by both Northwest 42 and Flight 30H. The effective braking coefficients for both flights correlated closely, each showing that the maximum effective braking coefficient obtained was about .08, less than that normally associated with smooth (unsanded) clear ice.

The theoretical stopping distances for a 365,000-pound DC-10 were then calculated for the AT/SC-engaged touchdown speed with both 35° and 50° trailing edge flap configurations and for the landing certification touchdown speed with a 35° flap configuration. Since the actual braking coefficients were not determinable for Flight 30H at low speeds, assumptions were used for these values based upon trends evident in antiskid braking tests conducted using a DC-9 airplane in 1973-1974. The stopping distance calculations also considered both actual and ideal time for applications of reverse thrust and wheel brakes. The calculations showed that, for the actual touchdown speed, configuration, and control-application time, the pilot could have needed as much as 8,390 feet to bring the airplane to a full stop after touchdown. 19/ This indicates that even had the air distance been reduced to 700 feet, the entire runway would have been needed to bring the airplane to a stop because of the lack of effective braking on the slippery surface.

The use of 50° flaps with ideal timing in applying reverse thrust and wheel brakes would have shortened the landing distance by only 730 feet. Moreover, the calculations showed that even with the minimum speed touchdown with 35° flaps and ideally timed control applications, the pilot may have needed as much as 7,460 feet to bring the airplane to a stop. 18/ Based upon these analyses, the Safety Board showed that Flight 30H may have been capable of stopping on runway 15R if the airplane had touched down at an acceptable nominal distance, between 1,500 and 1,800 feet beyond the displaced threshold, with a 50° flap configuration, minimum airspeed for configuration, and ideally timed application of reverse thrust and wheel brakes. The Safety Board believes that this ideal performance is not consistently achievable during line operations because of influencing factors such as wind and directional control on slippery surfaces. Northwest 42 was slowed to turn off the runway at the end under similar braking conditions. However, that airplane was 25,000 pounds lighter than Flight 30H, and consequently was landed at a slower speed than Flight 30H. The higher level of reverse thrust available from the DC-10-40 could produce greater decelerative force, thus the stopping distances of the two airplanes could not be directly compared by braking

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19/ Reference Table 4, mu'1. The Safety Board believes that the conditions described by mu'1 must be considered as a reasonable probability.

coefficient. Furthermore, the captain of that flight was familiar with the airport and descended below the VASI glideslope to touch down short of the VASI glideslope runway intercept point.

As a result of the analysis which indicates that the runway surface was so slippery that once the landing was made stopping the airplane on the runway may have been impossible regardless of crew performance, the Safety Board places the major causal emphasis on the runway condition and those factors which led to Flight 30H's being landed on that runway. The Safety Board believes that the captain should have requested an updated braking action report before landing which might have caused him to decide not to attempt the landing. Furthermore, the Safety Board concludes that although the captain followed permissible procedures during the conduct of the approach and landing, the knowledge available to him should have prompted him to plan an approach which would have provided a minimum runway stopping distance. The Safety Board believes that the captain's decision to use 35' flaps during the approach to MDA was reasonable because of the existing wind conditions. However, in order to reduce the touchdown speed, he could have followed the World Airways, Inc., 'Short or Contaminated Runway Procedures" and selected a 50' flap setting when the runway was in sight. The flightcrew could have planned on the use of the 50' flap setting before beginning the approach and should have been prepared to select 50° flaps and the appropriate approach speed when leveled at MDA approaching the VASI glidepath. The Safety Board recognizes that a configuration changed to 50' flaps at that point on the approach can introduce destabilizing effects requiring significant trim change. Furthermore, the 50' flap configuration provides a reduced performance margin for coping with windshear conditions. In view of the pilot's recognition that a windshear condition persisted to low altitudes, the Safety Board believes that the captain's decision to retain the 35° flap setting rather than reconfigure the aircraft to a 50 flap setting was appropriate for this approach. However, the Safety Board believes that the captain should have reverted to manual throttle control to dissipate speed during the flare to touch down closer to the displaced threshold. Although the airplane might still have run off the runway, its speed would have been less, and the consequences of the accident might have been less severe.

Normal Operational Practices and Federal Standards--While this analysis has concluded that the actions and inactions of pilots, controllers, and airport management contributed to this accident, the Safety Board believes that measures to prevent similar future occurrences must be actively addressed in the broader context of the relationship to aviation industry practices and Federal regulatory standards. Although the Board acknowledges that landing overrun accidents on wet, ice, or snow-covered runways have been infrequent, it is beyond question that present practices and requirements are not adequate to assure safe flight operations, takeoffs and landings, on slippery runways. This subject was examined extensively during a 3-day public hearing convened by the Safety Board on May 3, 1982, on the effects of runway surfaces on airplane performance.

The Federal Aviation Regulations and standards attempt to assure the safety of commercial transport operations by levying requirements on airplane manufacturers to demonstrate the performance capability of an airplane and by establishing operational limitations during certification of the airplane. Other operational requirements are imposed on the operator of the airplane as used in normal service. To assure that an airplane can take off or land safely on a given runway, the manufacturer must demonstrate the runway distances required to take off, to accelerate the airplane to a decision speed and stop, and to land the airplane from a 50-foot height and bring it to a full stop. The stopping capability of the airplane may be demonstrated using those decelerative devices which are "safe and reliable." The manufacturers and the FAA have excluded the use of reverse thrust for stopping during the certification demonstrations because reverse thrust is contingent upon all of the engines operating properly. The certification test data are analyzed, and takeoff and landing distances are determined for the airplane for its entire range of operational weights. These data are then included in the FAA-approved airplane flight manual All of the demonstration tests and the data provided are related to the airplane's performance on a dry, smooth, hard surface. There are no requirements either to demonstrate takeoff, accelerate-stop, or landing performance or provide distance data for operations on wet or slippery runways.

To provide a level of safety which would accommodate normal variations in operational circumstances and piloting techniques, the Federal standards require that operators ensure that there is a runway of sufficient length at the destination airport to permit the airplane to be landed and brought to a full stop within 60 percent of the effective runway length. This assumes that the airplane can be landed and stopped within the certification landing distance contained in the approved airplane flight manual. Additionally, since no equivalent data are provided for wet or slippery runways, the required runway length at the destination airport is increased by another 15 percent if weather forecasts indicate that the runway will be wet or slippery at the time of the airplane's arrival.

The Safety Board perceives several inadequacies in the present standards and practices. Most significant of these inadequacies is that all requirements are related to demonstrated and published takeoff or landing performance data for a dry, smooth, hard runway surface; yet takeoff and landing operations during the winter months are frequently conducted on wet or ice- and snow-covered runways where effective braking coefficients may be less than 20 percent of those obtainable on dry surfaces.

For landing on slippery runways, the FAA, manufacturers, and operators all contend that the total length of runway specified in the approved flight manual, about 1.9 times the length which was derived on a dry surface without the use of reverse thrust, is a sufficient safety factor. The Safety Board regards this contended margin as arbitrary and ill-defined. No attempts are made during airplane certification to establish the airplane's attainable braking coefficient on surfaces with various types of contamination, nor is there a requirement to provide data regarding the effective braking coefficients which would be needed to stop the airplane within the distance established by regulation for wet runways. Further, although tests are conducted during airplane certification to demonstrate the functional characteristics of the antiskid brake systems under slippery conditions, no attempts are made to quantify the efficiency of these systems on slippery runway surfaces.

The Safety Board believes this accident also exemplifies inadequacies in the existing regulatory standards. The FAA-approved landing distance on a wet runway for a 365,000-pound DC-10 using 35° trailing edge flaps is 6,753 feet. Thus, when allowing for a minimum air run segment of 1,131 feet, the airplane is expected to stop within the 5,622 feet remaining. 20/

However, in this accident, the stopping distance analysis for a DC-10-30, landing at the proper airspeed followed by ideally timed applications of the decelerative devices, showed that the airplane would need a minimum of 6,300 feet and possibly as much as 7,460 feet in which to stop; the minimum distance was calculated by using the most optimistic braking coefficients that may have been attainable on runway 15R during Flight 30H's landing. Consequently, given optimal pilot and airplane performance, Flight 30H's landing distance would have been at least 700 feet longer than the runway length

20/ The minimum air run segment demonstrated during airplane certification involves piloting techniques which are atypical to normal line operations. See NTSB-AAR-82-2. For related Safety Board recommendations and FAA responses, see Appendix L.

specified,by regulation for wet runway operations which, to repeat, was established on the basis that reverse thrust is not available.

The Safety Board is equally concerned that airport management is provided with little guidance by the FAA regarding the allowable deterioration of the braking conditions on a runway before they must close the runway to flight operations. Also, no specific requirements or recommended procedures have been published by FAA for airport operators to measure and quantify braking action on a wet, or ice– or snow–covered runway. Although considerable research efforts have been and are being directed toward the development and acceptance of improved equipment and procedures to accomplish these measurements, the Safety Board believes such improvements are essential to safe operation on contaminated runways and that progress must be accelerated. As matters currently stand, both pilots and airport operators rely heavily on the braking action reports provided by pilots after landing to determine the suitability of a runway for continued use.

The Safety Board, while recognizing the need to rely on pilot reports under today's operating conditions, is concerned that the reports are subject to too many variables. A pilot may base his report on his overall ability to slow the airplane on the lending runway rather than the actual braking attainable through tire to runway friction. If the airplane is light and the runway is considerably longer than that normally required for landing, the pilot may perceive little or no problem in slowing the airplane to a safe turnoff speed. Actually, under these conditions, most of the decelerative force may be provided by aerodynamic drag and reverse thrust with little need for augmentation from wheel brakes. Consequently, he may report braking conditions as "fair" or "fair to poor" when the actual braking conditions are worse. The pilot of a heavy airplane landing on the same runway will have a lesser margin and will need considerably greater braking force from the wheel brakes; consequently, he could be misled about the actual braking conditions by reliance on these pilot reports. Finally, the Safety Board believes that the braking action terms themselves (good, fair, poor, or nil) lack objective definition and finds that guidance is not provided by any source to pilots, ATC personnel, or airport managers as to a universal meaning of these terms.

The Safety Board believes that the potential for overrun accidents on slippery runways will continue until pilots are given- sufficient information to correlate- the existing runway condition with the stopping performance of their particular airplane. The pilots should be given a quantitative report of runway braking action conditions before dispatch, or before they begin their landing approach, which will enable them to refer to data in their airplane flight manual to determine whether they can land at their destination with a safe margin for the existing conditions. Further, given such quantitative reports, airplane weight limitations similar to those imposed for landing on dry and wet runways should be adopted. To accomplish this, airport operators must have equipment and standardized procedures for measuring runway surface friction coefficients -- there are several types of equipment available now for this purpose. However, there has not been universal acceptance by airport managers, airplane manufacturers, and airplane operators of the measurements obtainable from available equipment because the measurements cannot be accurately and reliably related to an airplane's stopping performance or otherwise provided to the pilots in a manner which mould be of use to them. Testimony at the Safety Board's public hearing by National Aeronautics and Space Administration (NASA) witnesses indicated promise that one or more types of ground equipment friction measuring devices can provide data which can be correlated to airplane performance. Further test and research programs by NASA and FAA are scheduled to continue toward achievement of this objective, and the Safety Board urges that these programs be given the emphasis needed to develop promptly reliable and economically acceptable equipment. Although while requirements for such equipment at major airports appears economically reasonable, the Safety Board recognizes that smaller airports with limited operating budgets and personnel may have difficulty in acquiring, maintaining, and operating sophisticated equipment. Therefore, the Safety Board believes that the NASA and FAA programs should be broadened to determine whether existing systems on an airplane can be redesigned or modified to present quantitative indications of effective braking coefficients to flightcrews. For example, antiskid system modulating pressures or cycling frequencies might be used in conjunction with appropriate pilot braking techniques to calculate and display a quantitative braking coefficient. Also, the potential for using inertial navigation systems to measure deceleration and provide a quantitative deceleration coefficient should be explored. The availability of quantitive pilot reports would then allow airport operators to monitor deteriorating runway conditions more closely.

The ability of pilots to use quantitative runway condition data would require that airplane manufacturers and operators must include in airplane flight manuals the stopping performance data on surfaces with various values of braking coefficient. The Safety Board is aware that although airplane manufacturers are not required for U.S. certification to demonstrate takeoff and landing performance on runways other than dry hard surface runways, the manufacturers of some airplanes do demonstrate performance and provide data for wet runway performance to meet United Kingdom certification requirements. Furthermore, estimated stopping performance data are provided for low braking coefficients and for no brake conditions for some airplanes. For example, such data are provided for the DC-10, and some operators use these data to derive charts to show increased stopping distances required for various reported braking action conditions. The Safety Board's review of some major operators' manuals disclosed that the presentations of such data are not standardized and, in some cases, landing distances for similar airplane weights and runway conditions differed significantly. The World Airways DC-10 manuals did not include any such data for slippery runway landing performance. The Safety Board recognizes that actual demonstration of airplane stopping performance as a function of runway surface friction coefficient is not practical However, the Board believes that it would be helpful to pilots if the FAA were to require manufacturers to extrapolate data from dry runway stopping performance to develop theoretical stopping performance data for lesser braking coefficients, and to provide these data in a standardized manner to the operators of all transport category airplanes. If possible, the presentation of these data should be in a form which allows correlation to runway friction coefficients obtainable from ground equipment friction measuring devices. In the interim, the data could be categorized in accordance with accepted braking action terminology -- good, fair, poor, and nil -- and in any event additional guidance should be provided regarding the meaning of these terms.

The Safety Board also believes that FAA should place increased emphasis on pilot training with regard to runway condition assessment and reporting techniques to reduce as much as possible the subjectivity of these reports. To reduce the subjectivity of these reports, pilots could compare the published theoretical stopping distances with actual distances used as a measure of braking action conditions. Their ability to assess conditions on this basis would be significantly enhanced by the installation of runway distance markers which the Safety Board recommended in Safety Recommendation A-72-3 issued on January 3, 1972; a recommendation which we recently reiterated in our report of the Air Florida B-737 accident that occurred at Washington National Airport on January 13, 1982. 21/ The Safety Board believes that pilot assessments of braking

21/ 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).

capabilities may be more accurate if based upon wheel brake effectiveness after the effects of reverse thrust and aerodynamic drag are substantially reduced. Finally, since pilots of airplanes requiring less distance in which to stop may not verify braking action during landing roll unless requested to do so by air traffic controllers, the controllers should be required to solicit braking action reports from pilots well in advance of landing.

In summary, the Safety Board concludes that the existing Federal Aviation regulatory standards and industry practices are deficient; they do not provide adequate guidance to airport management regarding the measurement of runway slipperiness; they do not provide flightcrews with adequate means to evaluate or correlate runway conditions with airplane stopping performance; and they do not provide runway length requirements consistent with reduced braking performance on slippery runways. Further, the Safety Board concludes that these deficiencies are directly related to the cause of this accident because Flight 30H was permitted by existing regulatory standards to use a runway on which the airplane probably was not capable of stopping.

2.4 Survival Aspects

The forces experienced by the passengers as the airplane came to rest in the water were not a factor in occupant survival except in the immediate area where the cockpit section nose separated from the fuselage. The two passengers who are presumed to have drowned were seated in the forward passenger seat row, and these seats separated when vertical loads caused the seat structures to fail. The entire cabin aft of the structural separation remained intact. There were no disabling passenger injuries and there were no significant obstructions presented by displaced cabin furnishings to impair an orderly evacuation of the cabin. Further, because there was no fire, the urgency of evacuation was diminished and there were no associated smoke inhalation or visibility problems. The cabin emergency lights provided adequate illumination for the passengers. The most significant hindrance to the evacuation was the continued operation of the No. 2 engine at full reverse thrust. The engine noise caused confusion among flight attendants and passengers in the rear cabin which delayed the initiation of the evacuation and hindered effective communication between flight attendants and passengers. The air flow from the No. 2 engine presented further difficulties when it caused the deployed slidehafts to twist. Exit L-4 was not usable when the slide blew against the fuselage; however, because the right side of the airplane was closer to the shore, the blockage of the L-4 exit did not affect the evacuation.

The flightcrew and passengers were able to evacuate the airplane and swim or wade to the shore with little help from crash-rescue personnel or other persons on shore. However, the immediate notification of the Logan Fire Department resulted in the quick response of crash-rescue emergency vehicles and personnel to the shoreline to provide illumination of the area and to assist the survivors in climbing the bank at the shoreline. After they reached the bank, however, the survivors were exposed to the near freezing temperatures, wind chill, and rain while awaiting transportation to a suitable shelter. After prolonged waiting, many survivors were taken in an open-stake truck to an open fire station where they remained in excess of an hour with minimum provisions for comfort. In this respect, the Safety Board believes that the Logan disaster planning placed insufficient attention to the transportation and comfort of the survivors of an accident, particularly to meet the needs of 200 or more people. Consequently, the Board believes that emergency response and disaster planning at airports serving large transport airplanes should be reviewed to assure that they provide for suitable transportation and a sheltered assembly area for survivors.

Since there was no fire and the airplane was close to shore, the total capability of the Logan Airport Emergency crash-fire-rescue plan, personnel, and equipment was neither required nor tested. During the investigation of the previously cited Air Florida, Inc., B-737 crash at Washington National Airport, the Safety Board noted that there were no specific FAA regulations regarding the type of equipment to be maintained to accomplish rescue from waters surrounding airports that service air carrier airplanes. The FAA provided guidance in Advisory Circular 150/5210-13 which goes beyond regulatory requirements and suggests that the emergency plans, facilities, and equipment at airports include the capability for water rescue for all conditions which might be encountered. The Safety Board recognizes that the Logan Airport Fire Department is equipped beyond regulatory requirements to respond to a water crash-rescue operation. However, the Safety Board's investigation of the Air Florida accident indicated that immediate response to effect water rescue can be significantly hampered during winter weather conditions, particularly when ice floes inhibit small rescue boat operations.

Therefore, the Safety Board believes that the circumstances of this accident were fortuitous because survival and rescue were not dependent upon the Logan Airport's water response capability. Had the airplane plunged into deeper water farther from the shore, the two crash boats operated by the Airport Fire Department would have been launched. However, it is not likely that the boats could have reached the scene in time to provide assistance for rapid evacuation of the airplane. Therefore, the immediate survival of the occupants would have depended on the equipment carried aboard the airplane, primarily the underseat life vests and cabin exit slidehafts The Safety Board is therefore concerned that some passengers reported that they had encountered difficulties in removing the life vests from their stowed position and in opening the plastic packaging. The Safety Board has addressed this problem after the National Airlines, Inc., B-727 accident near Pensacola, Florida, May 8, 1978, and again in the analysis of the Air Florida accident in Washington. The Safety Board understands that the issuance of TSO-C-13d is imminent and understands that the TSO will include standards to improve ease of removal of life vests from plastic packages. The Safety Board notes that some of the passengers believed that their seat cushions would serve as flotation aids. However, when they threw cushions into the water, the cushions absorbed water and sank. Following the B-727 accident near Pensacola, the Safety Board recommended to the FAA that passenger parrying aircraft be equipped with approved flotation-type seat cushions, (Safety Recommendation A-79-36); the FAA has responded that it is assessing the feasibility of Imposing this requirement.

Had the airplane entered deeper water, the water temperature would have been a most significant factor in survivability. The slidehafts functioned properly and assuming that the problems presented by the continued operation'of the No. 2 engine would not have existed in deeper water, it could be presumed that most of the passengers would have been able to enter the rafts. However, any passenger who did not enter a raft would have had only limited time to function in the 30° F water and would have been dependent upon rapid response of the airport's crash boats for survival. While U.S. Coast Guard and U.S. Navy units can be expected to respond to airport emergencies, they will not be dedicated to this function, having broader search and rescue responsibilities, and they generally will not be at close hand. It should be recognized in the airport emergency crash-€ire-rescue plan that these type units cannot reach the waters immediately surrounding the airport in time to provide immediate assistance to persons immersed in frigid waters. Therefore, the Safety Board urges the FAA to consider these additional factors during its consideration of Safety Board Recommendation A-82-88 in which we asked the FAA to evaluate the adequacy of water rescue plans, facilities, and equipment at certificated airports having approach and departure flightpaths over water.

3. CONCLUSIONS

3.1 **Findings**

1. Although the ambient temperature at the time of the accident was above freezing, ground surfaces were cold and covered with hard–packed snow. Continuing precipitation was freezing on contact to form glaze ice on the snow.

2. The airport snow plan was in effect and operational runways had been alternated during the afternoon while crews plowed and sanded closed runways to improve conditions.

3. Runway 15R had been reopened 2 hours before the accident after it had been plowed and sanded. Two members of the Snow Committee drove a 4–wheel-drive vehicle down the runway and assessed braking action as "fair to poor" before it was reopened.

4. Only 5 of 14 pilots landing on runway 15R during the 2–hour period before the accident volunteered braking action reports. One reported "poor to nil" conditions about 38 minutes before the accident and the two who landed ahead of Flight 30H reported "poor" conditions. The last pilot of a Northwest DC–10 who landed 8 minutes before Flight 30H reported to ground control that he had experienced compressor stalls during low speed reverse thrust application and that he had used the entire runway. The local controller was aware of the difficulty encountered by the NW DC–10, but did not pass on this information to Flight 30H.

5. That nine of the pilots landing on runway 15R did not volunteer braking action assessments and that eight of the landing airplanes were able to turn off of the runway with 1,900 feet remaining may have misled controllers and airport management into underestimating the critical conditions.

6. Four ,pilots stated following the accident that they were unable to slow their airplanes to turn off of the runway at the intersection with runway 27, 1900 feet before the end.

7. Tower controllers failed to take the initiative to request pilot braking action reports during the continuing precipitation which caused deterioration of runway conditions despite the known icy condition of the runway.

8. The ATIS Field Condition Report had not been updated for 2 hours before the accident and indicated braking action "fair to poor" although a 'poor to nil" and "poor" reports had been given by pilots.

9. Neither approach nor local controllers passed on the latest reported conditions of braking action to the pilots of several flights including Flight 30H. The failure to transmit this information may have influenced the pilot's decision to land.

10. The, ATC handbook requires local controllers to transmit braking conditions to arriving flights when braking action reports have been received.

11. Although airport management through the Operations Supervisor and Snow Committee should have been aware of a "poor to nil" braking action report since the tower had transmitted it via teleprinter, it did not take action to inspect runway **15R.**

12. Policy requires inspection after poor reports. Airport management was aware of one "poor" report. Had airport management been aware of more than one "poor" report, they may have been prompted to inspect the runway.

13. The flightcrew did not have the latest descriptive braking action reports and consequently had no cause to decide not to conduct the approach and landing.

14. The pilot of Flight **30H** used the AT/SC system **for** airspeed control during the approach and landing in accordance with World Airways standard operating practices.

15. The No. **1** AT/SC system was inoperative thereby precluding speed comparison between the two systems.

16. The AT/SC system is designed **so** as not to accept a minimum speed below that which provides an established stall margin. The minimum speed acceptable to the No. 2 system was **10** kns above the World Airways approach speed for the airplane's weight — **15** kns above the reference speed which is basis for establishing runway distance criteria. The reason the AT/SC system would not accept the low speed was not determined.

17. The airplane had achieved a stabilized descent along a normal profile and crossed the displaced threshold of runway **15R** at a normal height, but at the higher-than-normal airspeed controlled by the AT/SC.

18. The pilot did not raise the airplane's nose excessively but the higher-than-normal speed produced a longer-than-normal flare distance. The airplane touched down **2,500** feet beyond the displaced threshold with 6,690 feet remaining for stopping.

19. There were no runway lighted distance markers along the side of the runway to indicate to the flightcrew runway remaining at touchdown, and even had there been the crew probably would have considered the more than 6,000 feet as adequate based on normal stopping performance of the airplane.

20. All decelerstive devices were used to slow the airplane although the application of maximum reverse thrust and full wheel brake pressure were less rapid than have been demonstrated under ideal conditions. The application times were reasonable because of potential directional control difficulties on the slippery surface.

21. Analyses of the deceleration of both Northwest Flight **42**, a **DC-10-40,** and Flight **30H** disclosed that the effective braking coefficient was about 0.08 or less along the runway length. This is less than normally associated with a surface covered with smooth ice.

22. Ineffective friction between Flight 30H's tires and the runway surface resulted in low decelerative forces which slowed the airplane to only 49 kns by the time it departed the end of the runway.

23. The runway surface was so slippery that stopping the airplane on the runway may have been impossible regardless of crew performance.

24. The pilot's use of a 35° flap setting for the approach was not in accordance with World Airways Flight operations procedures for landing on short or contaminated runways but was appropriate in this case based on the wind condition and type of approach being conducted.

25. The standards and operating rules of the FAA regulatory system do not provide for the quantitative measurement of runway friction, minimum runway braking action conditions, or means to correlate actual conditions with an airplane's stopping performance.

26. FAA rules do not require definitive stopping performance data for surfaces with low friction coefficients in approved flight manuals and air carrier operational manuals. Pilots are not able to correlate data with more accurately defined runway braking action reports.

27. Present FAA standards and accepted operating practices do not preclude a pilot from landing an airplane on a runway which is too slippery to provide adequate friction to stop the airplane.

28. Pilot braking action reports are subjective and depend upon too many variables to provide quantitative information for decisions regarding continued operations on slippery runways. Pilots, having landed, may report on conditions/events specific to their airplane and these may not be as applicable to another airplane operating with different parameters.

29. The FAA should make mandatory the guidance provided in Advisory Circular 150/5210-13 which suggests that the emergency plans, facilities, and equipment at airports include capability for water rescue for all conditions that might be encountered.

30. The crash/fire/rescue response was timely and effective; however, the disaster plan was not adequate to meet a situation involving numerous survivors.

31. It was not known for several hours after the termination of the rescue operation that two passengers were missing. Passengers were not accurately accounted for because one passenger's ticket coupon had not been lifted when boarding and, although counted when deplaning, he had not been included in the total passenger count. Also, a fireman from the rescue group had been admitted to a hospital with passengers from the accident and he had been counted as a passenger.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the pilot landed the airplane without sufficient information as to runway conditions on a slippery, ice-covered runway, the condition of which exceeded the airplane's stopping capability. The lack of adequate information with respect to the runway was due to the fact that (1) the FAA regulations did not provide guidance to airport management regarding the measurement of runway slipperiness under adverse conditions; (2) the FAA regulations did not provide the flightcrew and other personnel with the means to correlate contaminated surfaces with airplane stopping distances; (3) the FAA regulations did not extend authorized minimum runway lengths to reflect reduced braking effectiveness on icy runways; (4) the Boston-Logan International Airport management failed to exercise maximum efforts to assess and improve the conditions of the ice-covered runways to assure continued safety of heavy jet airplane operations; and, (5) tower controllers failed to transmit available braking information to the pilot of Flight 30H.

Contributing to the accident was the failure of pilot reports on braking to convey the severity of the hazard to following pilots.

The pilot's decision to retain autothrottle speed control throughout the flare and the consequent extended touchdown point on the runway contributed to the severity of the accident.

4. RECOMMENDATIONS

See Appendix M.

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

December 15, 1982

Vice Chairman Goldman and Members Bursley and Engen filed the following statements:

VICE CHAIRMAN GOLDMAN concurring and dissenting:

I believe that the probable cause should in no way be read to imply pilot error. While I agree with the causal statement regarding the reasons of "inadequacy of information provided to the pilot," I disagree with the final paragraph regarding the "pilot's decision" contributing to the severity of the accident. I believe a more appropriate statement of the situation would be "The pilot's acceptance of an approach speed derived from the autothrottle speed command system resulted in a higher-than-normal air speed and longer-than-normal flare distance which contributed to the severity of the accident." I believe that the reason for this acceptance was that existing circumstances and recommended company practices led him to continue autothrottle use rather than reverting to manual operation. I believe that action was reasonable.

/s/ PATRICIA A. GOLDMAN
Vice Chairman

MEMBER BURSLEY concurring:

As I indicated in voting to approve the probable cause adopted by the Board, I believe that the elements relating to the Federal Aviation Regulations (FAR's) are more properly characterized as contributing factors. Since the remedial action which should be taken by the FAA is the same whether the FAR's are causal or contributory, I did not feel it necessary to dissent. Arrangement of the factors in the manner which I believe to be more appropriate would lead to a probable cause which reads as follows:

> The National Transportation Safety Board determines that the probable cause of this accident was the landing of World Airways Flight 30H on an ice covered runway which the management of Boston-Logan International Airport had not closed when it became unsafe for continued heavy jet airplane operations and on which braking was so ineffective as to preclude the stopping of the airplane in the total available runway length, and the failure of air traffic control to transmit the most recent pilot reports of braking action to the pilot of Flight 30H. Contributing to the accident were the inadequacy of the present system of reports to convey reliable braking effectiveness information and the absence of provisions in the Federal Aviation Regulations to require: (1) airport management to measure the slipperiness of runways using standardized procedures and to use standardized criteria in evaluating and reporting braking effectiveness and in making decisions to close runways, (2) operators to provide flightcrews and other personnel with information necessary to correlate braking effectiveness on contaminated runways with airplane stopping distances, (3) pilots to make braking action reports and controllers to request such reports when runways are contaminated with ice or snow, and (4) extended minimum runway lengths for landing on runways which adequately take into consideration the reduction of braking effectiveness due to ice or snow.

The pilot's decision to retain auto-throttle speed control throughout the flare and the consequent extended touchdown point on the runway contributed to the severity of the accident.

/s/ G. H. PATRICK BURSLEY
Member

MEMBER ENGEN concurring:

Although I have concurred in the statement of Probable Cause, I wish to state further that I view the three FAA regulatory elements as being more contributory than directly causal in nature. This does not decrease their importance, in my view, but does place greater emphasis on the Boston-Logan International Airport management role in failing to exercise maximum efforts to assess conditions and assure safety, and the failure of the tower controllers to transmit available braking information to the pilot of Flight **30H.**

/s/ DONALD D. ENGEN
Member

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The Safety Board was notified of the accident about 2030 on January 23, 1982. Air safety investigators in the areas of Operations/Air Traffic Control/Witnesses, Structures, Systems, Powerplants, Weather and Human Factors were dispatched immediately from the Washington, D.C. headquarters office. Later, Cockpit Voice Recorder, Flight Data Recorder, and Performance Specialists were assigned.

Representatives for the Federal Aviation Administration, World Airways, Inc., McDonnell Douglas Corporation, General Electric, Massport, United States Coast Guard, Massachusetts Aeronautical Commission, International Association of Teamsters, and the Air Line Pilots Association participated in the investigation.

2. Public Hearing

There was no public hearing and no depositions were taken.

APPENDIX B

PERSONNEL INFORMATION

Pilot

Captain Peter J. Langley, 58, holds Air Transport Pilot Certificate No. 1677657 with airplane multiengine land, and single engine land ratings. He holds type ratings in the Boeing B–727 and the McDonnell Douglas DC-8 and DC–10. His first class medical certificate was issued November 19, 1981, with the limitations that he must wear corrective lenses while exercising the privileges of his certificate. He completed a proficiency check on July 25, 1981, a company line check on January 25, 1981, and an en route check on January 8, 1982. He had about 18,091 flying hours of which about 1,969 hours were in the DC–10 airplane.

Copilot

First officer (F/O) Donald C. Hertzfeldt, 38, holds Airline Transport Certificate No. 2023812 with airplane multiengine land rating. He holds commercial privileges in airplane single engine land and glider aero tow. He also holds Flight Engineer Certificate No. 2236568 with turbojet privileges. His First Class medical certificate was issued on February 26, 1981. He had about 8,600 total flying hours.

Fliiht Engineer

Flight Engineer (F/E) William L. Rogers, 56, holds Flight Engineer Certificate No. 1391633 with turbojet privileges. His first class medical certificate was issued on October 31, 1981. His last proficiency check and line check were completed on February 19, 1981. He had about 20,000 total flying hours.

Fliiht Attendants

Position	Name	Hire Date	Date of Last Recurrent Training
1L	Lisa Jorgensen	03-06-72	08–31–81
1R	Lynne Paris	05–21–73	01–12–81
2L	Debi Groves	04–10–72	03–16–81
2R	Joan McCaul Sayeg	02–22–71	10-19-81
3L	Susan Hayes	02–28–77	10-16-81
3R	Annabella Pidlaoan	02–14-66	04-06-81
4L	Bobbi Sue Griffey*	10-16-67	03-30-81
4LA	Marcel F. deLannoy	04-02-79	01–18–82
4R	Brian J. Linke	04-04–77	02-09–81

*Ms. Griffey qualified as Senior Flight Attendant 07–28–70

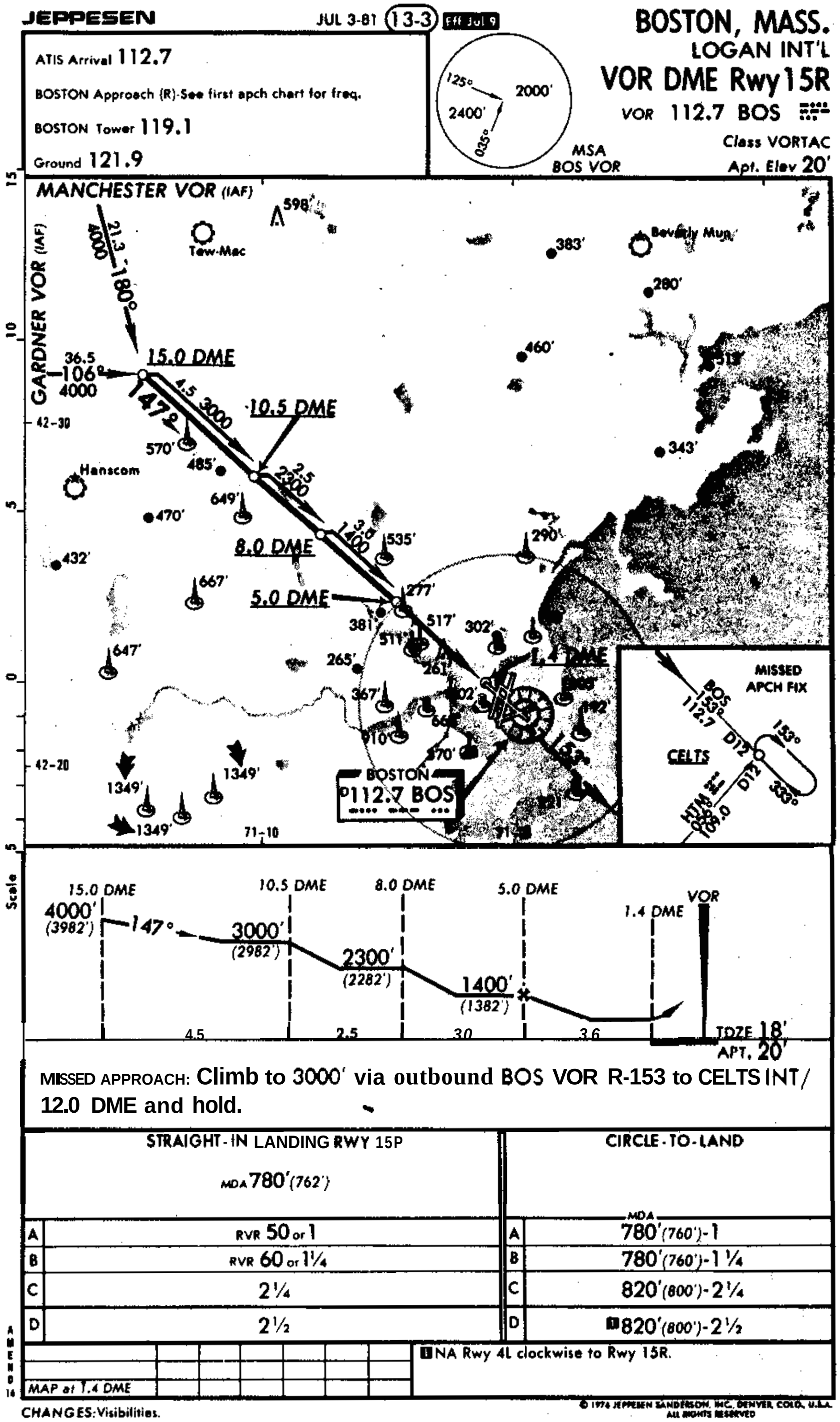
APPENDIX C

AIRCRAFT INFORMATION

The airplane was a McDonnell Douglas DC-10-30CF, United States Registry N113WA, serial number 47821. It had been purchased new by World Airways Inc. and it had about 6,327 hours in service.

The airplane was powered by three General Electric CF6 - 50C2 high bypass ratio turbofan engines. The Nos 1 and 3 engines had not been changed during the operational history of the airplane. The No. 2 engine had been removed from World Airways Inc. N106WA on January 9, 1981 for time-stagger purposes and installed in the No. 2 position of N113WA on March 29, 1981. The three engine fan reversers were the original installations. The engine performance trend monitoring data for the three engines did not show any trend deviation from normal operating patterns.

Engine Position	1	2	3
Serial Number	517-643	517-421	517-645
Time Since New	6,327	8,791	6,327
Time Since New (Hours)	6,327	8,791	6,327
Cycles Since Inspection	1,619	2,384	1,619



APPROACH CHART

"ILLUSTRATION ONLY - NOT TO BE USED FOR NAVIGATIONAL PURPOSES"

BOSTON, MASS. **KBOS** (11-1) OCT 30-81 **JEPPESEN**

LOGAN INT'L APT.

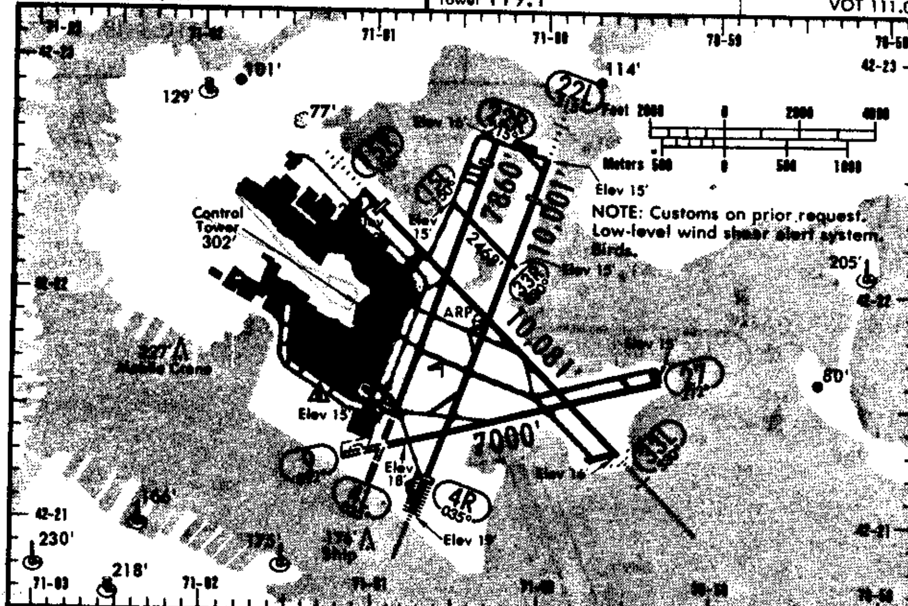
N42 21.9 W071 00.3 322.1°/0.7 From BOS 112.7

Elev 20' Var 15°W

ATIS Departure 125.55
BOSTON Clearance (Cpt) 121.65
Ground 121.9
Tower 119.1

BOSTON Departure (R) 118.25

VOT 111.0



ADDITIONAL RUNWAY INFORMATION

RWY				USABLE LENGTHS LANDING BEYOND Threshold	Glide Slope	TAKE-OFF	WIDTH
4R	HIRL CL ALSF-II TDZ	grooved	❶RVR	❺	7915'		150'
22L	HIRL CL MALS	grooved	❷RVR	8801'	7751'		
4L	HIRL REIL	grooved					150'
22R	HIRL VASI-L	grooved		7032'			
9	HIRL	grooved	❸RVR				150'
27	HIRL REIL VASI-L	grooved	❹RVR		5949'		
15R	HIRL CL MALS TDZ VASI-L	grooved	❷RVR	9191'	8008'		150'
33L	HIRL CL ALSF-I TDZ VASI-R	grooved	❷RVR		9106'		
15L / 33R	MIRL						125'

❶ Touchdown, Mid and Rollout.
❷ Touchdown, Mid and Rollout-Uses rwy 4R Mid RVR readings.
❸ Authorized for take-off-uses rwy 4R Touchdown RVR readings.
❹ Authorized for landing-uses rwy 33L Touchdown RVR readings.
❺ Day IFR and Night VFR & IFR-8836', Day VFR-10,001'.

[1][2] TAKE-OFF				[5] FOR FILING AS ALTERNATE				
	AIR CARRIER (FAR 121, 123 & 129) If Wx below Lndg Mim, T/o Altn Req. Rwys 4R, 15R, 22L & 33L		GENERAL		ILS Rwy 33L ILS DME Rwy 15R	LOC Rwy 33L LOC DME Rwy 15R VOR DME Rwy 15R NDB Rwy 22L	Other
1 & 2 Eng / 3 & 4 Eng	With CL and RCLM TDZ RVR 7 Mid RVR 7 Rollout RVR 6	any RVR out, other two req.	RVR 16 or 1/4	[3][4] RVR 50 or 1	A B	700-2	800-2	800-2
				[4] RVR 24 or 1/2	C	800-2 1/4	800-2 1/4	
					D	800-2 1/2	800-2 1/2	

[1] Rwy 4R: 300 ceiling-1 required or charted minimums with minimum climb of 320' NM to 300'.
Rwy 4L: 300 ceiling-1 required or charted minimums with minimum climb of 340' NM to 300'.
Rwy 9: 300 ceiling-1 required or charted minimums with minimum climb of 230' NM to 300'.
Rwy 22R: 400 ceiling-1 required or 300 ceiling-1 required with minimum climb of 310' NM to 400'.
Rwy 22L: 300 ceiling-1 required or charted minimums when Twr reports no tall vessels in departure area.
Rwy 27: 900 ceiling-1 required.
Rwy 33L: 500 ceiling-1 required or charted minimums with minimum climb of 250' NM to 500'.
[2] IFR departure procedure: Runway 22L R, climb runway heading to 700' before turning right.
Rwy 33L climb rwy heading to 700' before turning left.
[3] FAR 135: Rwy 15R, RVR 40. [4] FAR 135: Rwy 4R, RVR 18 with minimum climb of 320'/NM to 300'.
Rwy 33L, RVR 18 with minimum climb of 250' NM to 500'.
[5] ILS Rwys 4R, 22L & LOC Rwys 4R, 22L: 800-2 1/2 all acft.

AMEND 1

CHANGES: RVR deleted rwy 4L, rwy 15R ALS.

"ILLUSTRATION ONLY - NOT TO BE USED FOR NAVIGATIONAL PURPOSES"

ATIS X-RAY

Boston Logan information XRAY two three five zero

Boston weather measured ceiling eight hundred overcast visibility two and one half miles and light rain and fog. Temperature three five dewpoint two three the wind is one eight zero at six altimeter two niner five fie. Arrivals can expect radar vectors to be VOR DME Approach - - - ah - landing runway one five right. Departing runway one five right. Field condition report number six is being broadcasted on frequency one two five point five five. Braking action is fair to poor reported by a seven twenty seven on runway one five right. All field surfaces are covered with a thin layer of ice. Advise on initial contact you have information XRAY field condition report number six.

ATIS FIELD CONDITION REPORT NUMBER SIX

Boston Logan field condition report number six. The ah one seven three six local time January twenty third. Runway one five right three three left is open - and plowed full length and width surfaces sanded fifty feet on either side of the centerline.. Surfaces covered with up to one quarter inch hard packed snow with drifts up to one inch inside light lines at intersection of runway four right. The runway markings are obscurred, the braking action is fair to poor reported by a seven twenty seven. --- Use caution ah some runway and taxiway markings are obscurred windrows to three feet along some taxiway light lines and up to three - - three inch snow drifts inside some light lines. Use caution the snow banks up to one five feet at the beginning the north cargo apron - - area and snow banks to one zero feet in the vicinity of the Bravo taxiway and the jet ramp do not rely on the taxiway centerlines for surface guidance (unintelligible) and advise the controller on initial contact you have received field condition report number six

1755L Special observation - measured 800' overcast - 2½ miles visibility

light ran - temp 34°F - wind 120° @ 8 mph

TRANSCRIPT OF PERTINENT COMMUNICATIONS FROM COCKPIT VOICE RECORDER, FAIRCHILO A-100 REMOVED FROM THE WORLD AIRWAYS, INC. DC-10 INVOLVED IN THE ACCIDENT AT LOGAN INTERNATIONAL AIRPORT, BOSTON, MASSACHUSETTS, ON JANUARY 23, 1982

LEGEND

CAM	Cockpit area microphone voice or sound
RDO	Radio transmission from accident aircraft
-1	Voice identified as Captain
-2	Voice identified as First Officer
-3	Voice identified as Flight Engineer
-?	Voice unidentified
LCN	Tower (Local Control)
APP	Approach Control
*	Unintelligible word
#	Nonpertinent word
%	Break in continuity
( )	Questionable text
(( ))	Editorial insertion
---	Pause
Note:	Times expressed in eastern standard time.

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM-1	Okay, well there are the altitudes, the MSA is two thousand, that's fifteen DME and, ah, I'll give these to you and you can read them out, I've got them jotted down here
CAM-2	Okay
CAM-1	And, ah, the MDA is seven eighty, seven eighty and the touchdown zone is eighteen feet

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1910:32 APP	World thirty heavy, descend to six thousand, do you have X-ray and field condition six?
1910:37 RDO-2	We have X-ray sir and descending to six thousand World thirty heavy
1910:40 APP	Okay, do you have field condition six also?
1910:43 ROO-2	Affirmative
1910:44 APP	Okay
1911:15 APP	World thirty, fly heading zero two zero vectors to the one five right final
1911:19 RDO-2	World thirty heavy, heading zero two zero

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
		1911:21 APP	Roger, continue your descent to maintain four thousand
		1911:24 RDO-2	World thirty heavy, descending to four thousand
1911:27 CAM-1	Out of eleven		
CAM-1	Okay let's start slowing her down		
CAM-3	Okay you got it		
CAM-2	Thank you		
CAM-1	We can review the. ah		
CAM-3	Lights * *		
CAM-1	Alright		
CAM-3	Want the seatbelt sign on Pete		
CAM-1	Yeah		
CAM-1	In range check		
CAM-3	Altitudes		
CAM-1	Two nine six one		
CAM-2	Ah, the ATIS is two nine five five		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM-1	Five five
CAM-2	I've got the speed bugs set * *
CAM-3	Landing data and bugs
CAM-1	Checked
CAM-2	Checked
CAM-3	Altimeters
CAM-1	Checked
CAM-2	Checked
CAM-?	*
CAM-3	* two point seven
CAM-?	* in range is completed one twelve seven on both sides slats extend
1914:13 CAM	((Sound of altitude alert))

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1912:43 APP	World thirty, turn left to three six zero, reduce to two ten
1912:46 ROO-2	World thirty heavy heading three six zero reducing to two hundred and ten knots
1914:22 APP	World thirty, stop your descent at six thousand, over

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
		1914:25 RDO-2	World thirty heavy stop at six thousand
		1914:27 APP	Roger, turn right zero four zero World thirty, you'll be vectored across the final for a turn in from the northeast side
		1914:34 RDO-2	World thirty heavy turning zero four zero
			%
CAM-?	(* flaps)		
CAM-1	He is going to take us through that center line there		
		1915:32 APP	World thirty, there's a Delta ten eleven on the final at two thousand with the wind there at one ninety seven at sixty
CAM-2	Ah yes he is		
1915:34 CAM	((Sound of altitude alert))		
		1915:38 RDO-2	World thirty heavy thank you
		1915:57 APP	World thirty, descend and maintain five thousand

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1916:02 CAM	((Sound of altitude alert))
CAM-1	Okay, how we doing on the icing (states)
CAM-2	All right, on ten *
CAM-3	Just ten
1916:29 CAM	((Sound of altitude alert))
CAM-1	You talked to company
CAM-3	Yeah gate six
CAM-1	Gate six

AIR-GROUND COWNICATIONS

TIME & SOURCE	CONTENT
1915:59 ROO-?	World thirty heavy, down to five thousand
1916:59 APP	World thirty heavy, when you get to, correction, reduce to one seven zero knots World thirty
1917:04 ROO-2	World thirty reducing to one hundred and seventy knots, we're level at five
1917:07 APP	Thank you

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
1917:30 CAM-1	Flaps twenty-two		
		1917:35 APP	World thirty, descend and maintain four thousand
		1917:37 ROO-2	World thirty heavy out of five for four
CAM-?	* *		
CAM-1	Just crossing over the approach lights		
CAM-1	* * two and a half miles, I've got alpha speed		
		1918:53 APP	World thirty, turn right zero six zero
		1918:55 ROO-2	World thirty heavy turning zero six zero
CAM-1	You got alpha speed		
CAM-2	Yes I do		
CAM-?	* *		
CAM-1	Why should that be?		
CAM-1	(Maybe we've got the wrong bug speeds)		
CAM-2	Well that could be * one sixty four *		
CAM-?	((Muffled conversation relative to rechecking the numbers))		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM-?	* * *
CAM-2	Seems like a lot of grinding around for not much traffic
CAM-1	Uh huh
CAM-1	They always seem to do this, yeah * I've never landed on this runway
CAM-2	I landed here once
CAM-2	It's ten knots off

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1919:53 APP	World thirty turn left three three, make it three two zero
1919:57 ROO-2	World thirty heavy turning left three two zero
1920:05 APP	World thirty, you INS equipped, sir
1920:07 RDO-2	World thirty affirmative
1920:09 APP	What's the wind there now?
1920:12 RDO-2	It's, ah, two twenty six at sixty five
1920:14 APP	Thank you

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
CAM-1	Well, I've got six off, yeah one seven six		
CAM-1	Well we're out, way past the fifteen mile point		
CAM-2	Yeah		
1922:29 CAM-1	We're right over (Boston)		
		1922:50 APP	World thirty heavy, turn left two four zero
		1922:54 RDO-2	World thirty heavy, heading two four zero
CAM-1	* * *		
1926:12 CAM-1	Gonna take us through the other side		
CAM-2	Boy it sure looks like that		
CAM-1	* * *		
CAM-?	* * left		
CAM-1	Right		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
CAM-1	Heading select
CAM-1	Okay, fifteen degrees of bank
CAM-2	Do you want me to arm the VOR again?
CAM-1	Yeah, I don't know why it dropped off
CAM-1	Yeah, yeah
CAM-1	I had it on there
CAM-2	I think when I pulled heading select I may have scrubbed it or maybe when you, I guess heading hold
GAM-1	Heading hold wiped it out
CAM-1	Yeah that's right
CAM-1	When we start down, put in about seven hundred feet a minute, okay?
CAM-2	Okay

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1927:04 APP	World thirty heavy, turn left heading one eight zero, intercept the VOR final approach course, proceed inbound at four thousand feet one hundred and seventy knots
1927:11 RDO-2	World thirty heavy, heading one eight zero, proceed inbound at one hundred and seventy knots four thousand

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	CONTENT
CAM-2	Four thousand at fifteen and three at ten point five		
CAM-1	Yeah		
CAM-2	Sixteen degrees of drift		
		1928:25 APP	World thirty heavy, two zero miles from the VOR, cleared for the VDR DME approach runway fifteen right, maintain a speed of one hundred and seventy knots until the five DME
		1928:35 RDO-2	World fifteen or thirty heavy cleared for the VOR DME fifteen right and will maintain a hundred and seventy knots until five DME
CAM-1	Don't think we're making much headway on the VOR		
CAM-2	Yeah, do you want to take a better cut at it		
CAM-1	Ah no, it's coming in now		
CAM-2	Yeah		
CAM-1	(If I do, it will swing left)		
CAM-1	(Can't do it that way)		
CAM-1	Heading bug *		
CAM-?	*		

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
CAM-1	My old flight director is not taking much account for wind		
1930:22 CAM-1	Okay we're starting down four thousand for three thousand		
CAM-1	My vertical speed is set		
1930:42 CAM	((Sound of altitude alert))		
CAM-1	Two miles to three thousand		
CAM-1	A little less on the sink next, well maybe that looks about right for now		
		1931:30 APP	Attention all aircraft this frequency, monitor the appropriate VOR broadcast for sigmet november sancs, it's for, ah frequently moderately occasional severe turbulence below ten thousand feet specifically within thirty AGL across rough terrain with updrafts, low level wind shears possible due to stagnant low level winds, monitor the appropriate VOR broadcast for sigmet november sancs
1932:07 CAM-1	Okay, ten miles (two) point five down to twenty three hundred		
CAM-2	Fourteen degrees of drift		

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1932:30 CAM-1	Radio altimeter's alive, okay. put the gear down at two thousand feet		
CAM-2	Okay		
CAM-2	Twenty three at eight DME		
CAM-1	Okay		
CAM-1	Flight director		
1932:54 CAM-1	Okay five DME fourteen hundred feet		
		1932:58 APP	World thirty heavy, contact the tower one nineteen point one and good night
		1933:03 RDO-2	World fourteen heavy, good night
CAM-2	Okay, that's the final approach fix fourteen hundred, five DME		
CAM-1	Altitude checks no flags		
CAM-2	No flags		
CAM-2	No, no at five DME is final approach fix ((sound of altitude alert)) that should be at fourteen hundred		
1933:16 CAM-1	Gear down		
		1933:20 RDO-2	Tower World fourteen, ah, thirty heavy approaching the outer marker, ah, the final approach fix, over

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	CONTENT
		1933:26 LCN	World thirty heavy, Boston tower good evening sir, you're cleared to land --- runway one five right, the wind is one eight zero at three
		1933:33 RDO-2	World thirty heavy's cleared to land one five right
1933:36 CAM-3	We're cleared to land, flight attendants take your seats please		
1933:41 CAM-1	Final approach fix altitude checks no flags		
CAM-3	Altitude checks, no flags		
1933:50 CAM-2	Five OME fourteen hundred		
1933:55 CAM-1	Flaps thirty five, before landing checklist		
CAM-3	Before landing, flight instruments		
CAM-1	Checked give me * * vertical speed		
CAM-2	Checked		
CAM-3	Flight guidance panel		
CAM-?	Ah-h-h		

73 -

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1934:12 CAM	((Sound of altitude alert)) .
1934:13 CAM-3	Flight guidance panel
CAM-2	Checked
CAM-1	Checked
CAM-3	Gear lights
CAM-2	Down and green
CAM-3	Annunciator panel
CAM-2	Checked
CAM-3	Spoilers ((sound of click))
1934:21 CAM-2	Armed
CAM-3	Flaps and slats
1934:25 CAM-2	Thirty five, thirty five, land light
1934:31 CAM-3	Before landing is complete
1934:32 CAM-2	(* * seventy) one hundred feet to, to minimums, ground is in sight
1934:38 CAM-2	You're at your MDA

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1934:40 CAM-1	Okay
CAM-?	* *
1934:48 CAM-2	Runway's in sight slightly left
CAM-1	* *
CAM-2	Little bit by below the VASI
CAM-?	* *
1935:05 - 1935:07 CAM	((Sound of four clicks))
1935:13 CAM-2	Five hundred feet
1935:23 CAM-2	Four hundred
1935:30 CAM-2	Three hundred
1935:35 CAM-2	Two hundred
1935:40 CAM-2	One hundred
1935:45 CAM-2	Fifty'

AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
1935:46 CAM-2	Forty		
1935:48 CAM-2	Thirty		
1935:50 CAM-2	Twenty		
1935:52 CAM-2	Ten		
1935:57 CAM	((Sound *of* touchdown))		
1936:04 CAM-2	One hundred twenty knots		
1936:08 CAM-1	No braking		
1936:11 CAM-2	One hundred knots		
1936:17 CAM-2	Eighty knots		
1936:22 CAM-1	No braking, oh #		
1936:24 CAM-2	Sixty knots'		
1936:27 CAM-3	Oh #		
1936:31 CAM-1	We're going off the end		

INTRA-COCKPIT

TIME & SOURCE	CONTENT
1936:39	((Sound of impact))

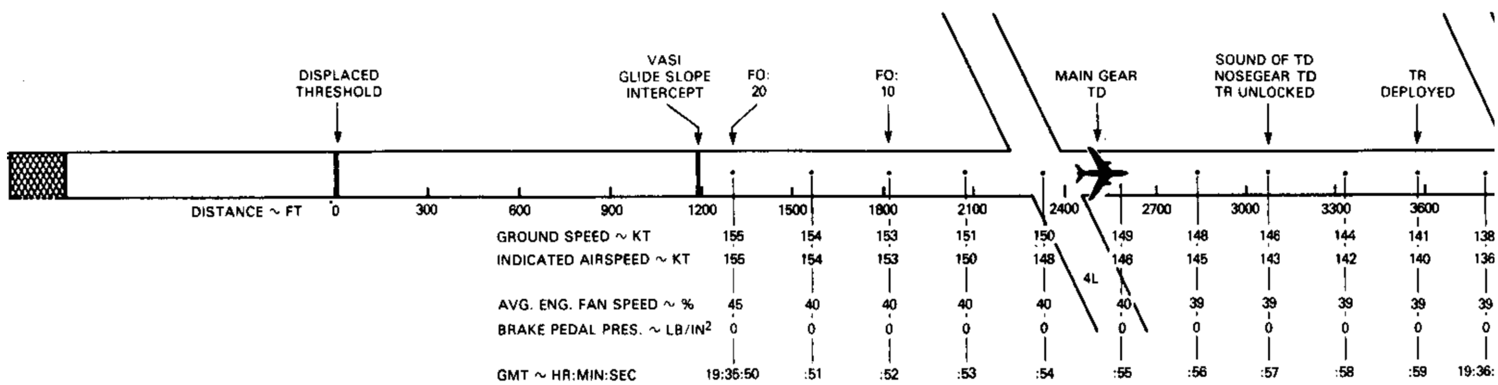
AIR-GROUND COMMUNICATIONS

TIME & SOURCE	CONTENT
1936:32 RDO-2	World's going off the end
1936:36 LCN	World's thirty heavy, ah off the end, sir, or are you able to right turn

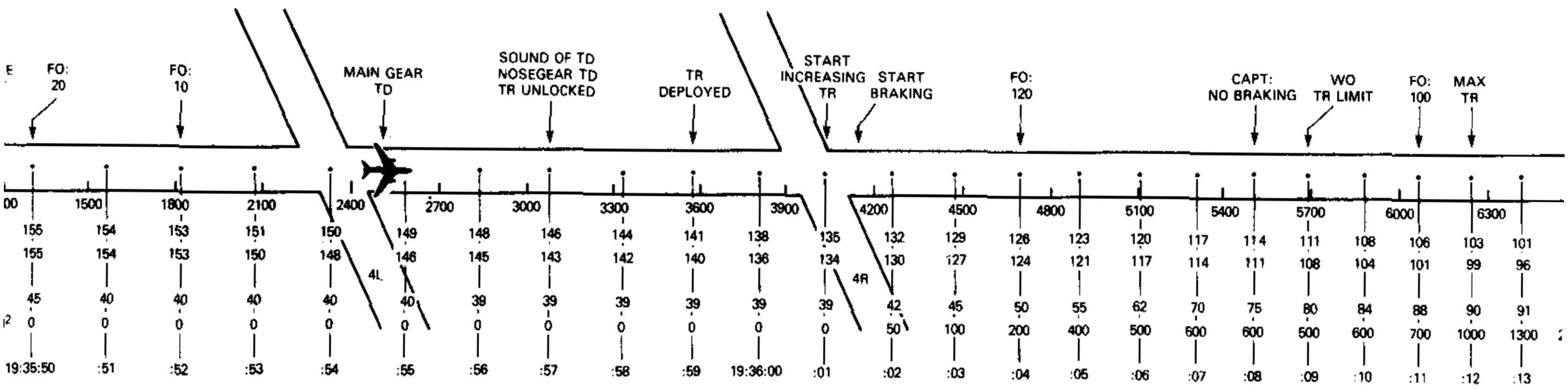
World 30 Runwa
Stop

LEGEND

CAPT - CAPTAIN
FO — FIRST OFFICER
FE — FLIGHT ENGINEER
MAX — MAXIMUM
TD — TOUCH DOWN
TR — THRUST REVERSERS
WO — WORLD AIRWAYS

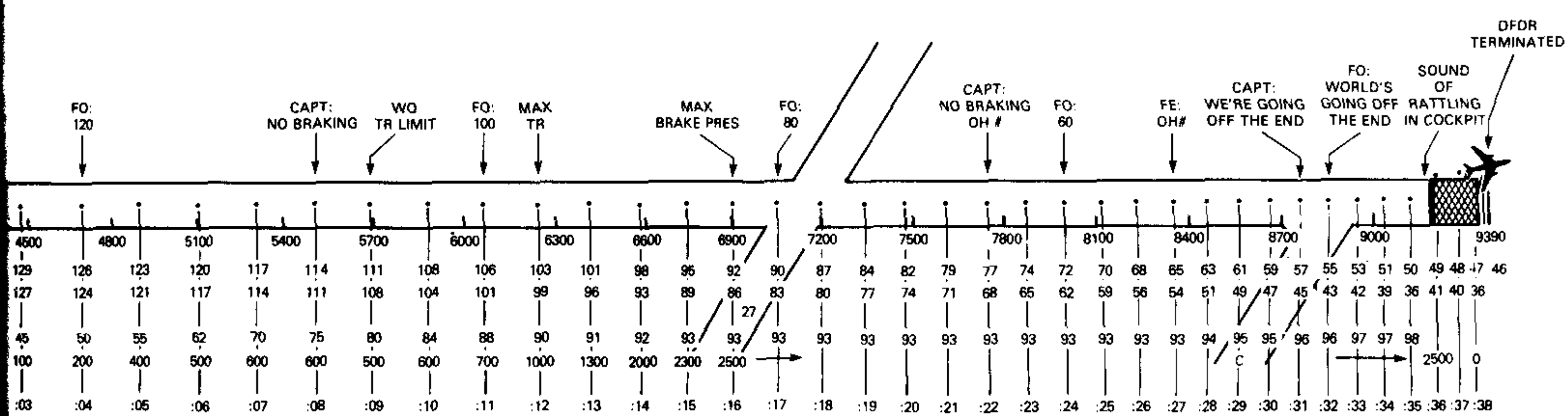


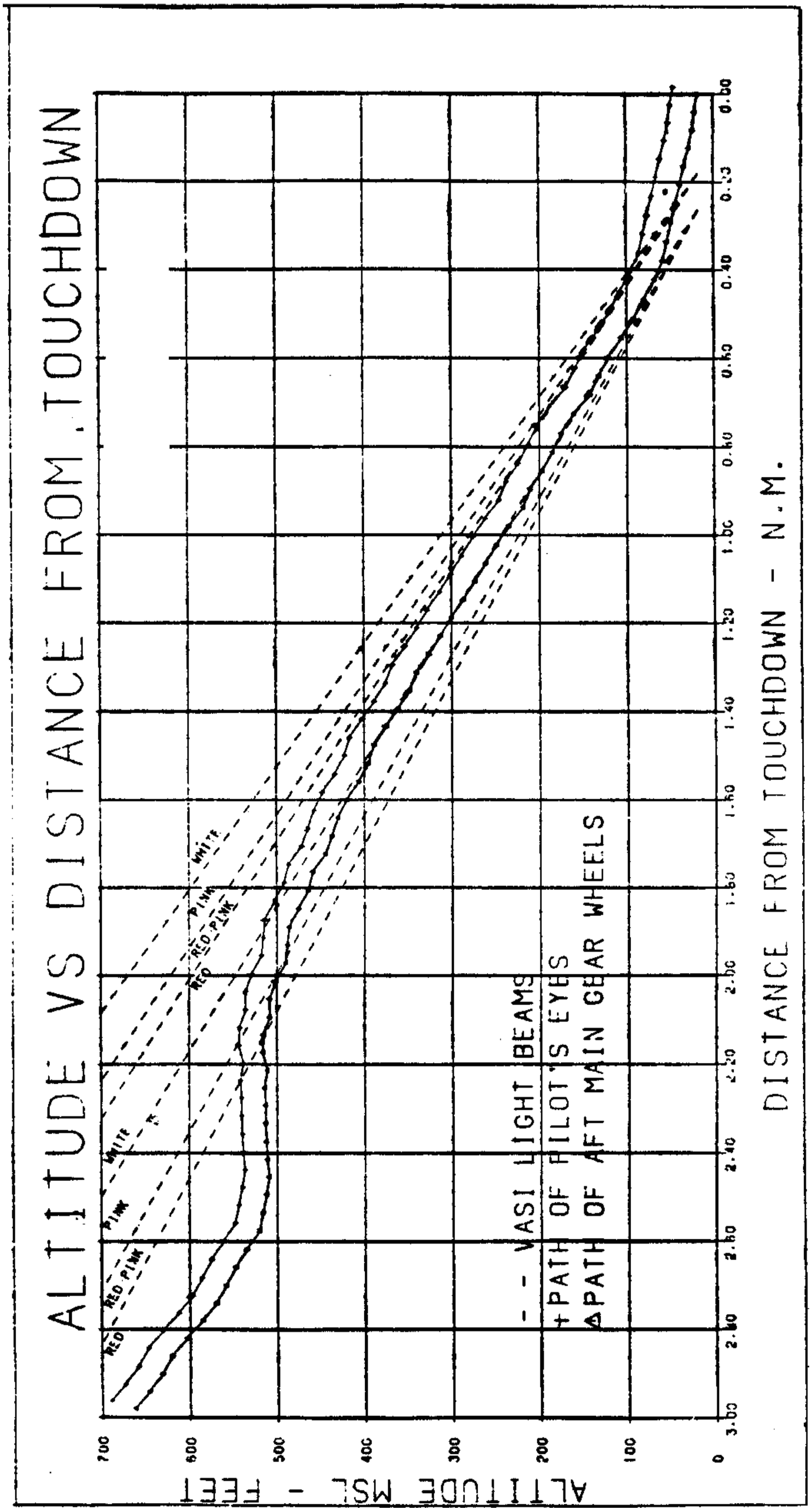
World 30 Runway 15R Logan International Airport
Stopping Performance

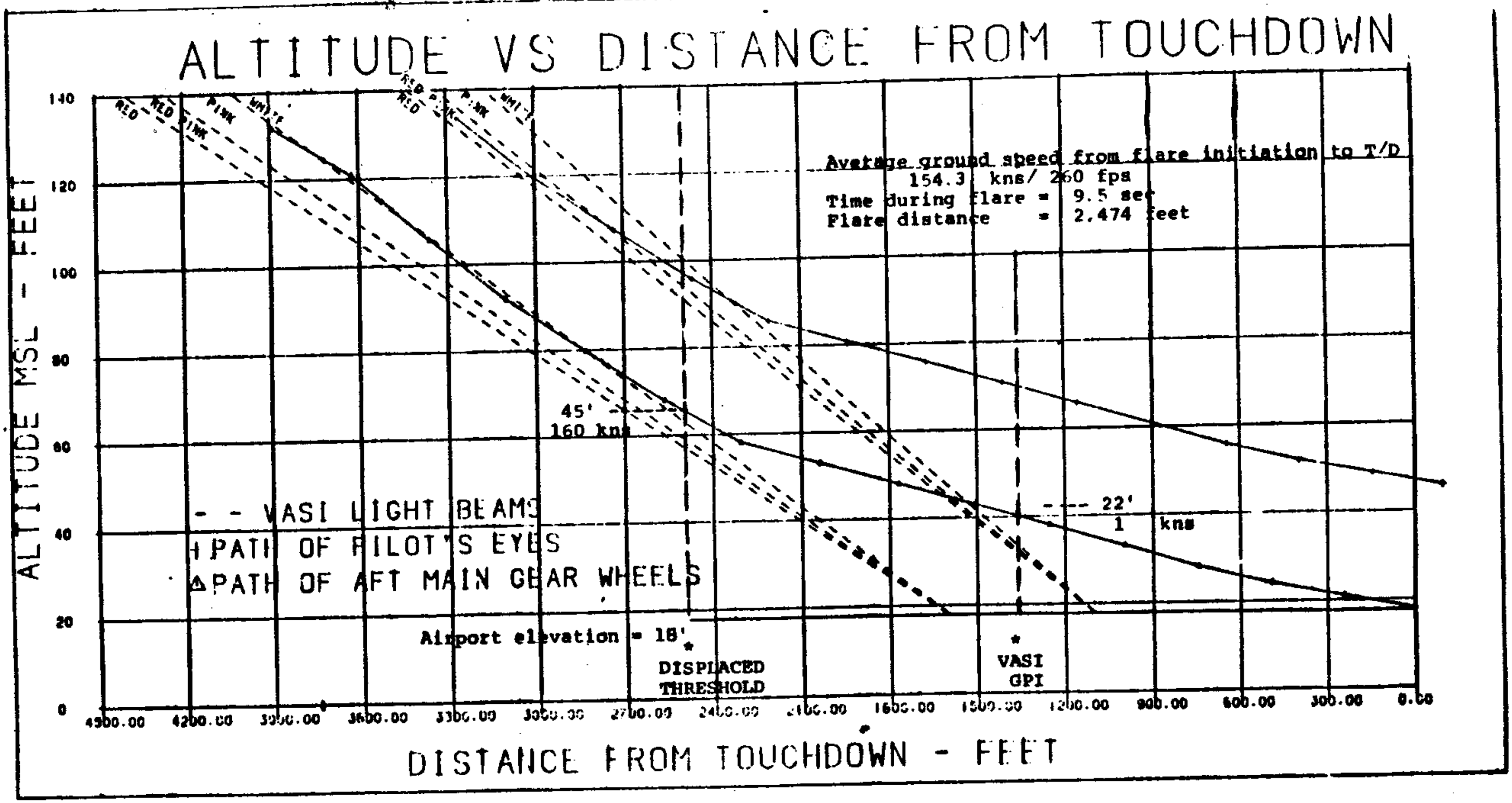


gan International Airport
formance

APPENDIX H

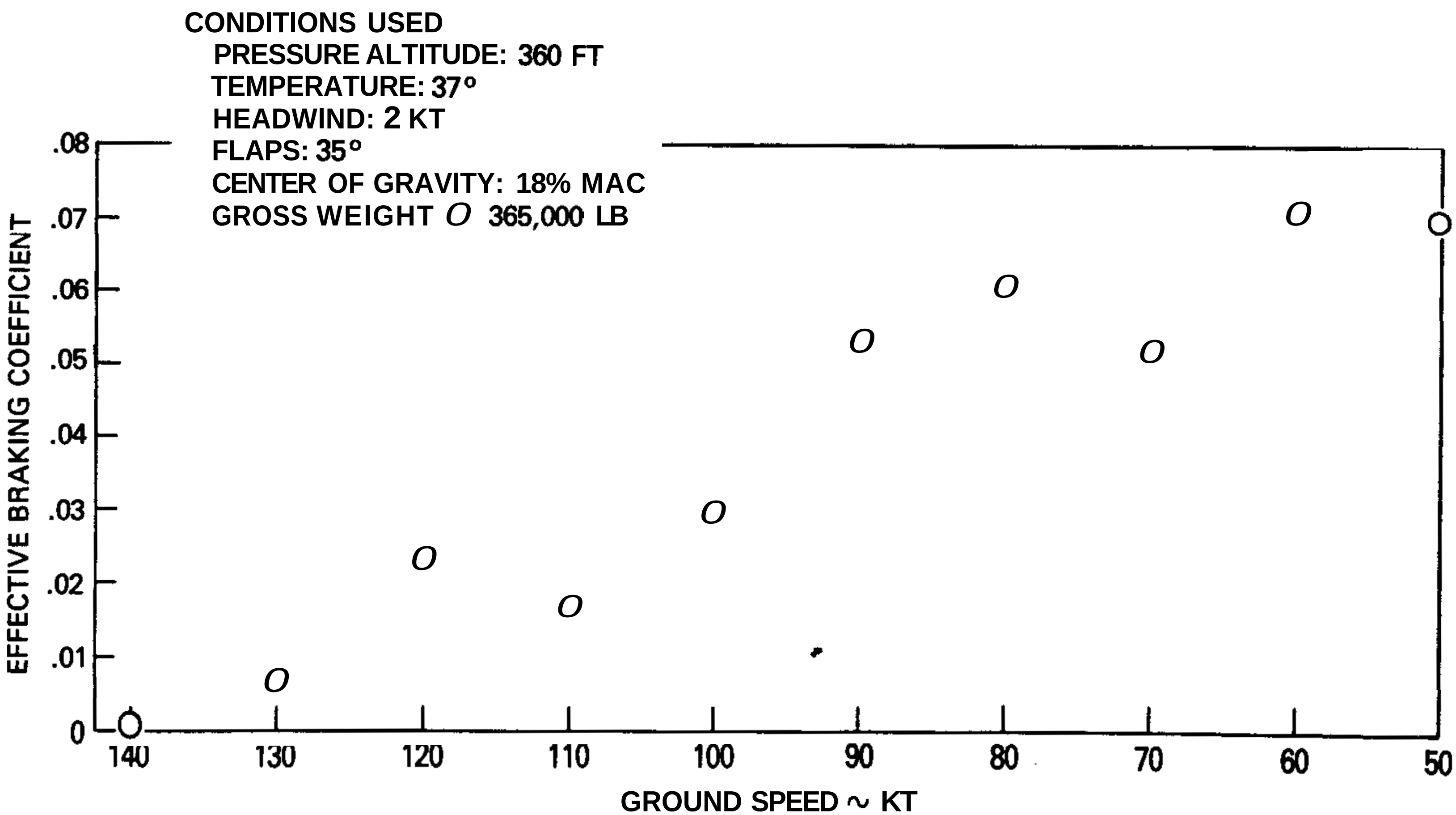



ALTITUDE VS DISTANCE FROM TOUCHDOWN
ALTITUDE MSL - FEET
DISTANCE FROM TOUCHDOWN - N.M.
- - VASI LIGHT BEAMS
+PATH OF PILOT'S EYES
ΔPATH OF AFT MAIN GEAR WHEELS
RED
RED PINK
PINK
WHITE
0
100
200
300
400
500
600
700
3.00
2.80
2.40
2.00
1.40
1.20
0.40


ALTITUDE VS DISTANCE FROM TOUCHDOWN
Average ground speed from flare initiation to T/D
154.3 kns/ 260 fps
Time during flare = 9.5 sec
Flare distance = 2,474 feet
RED
RED
PINK
WHITE
RED
PINK
WHITE
45'
160 kns
22'
1 kns
- - VASI LIGHT BEAMS
+ PATH OF PILOT'S EYES
△ PATH OF AFT MAIN GEAR WHEELS
Airport elevation = 18'
DISPLACED THRESHOLD
VASI GPI
ALTITUDE MSL - FEET
140
120
100
80
60
40
20
0
4500.00
4200.00
3900.00
3600.00
3300.00
3000.00
2700.00
2400.00
2100.00
1800.00
1500.00
1200.00
900.00
600.00
300.00
0.00
DISTANCE FROM TOUCHDOWN - FEET

Appendix K

Effective Braking ***Coefficients***
Runway *15R Logan*



NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

ISSUED: March 5, 1982

Forwarded to:

Honorable J. Lynn Helms
Administrator
Federal Aviation Administration
Washington, D. C. 20591

SAFETY RECOMMENDATION(S)

A-82-24 and -25

About 0634 Pacific daylight time, May 2, 1980, a McDonnell Douglas Corporation DC-9-80. N980DC, was damaged substantially during a landing on runway 22 at Edwards Air Force Base, California. The accident occurred during a landing in which the flightcrew was using procedures established for the official certification test to determine the horizontal distance required to land and bring the airplane to a full stop as required by 14 CFR 25.125.

The airplane touched down about 2,298 feet beyond the runway threshold. The descent rate at touchdown exceeded the structural limits of the airplane; the empennage separated and fell to the runway. The airplane came to rest about 5,634 feet beyond the landing threshold. Seven crewmembers were on board; one crewmember, a flight test engineer, suffered a broken ankle when the airplane touched down.

The National Transportation Safety Board determined that the probable cause of this accident was the pilot's failure to stabilize the approach as prescribed by the manufacturer's flight test procedures. Contributing to the cause of the accident was the lack of a requirement in the flight test procedures for other flight crewmembers to monitor and call out the critical flight parameters. Also contributing to this accident were the flight test procedures prescribed by the manufacturer for demonstrating the aircraft'? landing performance which involved vertical descent rates approaching the design load limits of the aircraft.

Basically, the certification requirements in 14 CFR 25, and more particularly sections 25.101 and 25.125, relate to the determination of horizontal landing distances which are then used in conjunction with the appropriate operational requirements of 14 CFR 121.195 to determine the maximum weight at which the airplane can be landed during, air carrier operations for a given runway length. Sections 25.101 and 25.125 specifically state that the procedures established for the certification tests must be able to be consistently executed in service by crews of average skill; that the methods used must be safe and reliable; that the landing must be made without excessive vertical acceleration; and that the landing may not require exceptional piloting skill or alertness. The Safety Board believes that these requirements, as stated, may be too subjective. All of the airframe manufacturers have established procedures in the context of these regulations which involve a minimum air distance from a point 50 feet above the runway threshold and a touchdown speed below Vref to produce a minimum rollout distance.

It is understandable that the manufacturers will attempt to demonstrate the shortest landing distance possible and thus maximize the operational specifications of their aircraft. However, the Safety Board notes that the procedures specified and used for these certification tests differ from those used during normal line operations. For example, the procedures established for demonstration of the DC-9-80 landing distances specified that thrust be reduced to idle at 50 feet above ground level and that the rate of descent be reduced to no more than 10 feet per second (600 fmp) or no less than 8 feet per second (480 fpm) at touchdown. Thus, the procedure not only allows but requires that the airplane be landed in such a manner that limit or near limit structural loads (as specified in 14 CFR 25.473) are imposed. The procedures also require skill and precise actions by the test pilots as evidenced by the admitted need to practice before undertaking official tests.

The certification tests for demonstrating airplane structural limits (such as 14 CFR 25.473) are conducted separate from the landing distance tests of 14 CFR 25.125 since these tests have entirely different objectives. There are considerable risks involved in taking an airplane to its structural limits during the landing distance demonstration. Furthermore, it is not necessary to do so when the test objective is to determine operational landing distances.

The Safety Board further notes that another accident occurred on May 14, 1959, when similar procedures were being used to demonstrate the minimum landing distance of the DC-8 airplane during its certification tests. In that instance, the airplane also touched down at an excessive descent rate which resulted in structural failure of the fuselage and separation of the No. 1 engine.

These *two* accidents indicate that, under current regulations, procedures are being used during certification which are not consistent with line operations so that the distances determined during certification are not actually achievable by a line pilot using accepted operational procedures. Accordingly, the Safety Board believes that this aspect of the certification process should be revised. Section 25.125 should be more specific in terms of approach path deviations, thrust reduction schedules, and maximum allowable vertical acceleration at touchdown. For example, landings equivalent to those resulting from ILS approaches or equivalent to the performance attainable from an autoland system could be established.

The Safety Board recognizes that changes in the landing distance demonstration procedures during certification could result in penalizing the operational specifications of the airplane as they are presently determined using the existing minimum landing distance procedures. For actual line operations on dry runways, a safety margin is currently provided by the operational limitation of 14 CFR 121.195 which requires that the minimum effective runway length be the airplane's landing distance as determined during certification divided by 0.6 (or multipliea by 1.667). The Safety Board's accident investigation experience has not indicated to date that the actual runway lengths used in line operations for dry runways do not afford a proper level of safety. Therefore, the Safety Board recognizes that a change in the aircraft certification criteria specified in 14 CFR 25.101 and 25.125 [illegible] necessitate a corresponding review of the operational limitations in 14 CFR 121.195 so that operational specifications are not unjustifiably penalized. Of course, we are not suggesting that current runway length requirements be compromised to the detriment of present levels of safety.

Accordingly, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Revise the procedures which are currently being used to demonstrate minimum landing distances for compliance with 14 CFR 25.125 for certification of transport category airplanes to: (a) provide a higher margin of safety during certification and (b) establish landing distances which are more representative of those encountered when an airplane is operated during air carrier service. (Class II, Priority Action) (A-82-24)

> Upon adoption of revised procedures for demonstrating operational landing distances for compliance with 14 CFR 25.125, review the operational runway length limitations in 14 CFR 121.195 which are applied to certification landing distances so that they do not unjustifiably penalize the operational specifications of airplanes. (Class II, Priority Action) (A-82-25)

BURNETT, Acting Chairman, and McADAMS, GOLDMAN, and BURSLEY, Members, concurred in these recommendations.

Jim Burnett

By: Jim Burnett
Acting Chairman

U.S. Department of Transportation
Federal Aviation Administration

Office of the Administrator

800 Independence Ave., S.W.
Washington, D.C. 20591

May 19, 1982

The Honorable Jim Burnett
Chairman, National Transportation
Safety Board
800 Independence Avenue, SW.
Washington, D.C. 20594

Dear Mr. Chairman:

This is in response to NTSB Safety Recommendations A-82-24 and A-82-25 issued by the Board on March 5, 1982. These recommendations resulted from the Board's investigation of an accident involving a McDonnell Douglas DC-9-80, N980DC, at Edwards Air Force Base, California, on May 2, 1980. The accident occurred during a landing in which the flightcrew was using procedures established for the official certification test to determine the horizontal distance required to land and bring the airplane to a full stop as required by 14 CFR 25.125. The airplane touched down about 2,298 feet beyond the runway threshold. The descent rate at touchdown exceeded the structural limits of the airplane; the empennage separated and fell to the runway. The airplane came to rest about 5,634 feet beyond the landing threshold.

A-82-24. Revise the procedures which are currently being used to demonstrate minimum landing distances for compliance with 14 CFR 25.125 for certification of transport category airplanes to: (a) provide a higher margin of safety during certification and (b) establish landing distances which are more representative of those encountered when an airplane is operated during air carrier service.

FAA Comment. The Federal Aviation Administration's (FAA) Transport Airplane Directorate has been reviewing all policies related with the air phase of landing distances. An FAA proposal to revise the method by which the air phase of the lending distance is determined is being prepared and should be circulated for comment soon. The essential points of this are:

(a) The air phase of the landing distance would be determined by calculation or demonstration with rational constraints on the approach path and rate of descent at touchdown. At the present time the precise value for these parameters has not been established. However, the demonstration proposed will result in a rational approach and landing which would result in a higher margin of safety during the air phase of lending distance certification testing.

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(b) Since both the calculation and demonstration method will be based on an approach to landing more in line with that encountered during airline operation, a modest increase in the landing air distance may result.

A-82-25. Upon adoption of revised procedures for demonstrating operational landing distances for compliance with 14 CFR 25.125, review the operational runway length limitations in 14 CFR 121.195 which are applied to certification landing distance so that they do not unjustifiably penalize the operational specifications of airplanes.

FAA Comment. There is general agreement within the FAA that the landing distance field lengths addressed in 14 CFR 121.195 are acceptable. The FAA proposal to revise the method by which the air phase of the landing distance is determined, as discussed in our response to Safety Recommendation A-82-24, should not result in substantial changes in field lengths. Only the method of determining the air distance, from 50 feet above the landing surface to the point of touchdown, would be affected. The resulting changes in 14 CFR 121.195 field lengths should be minimal.

We will keep the Board informed of significant progress in this area.

Sincerely,

J. Lynn Helms
Administrator

30 SEP 1982

Honorable J. Lynn Helms
Administrator
Federal Aviation Administration
Washington, D.C. 20591

Dear Mr. Helms:

Thank you for your letter of May 19, 1982. in response to the National Transportation Safety Board's Safety Recommendations A-82-24 and A-82-25 which were issued on March 5, 1982. as a result of information obtained during the investigation of an accident involving a McDonnell Douglas DC-9-80, at Edwards Air Force Base, California, on May 2, 1980.

We have the following comments:

A-82-24

Your review of all policies relating to the air phase of landing distances, and your proposal to revise the method by which the air phase of the landing distance is determined, fulfill the intent of the recommendation. Therefore, A-82-24 has been classified as "Open—Acceptable Action" pending completion of your review and the implementation of revisions to the procedures which are currently being used to demonstrate landing distances.

A-82-25

Your review of operational runway length limitations as specified in 14 CFR 121.195 which are applied to certification landing distances to ascertain that they do not unjustifiably penalize the operational specifications of airplanes. fulfills the intent of the recommendation. However, A-82-25 will be classified in an "Open—Acceptable Action" status pending the completion of your review relating to the air phase of landing distances and the adoption of revised procedures for demonstrating operational landing distances.

Honorable J. Lynn Helms

We look forward to information on the FAA's progress in these areas.

Respectfully yours,

/S/

Jim Burnett
Chairman

U.S. Department of Transportation
Federal Aviation Administration

Office of the Administrator

800 Independence Ave., S.W
Washington, D.C. 20591

NOV 22 1982

The Honorable Jim Burnett
Chairman, National Transportation
Safety Board
800 Independence Avenue, SW.
Washington, D.C. 20594

Dear Mr. Chairman:

This is in further response to NTSB Safety Recommendations A-82-24 and A-82-25 issued by the Board on March 5, 1982, and supplements our letter of May 19, 1982. This also responds to your letter dated September 30, 1982, in which you advised the Federal Aviation Administration (FAA) that these recommendations were being maintained in an "Open--Acceptable Action" statua. These recommendations resulted from the Board's investigation of an accident involving a McDonnell Douglas DC-9-80, N980DC, at Edwards Air Force Base, California, on May 2, 1980. The accident occurred during a landing in which the flightcrew was using procedures established for the official certification test to determine the horizontal distance required to land and bring the airplane to a full stop as required by 14 CFR 25.125. The airplane touched down about 2,298 feet beyond the runway threshold. The descent rate at touchdown exceeded the structural limits of the airplane; the empennage separated and fell to the runway. The airplane came to rest about 5,634 feet beyond the landing threshold.

A-82-24. Revise the procedures which are currently being used to demonstrate minimum landing distances for compliance with 14 CFR 25.125 for certification of transport category airplanes to: (a) provide a higher margin of safety during certification and (b) establish landing distances which are more representative of those encountered when an airplane is operated during air carrier service.

A-82-25. Upon adoption of revised procedures for demonstrating operational landing distances for compliance with 14 CFR 25.125, review the operational runway length limitations in 14 CFR 121.195 which are applied to certification landing distances so that they do not unjustifiably penalize the operational specifications of airplanes.

FAA Comment. As noted in our letter of May 19, 1982. the FAA's Transport Airplane Certification Directorate has been reviewing the certification policies related to the air phase of landing distance determination. A proposed change to the Engineering Flight Test Guide For Transport Category Airplanes, FAA Order 8110.8 has been circulated within the FAA for review and coordination.

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When this internal FAA coordination is completed, the proposed change will be released for review and comment by various industry organitations prior to issuance in its final form.

We will keep the Board informed of significant progress in this area.

Sincerely,

J. Lynn Helms
Administrator

NATIONAL TRANSPORTATJON SAFETY BOARD
WASHINGTON, D.C.

ISSUED: DEC 2 3,1982

Forwarded to:

Honorable J. Lynn Helms
Administrator
Federal Aviation Administration
Washington, D.C. 20591

SAFETY RECOMMENDATION(S)

A-82-152 through -169

On January 23, 1982, World Airwayg Inc., Flight 30H, a McDonnell Douglas DC-10-30, was a regularly Scheduled passenger flight from Oakland, California, to Boston, Massachusetts, 1/ with an en route stop at Newark, New Jersey. Following a nonprecision instrument approach to runway 15R at Boston-Logan International Airport, the airplane touched down about 2,500 feet beyond the displaced threshold of the runway, leaving 6,691 feet remaining on which to stop. About 1936:40, the airplane veered to avoid the approach light pier at the departure end of the runway and slid into the shallow water of Boston Harbor. The nose section separated from the forward fuselage after the airplane dropped onto the shore embankment. Of the 212 persons on board, 2 are missing and presumed dead The others evacuated the airplane safely, but with some injuries The reported weather was a measured 800-foot overcast, 2 1/2-mile visibility, light rain and fog, temperature 35°, and wind 165' at 3 kns. The wet runway was covered with hard-packed snow and a coating of rain and/or glazed ice.

The National Transportation Safety Board's investigation of the accident showed that when the flight departed Newark, the flightcrew was aware of the **poor** weather conditions that would be encountered at Boston. As the flight approached the Boston area, the flightcrew was advised by the Automatic Terminal Information Service (ATIS) report that braking action was "fair to poor." They received no further braking action advisories from air traffic control (ATC). In preparing for the approach, the pilot chose to use the autothrottle speed control (AT/SC) system for airspeed control, a normal World Airways, Inc, procedure. When he attempted to insert the flight manual reference speed into the AT/SC controller, he noted that the minimum speed acceptable to the system, which is programmed to provide a 30-percent airspeed margin above stall, was about 10 kns higher than that calculated by the flightcrew. He was using the airplane's No. 2 AT/SC and because the No. 1 system was inoperable, the flightcrew had no means of crosschecking the AT/SC computers Nevertheless, the pilot accepted the higher approach speed (as permitted by the flight manual) and continued to use the AT/SC for the approach and landing. He configured the airplane with 35° trailing edge flaps, made a

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1/ **For** more detailed information see: Aircraft Accident Report: World Airways Inc., Flight 30H, N113WA McDonnell Douglas DC-10-30, Boston-Logan International Airport, Boston, Massachusetts, January 23,1982. (NTSB-AAR-82-15.)

descent below the ceiling on the nonprecision approach, leveled, intercepted the 2-bar visual approach slope indicater (VASI) glide slope, and stabilized the descent. About 120 feet above the runway, the pilot took the airplane above the VASI glidepath as he adjusted for a safe touchdown aiming point as prescribed in wide-bodied airplane procedures. The airplane crossed the displaced threshold at a normal height; however, the landing flare was extended as the airspeed dissipated, leading to the extended touchdown point. The pilot used all of the airplane's decelerative devices, but he was not able to stop the airplane on the runway. About 43 seconds after touchdown, while still moving about 49 kns, the airplane was veered left to avoid collision with the approach light pier at the departure end of the runway and slid into the harbor. The nose section separated from the forward fuselage after the airplane went over a seawall and dropped onto the shore embankment.

The Boston area had had subfreezing temperatures for 2 days before the accident. On January 23, the temperature had risen from 6° F at midnight to 35° F at the time of the accident. Light snow had fallen in the morning hours and had changed to light rain in the late afternoon. Because of these conditions the Massachusetts Port Authority's snow plan had been implemented. In accordance with this plan, runway 15R had been closed periodically during the day for plowing and sanding. The runway had been reopened for flight operations at 1736, 2 hours before the accident At that time, an inspection by vehicle prompted the airport snow committee to assess the runway braking action as "fair to poor." The drizzle and light rain continued to fall and 14 airplanes landed on runway 15R during the 2 hours before Flight 30H landed. Only 5 of the 14 flightcrews volunteered braking action reports to the tower or ground controllers, and 1 crew provided a report upon request. One pilot, who had landed a DC-8 38 minutes before Flight 30H landed, had reported braking as "poor to nil." Two other pilots, who landed 8 and 11 minutes before Flight 30H, respectively, including the pilot of a DC-10-40 airplane, reported braking action as "poor." Several of the landing flights were unable to slow as necessary to turn off of the runway at an intersection 7,300 feet from the displaced threshold The DC-10-40 airplane encountered compressor stalls on one engine as continued reverse thrust was applied as the airplane proceeded.

The Safety Board's analysis of the digital flight data recorder (DFDR) of the DC-10-40 flight on which the pilot reported "**poor**" braking action and the analysis of the DFDR from Flight 30H indicated that the effective braking coefficient along runway 15R was about 0.08 or less for both flights Braking coefficients of this magnitude are typically representative of wet, icy surfaces An analysis of the theoretical stopping performance of Flight 30H, a DC-10-30 loaded to 365,000 pounds, indicated that the airplane would possibly have needed as much as 7,460 feet remaining after touchdown on which to stop with the effective braking coefficient achievable even if the airplane had been landed at the normal touchdown speed and with rapid deployment of ground spoilers and maximum use of reverse thrust. For comparison, the FAA-approved landing distance on a wet runway for the airplane is 6,753 feet, including the air segment from threshold to touchdown. If one allows for a minimum air run segment of 1,131 feet, as established during the airplane's certification, the FAA criterion allows a distance of 5,622 feet for stopping.

The Safety Board concluded that the World Airways accident exemplifies a problem which has been of continuing concern to it: under existing criteria heavy airplanes are permitted to land on runways known to be slippery and on which the braking coefficient may be so low that the airplane cannot be stopped, and as to which pilots may not be provided adequate guidance for making a knowledgable decision to land.

As a result of this accident and others involving operations on contaminated runways, the Safety Board convened a public hearing in Washington, D.C., May 3 to 5,1982, to examine further the problem of runway surface conditions and their effects on airplane takeoff and landing performance. All segments of the aviation industry participated in the hearing.

The information developed during the hearing reinforced the Safety Board's belief that the many positive actions taken during the past 10 to 15 years by airport operators, airplane manufacturers, airlines, and Qovernment research and regulatory agencies to enhance the safety of airplane takeoff and landing operations during periods of inclement weather have not been sufficient. The installation of precision approach aids, grooving of runways, improvements in airplane brake systems, improvements in tire design, more effective engine thrust reversers, automatic deployment of ground spoilers, and better pilot training programs have undoubtedly contributed to the prevention of many accidents This nothwithstanding, the Safety Board views the World Airways DC-10 accident at Boston-Logan International Airport on January 23, 1982, as evidence that the potential for serious and catastrophic runway overrun accidents will remain as long as takeoffs and landings must be made on slippery runways which provide, at best, minimum safety margins beyond the airplane's stopping performance.

The ideal solution to preventing accidents is to assure that runway surfaces are kept in a condition which provides for braking coefficients of friction compatible with airplanes' demonstrated performance and, when this is not possible, to prohibit flight operations to or from that runway. Unfortunately, this solution may not be completely feasible, particularly during winter storm conditions Therefore, acceptable alternatives must be sought. The Safety Board views the alternatives as consisting of the following:

1) Require that runway surfaces be maintained in the best possible condition through effective certification and inspection requirements, and require programs which will result in timely removal of contaminants

2) Refine communications between pilots, ATC, and airport management to keep all parties informed promptly when runway surface conditions change, particularly when braking performance is degraded.

3) Develop a means of quantifying pilot assessments and ground vehicle measurements of runway surface conditions in terms that will allow pilots to relate the reported conditions to their airplane's performance.

4) Provide pilots with sufficient information about their airplane's performance to enable them to make better decisions regarding takeoff and landing operations upon receipt of reports of contaminated runway conditions and;

5) Establish the extreme limits, based on runway surface condition and airplane performance, at which increased runway length safety margins ere needed or at which flight operations should be suspended by airport management.

The foregoing alternatives are a continuum in which the roles of the pilot, ATC, and airport management closely relate. Although airport management is responsible for maintaining the runways, it depends upon pilots and ATC to provide timely information on rapidly changing conditions during winter weather. The Board believes that more guidance to airport management, more accurate and timely runway condition reports, and the development of economical, reliable runway friction measuring devices would assist airport management in carrying out its responsibilities.

The Safety Board believes that airport management should be required to address the criteria for contaminant removal from runways in specific terms in the airport operations manual. The Board believes that rigid, uniform specifications should not be imposed by regulation. Rather, 14 CFR 139 should require that each airport operations manual specifically include the limits of snow, slush, or ice above which inspection and/or removal are required before operations at that airport can be continued.

The Board recognizes the subjectivity of current pilot braking action reports; however, in the absence of a better means of assessing runway surface condition, the Board believes that airport management should respond affirmatively to such reports. The judgment by a pilot that braking action is "poor" or "nil" is sufficient reason for airport management to take positive action to determine whether actual runway conditions are unsafe, particularly for heavier airplanes. Therefore, the Safety Board believes that 14 CFR 139 should require airport management to close, inspect, and improve as needed operational runways after receipt of "poor" or "nil" braking reports from pilots.

Amendment of 14 CFR 139, as recommended above, with a view to attaining improvements which should result in better runway conditions during inclement weather will not be fully effective if the FAA does not undertake positive measures to promote a program of measuring dry runway friction coefficients and monitoring to assure that dry runways are not degraded by contaminants, primarily rubber deposits. In this regard, the Safety Board issued two safety recommendations on November 18, 1976. These recommendations were directed to requiring airport operators to adhere to the guideline material contained in Advisory Circular 150/5320-12. In its latest response to these recommendations, dated December 9, 1982, the FAA stated that it planned no further action because: "Under the circumstances, we conclude that the imposition of the regulatory requirement recommended by NTSB would be neither appropriate nor justified." The FAA's contention was based on the premise that the accuracy and repeatability of the reported friction values are highly dependent on the calibration of the equipment, the training and qualifications of personnel, and strict adherence to recommended operating procedures.

The Safety Board believes that testimony at its public hearing by National Aeronautics and Space Administration (NASA) personnel and those airport managers who use friction measuring devices on a regular basis, as well as representatives from Canada and Sweden tends to refute the FAA's contention that such devices cannot be used to produce reliable readings. The means expressed by the FAA are valid, but they can be overcome. As a matter of fact, the FAA's own national program to measure runway slipperiness and. its followup series of more closely controlled runway friction measurements clearly demonstrated that reliable and repeatable readings can be achieved. Therefore, the Safety Board believes that friction data can be developed and applied to formulate a universal standard so that objective evaluations of the braking quality of a runway surface can be made. In view of this fact, it is appropriate that the FAA measure runway friction at all full-certificate airports during the annual inspection of the airport. The friction measurements could be made either by the FAA with FAA equipment or by airport personnel using airport equipment under the supervision of the FAA. Such a program would lead to the upgrading of the overall quality of runway friction measurement at certificated air carrier airports. Moreover, a continuing program of measurements would promote standardization of methodology and provide the needed experience to enhance.the reliability of equipment and qualifications of airport personnel to operate and calibrate the equipment,

The Safety Board recognizes that further research is needed to establish the value of devices to measure runway friction for operational purposes when the runway is covered with contaminants and to establish a correlation of measured values with airplane stopping performance. However, the Safety Board believes that the development of reliable equipment to determine runway condition in quantitative terms for advisory purposes is a realistic objective. Further, the Safety Board believes that runway friction data thus determined could be related to airplane weight and performance. As a consequence, the Safety Board urges NASA and the FAA to continue research in the 'measurement of runway friction coefficients for correlation to airplane stopping performance so that stopping distances on contaminated runways can be predicted with substantial accuracy.

Since pilot braking action reports likely will continue to be a primary source of runway condition information at large airports, pending the development and general acceptance of runway friction measuring equipment for operational purposes, and at smaller airports well into the future, action is needed to improve the quality of these reports and to reduce their subjectivity. The Board believes that many pilot braking reports probably are based on the pilot's perception of his total ability to slow the airplane on the landing runway rather than the actual braking attained through tire-to-runway friction. If the airplane is light and the runway is considerably longer than that normally required for landing, the pilot may perceive little or no problem in slowing the airplane to a safe turnoff speed Actually, under these conditions, most of the decelerative force may be provided by aerodynamic drag and reverse thrust with little augmentation by wheel brakes. Consequently, the pilot may report braking condition as "fair" or "fair to poor" when the actual braking conditions are worse. The pilot of a heavier airplane landing on the same runway will have a lesser margin and will need considerably greater braking force from the wheel brakes; consequently, he could be misled about the actual braking conditions by reliance on these pilot reports

The Safety Board believes that immediate action should be taken by the FAA to convene an industry-government group to develop standardized terminology and criteria for pilot braking reports, with the view that more guidance should be incorporated into certificated air carrier and commuter air carrier flight manuals and pilot training programs concerning the quality and accuracy of braking reports.

Additionally, the Safety Board believes that the NASA and FAA programs should be broadened to determine whether existing systems on an airplane can be redesigned or modified to present quantitative indications of effective braking coefficients to flightcrews. For example, antiskid system modulating pressures or cycling frequencies might be used in conjunction with prescribed pilot braking techniques to calculate and display a quantitative braking coefficient. Also, the potential for using inertial navigation systems to measure deceleration and to provide a quantitative braking coefficient for those airplanes so configured should be explored Such quantitive pilot reports would allow airport management to monitor deteriorating runway conditions more closely.

The FAA should also address the problems of communicating essential runway surface information to pilots. The existing two principal methods of relaying information to pilots are ATIS and individual controller reports. The Board has found that, for various reasons, these methods sometime are not effective, particularly in heavy workload situations. The investigations of the World Airway's accident at Boston-Logan International Airport and the Air Florida Boeing 737 accident at Washington National

Airport on January 13, 1982, 2/ revealed two examples where the ATIS reports did not reflect the most current runway conditions during changing weather conditions. ATIS can effectively provide general information about airport conditions; however, when airport conditions change rapidly, controllers cannot update the ATIS rapidly enough to provide the most current information. Moreover, under these circumstances, the controller may not have time to volunteer the most recent information and the pilot may rely on outdated ATIS information rather than ask for more current information. As a result, the whole system may fail to provide essential information to pilots during critical phases of flight.

At the Safety Board's public hearing, one witness stated that the transmission of runway condition reports would be more effective

> ". . . if, during periods of runway contamination, when braking action reports are 'poor or nil,' or conditions are changing rapidly, the FAA would state on the ATIS that 'braking action advisories are in effect,' and then issue the latest braking action reports at the time that final landing clearance is given; we believe this would do two things:
>
> (1) The pilot would realize there are braking action problems and that he should obtain a braking action report before landing;
>
> (2) It would require the FAA to issue the most up-to-date braking action reports when landing clearance is given, and to keep to a minimum the chances that a pilot will receive an outdated braking action report."

The Safety Board agrees that such a notice on the ATIS would alert pilots to runway contamination problems and would establish a specific consciousness in pilots and controllers of the runway conditions. Moreover, it could result in additional and more descriptive braking reports from pilots. Most importantly, however, it would assure that pilots would have the latest runway information in sufficient time to plan the landing or the takeoff. Although longer radio transmissions between pilots and controllers would be required, the Board believes that the need for critical runway information to more positively assure safety during takeoff and landing on contaminated runways warrants the increased controller and flightcrew workloads

For runway condition information to be totally effective, fliihtcrews must have more data regarding the stopping performance of their airplanes. The Safety Board is aware that, although airplane manufacturers are not required to demonstrate landing performance on runways other than dry, hard-surface runways for U.S. certification, the manufacturers of some airplanes have demonstrated performance and have provided data for wet runway performance to meet United Kingdom certification requirements. Furthermore, some manufacturers provide operators estimated stopping performance data for low braking coefficients and for no-brake conditions For example, such data are provided for the DC-10, and some operators use these data to derive tables or graphs of increased stopping distances required for various reported braking action conditions for use by flightcrews. The Safety Board's review of some major operators' manuals disclosed that the presentations of such data are not standardized and, in some cases, the landing distances for similar airplane weights and runway conditions derived by various

2/ For more information see: Aircraft Accident Report: Air Florida, Inc., Boeing 737-222, N62F, Collision with 14th Street Bridge, Near Washington National Airport, Washington, D.C., January 13, 1982. (NTSB-AAR-82-8.)

operators differed significantly. The Safety Board recognizes that actual demonstration of airplane stopping performance as a function of runway surface friction coefficient is not practical. However, we believe that manufacturers can extrapolate data from dry runway stopping performance to produce theoretical stopping performance for the lesser braking coefficients representative of typical wet and icy runway surface conditions. We believe that such data is needed by flightcrews and should be required, Further, the FAA should assure that the analytical assumptions used in the derivation of such data reflect consideration for antiskid brake system efficiency or any other landing 'gear or brake characteristics which can affect stopping performance on slippery surfaces. To accomplish this, the FAA should require manufacturers to demonstrate antiskid brake system performance by actual fliiht test or laboratory simulations.

The Safety Board believes that the inclusion of analytically derived stopping performance data in present airplane performance manuals is less helpful than it could be because the data are not available to flightcrews for quick reference when needed for takeoff and landing decisions. The FAA should, therefore, require that the data be presented to flightcrews in a form which allows correlation to runway friction coefficients obtainable from ground measuring devices. In the interim, the data should be categorized in accordance with accepted braking action terminology -- good, fair, poor, and nil -- and in any event additional guidance should be provided regarding the meaning of these terms.

Furthermore, the Safety Board believes that it is feasible to use analytically derived airplane stopping performance data to establish airplane weight limitations for operations on slippery runways for which friction measurements are available. The Safety Board is not convinced of the airplane manufacturers' and airlines' view that such requirements would impose severe economic penalties since only those scheduled flights which operate from slippery runways at or near maximum allowable gross weight limits would be affected.

The Safety Board believes that to enhance the safety margin during takeoff on contaminated runways flightcrews should be provided data for the lowest V_1 speed which would produce the existing acceleratego safety margin (35 feet end of runway crossing height) during "unbalanced field" takeoffs. The Safety Board, however, does not view an allowable reduced end of runway crossing height with a further reduced V_1 speed as an alternative to an increased runway length safety margin under slippery conditions. The Board is concerned that the reduced margin would present a hazard during a continued takeoff following an engine power loss at or just after V_1 because takeoff positioning variations or subnormal takeoff acceleration due to slow thrust application, contaminant retardation drag, or tire failure could not be predicted adequately.

The accelerate-stop performance and thus the field length and decision speed computations: are based upon the demonstrated and theoretical acceleration of the airplane using normal takeoff power. If, for any reason, the airplane acceleration 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 during the takeoff of Air Florida Flight 90, there is no assurance that from V_1 the airplane can stop on the remaining runway even if the runway surface is clean and dry. Consequently, a takeoff may have to be rejected at an airspeed much lower then V_1 -- when airplane acceleration is subnormal -- to assure adequate stopping distance, and the pilot must be able to recognize the subnormal acceleration rates early in a takeoff roll. There was extensive testimony at the public hearing about the development and use of takeoff performance monitoring systems. The doubts and concerns about the technical feasibility and complexity of a takeoff performance monitoring system are well founded. But the Safety Board is not convinced that they are insurmountable with today's technology and with industry's engineering and development capability. Instead, the Board believes that a concerted effort 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 make a significant contribution to flight safety. The Board believes that a joint government–industry task force should be formed under the leadership of the FAA at an early date to establish a program and guidelines for the development of a takeoff performance monitoring system. Moreover, this effort should be coordinated with other development and evaluation efforts pertaining to heads–up displays, flight guidance and control systems, and other related avionics systems in order to take advantage of advances in these areas and to assure integration of all takeoff performance monitor functions.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Amend 14 CFR 139.31 and 14 CFR 139.33 to require that airports certificated under 14 CFR 139 and located in areas subject to snow or freezing precipitation have an adequate snow removal plan, which includes criteria for closing, inspecting, and clearing contaminated runways following receipt of "poor" or "nil" braking action reports and to define the maximum snow or slush depth permissible for continued flight operations. (Class II, Priority Action) (A–82–152)

> Use a mechanical friction measuring device to measure the dry runway coefficient of friction during annual certification inspections at full certificate airports and require that a Notice to Airmen (NOTAM) be issued when the coefficient of friction falls below the minimum value reflected in Advisory Circular 150/5320-12, Chapter 2. (Class III, Longer–Term Action) (A–82–153)

> Require that full certificate airports have a plan for periodic inspection of dry runway surface condition which includes friction measuring operations by airport personnel or by contracted services and which addresses the training and qualification of operators, calibration and maintenance of the equipment, and procedures for the use of the friction measuring equipment. (Class III, Longer–Term Action) (A–82–154)

> Convene an industry-government group to develop standardized criteria for pilot braking action assessments and guidance for pilot braking action reports for incorporation into pilot training programs and operations manuals (Class II, Priority Action) (A–82–155)

> Amend air traffic control procedures to require that controllers make frequent requests for pilot braking action reports which include an assessment of braking action along the length of the runway whenever weather conditions are conducive to deteriorating braking conditions and that the requests be made well before the pilot lands (Class II, Priority Action) (A–82–156)

> Amend air traffic control procedures to require that controllers disseminate "poor" and "nil" braking action reports promptly to airport management and to all departing and arriving flights until airport management reports that the braking action is "good". (Class II, Priority Action) (A–82–157)

Stress in initial and recurrent air traffic controller training programs, the importance of transmitting all known contaminated runway condition information to departing and arriving flights, that a "fair" or "poor" braking report from a pilot may indicate conditions which are hazardous for a heavier airplane, and that departing and arriving pilots should be informed when no recent landing by a comparable airplane has been made. (Class II, Priority Action) (A–82–158)

Amend air traffic control procedures to require that Automatic Terminal Information Service broadcasts: (1) be updated promptly after receipt of reports of braking conditions worse than those reported in the current broadcast, and (2) when conditions are conducive to deteriorating braking action, include a statement that braking' action advisories are in effect. (Class II, Priority Action) (A–82–159)

At such time as air traffic control procedures are amended to require Automatic Terminal Information Service (ATIS) broadcasts to be modified, amend the Airman's Information Manual to alert pilots that when advised on ATIS that braking action advisories are in effect they should be prepared for deteriorating braking conditions, that they should request current runway condition information if not volunteered by controllers, and that they should be prepared to provide a descriptive runway condition report to controllers after landing. (Class II, Priority Action) (A–82–160)

Require that air carrier principal operations inspectors review the operating procedures and advisory information provided to flightcrews for landing on slippery runways to verify that the procedures and information are consistent with providing minimum airplane stopping distance. (Class II, Priority Action) (A–82–161)

Require that airplane manufacturers and air carriers provide advisory information and recommended procedures for flightcrew use during a landing approach with the autothrottle speed control system engaged when there is a disparity between the minimum speed the autothrottle speed control system will accept and the flight manual reference speed. (Class II, Priority Action) (A–82–162)

Amend 14 CFR 25.107, 25.111, and 25.113 to require that manufacturers of transport category airplanes provide sufficient data for operators to determine the lowest decision speed (V_1) for airplane takeoff weight, ambient conditions, and departure runway length which will comply with existing takeoff criteria in the event of an engine power loss at or after reaching V_1. (Class III, Longer–Term Action) (A–82–163)

Amend 14 CFR 121.189 and 14 CFR 135.379 to require that operators of turbine engine-powered, large transport category airplanes provide flightcrews with data from which the lowest V_1 speed complying with specified takeoff criteria can be determined. (Class III, Longer–Term Action) (A–82–164)

Amend 14 CFR 25.109 and 14 CFR 25.125 to require that manufacturers of transport category airplanes provide data extrapolated from demonstrated dry runway performance regarding the stopping performance of the airplane on surfaces having low friction coefficients representative of wet and icy runways and assure that such data give proper consideration to pilot reaction times and brake antiskid control system performance. (Class III, Longer–Term Action) (A–82–165)

Amend 14 CFR 25.735 to require that manufacturers of transport category airplanes determine and demonstrate the efficiency of brake control systems on surfaces with low friction coefficients representative of wet and icy runways by using simulation techniques incorporating dynamometer tests and actual brake system components, or by actual flight test (Class II, Longer-Term Action) (A-82-166)

Amend 14 CFR 121.135 to require that air carriers and other commercial operators of large transport category airplanes include in flightcrew operations manuals takeoff acceleration retardation data in accordance with guidance provided in Advisory Circular 91-6A and stopping performance data on surfaces having low friction coefficients, beginning immediately when such data are available from airplane manufacturers. (Class II, Priority Action) (A-82-16?]

In coordination with the National Aeronautics and Space Administration, expand the current research program to evaluate runway friction measuring devices which correlate friction measurements with airplane stopping performance to examine the use of airplane systems such as antiskid brake and inertial navigation systems to calculate and display in the cockpit measurements of actual effective braking coefficients attained. (Class III, Longer-Term Action) (A-82-168)

Convene an industry-government group which includes the National Aeronautics and Space Administration to define a program for the development of a reliable takeoff acceleration monitoring system. (Class II, Priority Action) (A-82-169)

On January 3, 1972, the Safety Board issued Safety Recommendation A-72-3 which was reiterated following the Air Florida, Inc., Fliiht 90 accident. The Safety Board recommended that the Federal Aviation Administration: "Require the installation of runway distance markers at all airports where air carrier aircraft are authorized to operate." The objective of the recommendation, which has not been implemented, was to provide flightcrews with a means to measure takeoff acceleration performance. The recommendation was reiterated after the Air Florida accident because the accident might have been prevented had the Air Florida flightcrew used some means to better assess the substantially subnormal takeoff acceleration. Although the runway marker system is not intended as a substitute for the installation of a takeoff performance monitoring system in the cockpit, the Safety Board believes that, pending development and installation of the latter system, the runway marker system would provide flightcrews with an interim means for assessing takeoff performance. Further, the Safety Board believes that the runway marker system would provide valuable information to fliihtcrews of landing airplanes because it would provide quick recognition of the touchdown point with respect to the length of runway remaining, enabling the flightcrews to modulate stopping performance as necessary. Further, this system would provide a means for flightcrews to compare actual stopping performance on contaminated runways with the published performance for dry runways; this comparison could be used as a more objective basis for identification of the braking conditions on contaminated runways

Given the existing lack of any means to measure takeoff performance or to predict stopping performance on contaminated runways, the Safety Board again urges the Federal Aviation Administration to implement Safety Recommendation A-72-3.

BURNETT, Chairman, GOLDMAN, Vice Chairman, McADAMS, BURSLEY, and ENGEN, Members, concurred in these recommendations.

Jim Burnett

By: Jim Burnett
Chairman

DOUGLAS AIRCRAFT COMPANY

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KNOW YOUR DC-10

LETTER NO. 64
DATE 5 November 1979

TO: ALL DC-10 OPERATORS

FROM: G. R. Jansen, Director, Flight Operations
DOUGLAS AIRCRAFT COMPANY

SUBJECT: DC-10 AUTOTHROTTLE/SPEED COMMAND ALPHA SPEED FUNCTIONS

The purpose of this Know Your DC-10 Letter is to present information on the speed mode of the autothrottle speed control system (AT/SC) so that flight crews will better understand the significance of alpha speed annunciations and to suggest procedures to follow when unexplained alpha speed annunciations are encountered.

The alpha speed floor of the AT/SC is provided to prevent flying below operational minimum maneuver speeds in the event that a speed less' than the nominal value is selected on the AT/SC control panel with autothrottle(s) engaged. Alpha speed is based on angle-of-attack as computed by the speed control computer. Figure 1 tabulates alpha speed for various configurations in terms of margin above stall. The first column is the alpha speed margin in relation to V stall minimum (V_S min.). All takeoff and landing performance is based on V_S min. and therefore the computed alpha speeds are based on this relationship. The second column is the alpha speed margin in relation to V stall 1G (V_{S1G}) which is significant when in cruise or in a holding pattern at high altitudes. More about this later, but now let's examine some chronic misunderstandings.

Pilots have complained that they observed alpha speed annunciated on one flight mode annunciator (FMA)while speed was annunciated on the other. This is explained by the fact that there are two separate speed control computers. Inputs to each of the computers may vary slightly within acceptable tolerance limits and, therefore, there may be small differences in alpha speed from one computer to the other.

Pilots have also complained when they have selected a speed near, but above, the minimum maneuver speed for the configuration, that alpha speed would frequently annunciate on one or both FMA's. The cause of this may be due to the tolerances in the alpha speed floor (reference Figure 2), or the pilot may have inadvertently made a speed selection below the actual minimum maneuver speed based upon an incorrect aircraft gross weight. 'How is the pilot then to know why alpha speed is annunciated?

FLAPSISLATS	Vα VERSUS $V_{S\ MIN}$	Vα VERSUS V_{S1G}
0 DEG/RET	1.5 $V_{S\ MIN}$	1.39
0 DEGITAKEOFF	1.5 $V_{S\ MIN}$	1.48
5 DEGITAKEOFF	1.5 $V_{S\ MIN}$	1.41
15 DEGITAKEOFF	1.45 $V_{S\ MIN}$	1.38
22 DEGITAKEDFF	1.4 $V_{S\ MIN}$	1.33
35 DEGILAND	1.3 $V_{S\ MIN}$	1.24
50 DEGILAND	1.3 $V_{S\ MIN}$	1.23

FIGURE 1. α SPEED MARGINS ABOVE STALL FOR ALTITUDES BELOW 15,000 FEET

	SERIES 10			SERIES 30			
GW x 1000 LB	310	340	380	310	340	380	400
FLAPSISLATS							
0 DEGITO	±10	±11	111	f10.5	±10	116	±17
22 DEGITO	±7	±7	17	27	'8	•8	18
35 DEGILAND	±7	±7	t7	17	±7	t7	±7
50 DEGILAND	±6	±6	16	±6	t6	16	±6

FIGURE 2. α SPEED TOLERANCES – MAXIMUMACCEPTABLE DEVIATION FROM NOMINAL (KNOTS)

	310	340	380	400	450	500
25,000 FT	1.245	1.250	1.245	1.240	1.220	1.220
35,000 FT	1.215	1.195	1.170	1.160	1.130	
40,000 FT	1.170	1.135	1.105	1.090		

FIGURE 3. α SPEED MARGINS FOR CRUISE FLIGHT (Vα VERSUS V_{S1G})

in Figure 2, it is a usable system. If it is out of tolerance on the high side, actual aircraft weight may be greater than computed for dispatch. If time permits, a similar individual check of the other AT/SC may be made.

NOTE 1: The disengaged AT/SC may be operating within tolerance. If desired, steps outlined in Case 3 may be used to determine if it is within tolerance.

The alpha speed floor margins shown in Figure 1 are accurate up to 15,000 feet but for practical purposes, are valid up to 21,000 feet where typically the system is checked during the production acceptance flight tests. At this altitude the indicated alpha speeds may be as much as two knots higher than they would be at sea level due to compressibility effects. This difference is considered acceptable in view of other tolerances in the AT/SC, and for the basic purpose of the alpha speed floor which is to command a safe speed if the pilot makes an error in his speed selection.

As altitude is increased above 21,000 feet in long range cruise or high altitude holding, the pilot is more concerned with low speed buffet protection and maneuvering speed margins as related to the 1G stall since pertinent data in the Flight Crew Operating Manual is based on the 1G stall. As altitude increases, the actual 1G stall speed also increases due to compressibility effects. The alpha speed computations are optimized for approach configurations (low speed low altitude conditions) to provide greatest accuracy in these flight regimes. Therefore, as altitude increases, the alpha speed floor stall margins versus the 1G stall are gradually reduced from the values given in Figure 1 for a clean airplane to those values shown in Figure 3. As an example, at 35,000 feet a 450,000 pound airplane will annunciate alpha speed at a Mach number of 0.71 which is well below the minimum cruise Mach number of 0.80 which provides a maneuvering margin of 1.27 V_{S1G}. For this flight condition the alpha speed floor provides a margin to the stall of 1.13 V_{S1G}. These speeds and speed margins are nominal values and if the low side of the tolerance band is experienced much of the margin provided by 1.13 V_{S1G} is removed.

C. R. Jansen
Director
Flight Operations

FLAPS/SLATS	Vα VERSUS $V_{S\ MIN}$	Vα VERSUS V_{S1G}
0 DEG/RET	1.5 $V_{S\ MIN}$	1.39
0 DEG/TAKEOFF	1.5 $V_{S\ MIN}$	1.48
5 DEG/TAKEOFF	1.5 $V_{S\ MIN}$	1.41
15 DEG/TAKEOFF	1.45 $V_{S\ MIN}$	1.38
22 DEG/TAKEOFF	1.4 $V_{S\ MIN}$	1.33
35 DEG/LAND	1.3 $V_{S\ MIN}$	1.24
50 DEG/LAND	1.3 $V_{S\ MIN}$	1.23

FIGURE 1. α SPEED MARGINS ABOVE STALL FOR ALTITUDES BELOW 15,000 FEET

	SERIES 10			SERIES 30			
GW x 1000 LB	no	vv	380	310	340	380	400
FLAPS/SLATS							
0 DEG/TO	110	111	tll	t10.5	110	±16	t17
22 DEG/TO	±7	±7	t7	r7	±8	±8	18
35 DEGILAND	±7	±7	±7	±7	±7	17	±7
50 DEG/LAND	r 6	±6	±6	16	±6	t6	16

FIGURE 2. α SPEED TOLERANCES – MAXIMUMACCEPTABLE DEVIATION FROM NOMINAL (KNOTS)

	310	340	380	400	450	500
25,000 FT	1.245	1.250	1.245	1.240	1.220	1.220
35,000 FT	1.215	1.195	1.170	1.160	1.130	–
40,000 FT	1.170	1.135	1.105	1.090	–	–

FIGURE 3. α SPEED MARGINS FOR CRUISE FLIGHT (Vα VERSUS V_{S1G})

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