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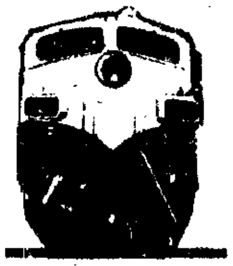
NATIONAL TRANSPORTATION SAFETY BOARD



WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

PIEDMONT AIRLINES FLIGHT 467
BOEING 737-222, N752N
CHARLOTTE DOUGLAS INTERNATIONAL AIRPORT
CHARLOTTE, NORTH CAROLINA
OCTOBER 26, 1986

NTSB/AAR-87/08

UNITED STATES GOVERNMENT

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16. Abstract

On October 25, 1986, Piedmont Airlines flight 467, a Boeing 737-222, N752N, was a regularly scheduled flight operating under 14 CFR 121 from Newark International Airport to Myrtle Beach, South Carolina, with an en route stop at Charlotte Douglas International Airport, Charlotte, North Carolina. There were 114 passengers and 5 crewmembers on board. The flight was routine until its arrival into the Charlotte area, where instrument meteorological conditions prevailed. At 2004:17, the flight was cleared for the instrument landing system approach (ILS) to runway 36R. The airplane touched down at 2007:19 and about 2007:43 it departed the runway. The airplane struck the localizer antenna array located about 300 feet from the departure end of the runway, struck a concrete culvert located 18 feet beyond the localizer, and continued through a chain link fence. It came to rest upon the edge of railroad tracks located 440 feet from the departure end of the runway. The airplane was destroyed, 3 passengers sustained serious injuries, and 3 crewmembers and 28 passengers sustained minor injuries in the accident.

The National Transportation Safety Board determines that the probable cause of the accident was the captain's failure to stabilize the approach and his failure to discontinue the approach to a landing that was conducted at an excessive speed beyond the normal touchdown point on a wet runway. Contributing to the accident was the captain's failure to

17. Key Words

Boeing 737; antiskid system; crew coordination; cockpit resource management; runway friction; spoiler; air/ground safety sensor

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optimally use the airplane decelerative devices. Also contributing to the accident was the lack of effective crew coordination during the approach. Contributing to the severity of the accident was the poor frictional quality of the last 1,500 feet of the runway and the obstruction presented by a concrete culvert located 318 feet beyond the departure end of the runway.

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EXECUTIVE SUMMARY

On October 25, 1986, Piedmont Airlines flight 467, a Boeing 737-222, N752N, was a regularly scheduled flight operating under 14 CFR 121 from Newark International Airport to Myrtle Beach, South Carolina, with an en route stop at Charlotte Douglas International Airport, Charlotte, North Carolina. There were 114 passengers and 5 crewmembers on board. The flight was routine until its arrival into the Charlotte area, where instrument meteorological conditions prevailed. At 2004:17, the flight was cleared for the instrument landing system approach (ILS) to runway 36R. The airplane touched down at 2007:19 and about 2007:43 it departed the runway. The airplane struck the localizer antenna array located about 300 feet from the departure end of the runway, struck a concrete culvert located 18 feet beyond the localizer, and continued through a chain link fence. It came to rest upon the edge of railroad tracks located 440 feet from the departure end of the runway. The airplane was destroyed, 3 passengers sustained serious injuries, and 3 crewmembers and 28 passengers sustained minor injuries in the accident.

The safety issues in this accident concern flightcrew nonadherence to operating procedures. The evidence indicates that the airplane was not configured for a landing, as required, upon crossing the final approach fix. Rather, the final flap setting was attained about 500 feet above ground level. In addition, several issues relating to postaccident survivability were identified. These include removing obstacles located beyond the runway safety area, and serving alcohol to intoxicated passengers.

The National Transportation Safety Board determines that the probable cause of the accident was the captain's failure to stabilize the approach and his failure to discontinue the approach to a landing that was conducted at an excessive speed beyond the normal touchdown point on a wet runway. Contributing to the accident was the captain's failure to optimally use the airplane decelerative devices. Also contributing to the accident was the lack of effective crew coordination during the approach. Contributing to the severity of the accident was the poor frictional quality of the last 1,500 feet of the runway and the obstruction presented by a concrete culvert located 318 feet beyond the departure end of the runway.

As a result of its investigation, the Safety Board issued a recommendation to the Federal Aviation Administration (FAA) to require airport managers, at the earliest opportunity, to repair or remove obstacles, such as concrete culverts, that are adjacent to airport operating areas. The Safety Board also issued recommendations to the FAA urging it to issue operations bulletins to principal operations inspectors of air carriers operating aircraft with flight attendants informing them of the need to cease providing alcohol to passengers who are in, or appear that they are about to be in, an intoxicated state; and to require a one-time inspection of flight attendant seat pan roller assemblies. In addition two recommendations concerning the measurement of runway friction were issued to the FAA.

Two recommendations to the American Association of Airport Executives and the Airport Operators Council International, Inc., requested their memberships to repair or remove obstacles adjacent to airport operating areas, to identify deficient runways conditions, to use approved friction measuring devices to measure dry runway coefficients of friction, and to correct runway conditions that do not meet the FAA-recommended criteria.

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

Adopted: September 1, 1987

PIEDMONT AIRLINES FLIGHT 467
BOEING 737-222, N752N
CHARLOTTE DOUGLAS INTERNATIONAL AIRPORT
OCTOBER 25, 1986

1. FACTUAL INFORMATION

1.1 History of the Flight

On October 25, 1986, Piedmont Airlines flight 467 (PI 467), a Boeing 737-222, N752N, was a regularly scheduled flight operating under 14 Code of Federal Regulations (CFR) 121 from Newark International Airport (EWR) to Myrtle Beach, South Carolina, with an en route stop at Charlotte Douglas International Airport (CLT), Charlotte, North Carolina. There were 114 passengers, 2 flightcrew members, and 3 flight attendants on board.

The flightcrew arrived at Newark about 1500 following a "deadhead" flight from their base at Baltimore-Washington International Airport. Each met with friends at EWR until it was time to report for the flight. 1/. They prepared for their preflight activities about 1 hour before the scheduled departure time of 1820 and noted nothing unusual about the airplane. The route of flight, following the departure from Newark, was direct to Kenton, then via airway J14 to Greensboro and into CLT via the LEEON4 arrival. The en route altitude was 31,000 feet above mean sea level (msl).

The flight, which was 1 hour 20 minute in duration, was reported to be routine until its arrival into the Charlotte area. At 1953:06 PI 467 contacted Charlotte approach control and was told to expect an instrument landing system (ILS) approach to runway 36R. According to the flightcrew, before reaching 6,000 feet the first officer received the current CLT automatic terminal information service (ATIS) information and the captain performed the preapproach briefing.

ATIS information Juliet, which was current when PI 467 initially contacted Charlotte approach control, indicated that at 1850 the ceiling at Charlotte was 500 feet overcast, visibility was 1/2 mile with rain and fog, the temperature was 60° F, the dew point was 59° F, the wind was from 100° at 6 knots, and the altimeter was 30.04 inHg. Runway 5/23 was out of service and simultaneous ILS approaches were being conducted to runways 36R and 36L. At 2001:18, the Charlotte final controller transmitted to all aircraft inbound to CLT, including PI 467, the following local weather information: "measured ceiling 400 overcast, visibility 2, light rain and fog, temperature and dew point remain the same, wind 090 at 8, altimeter 30.01." (See appendix B.)

At 2001:02, the Charlotte final controller directed PI 467 to fly a heading of 195° "for a close in base leg." PI 467 acknowledged. Forty-three seconds later, PI 467 was directed to descend to 2,400 feet mean sea level (msl).

1/ All times herein are eastern daylight, based on the 24-hour clock, unless otherwise specified.

At 2002:42, the CLT final controller informed Piedmont flight 309, which was ahead of PI 467 in the sequence to runway 36R, that there was a right-to-left wind of 20 to 25 knots on the final approach course. According to the cockpit voice recorder (CVR), PI 467 received this information, although neither crewmember commented on the winds or discussed possible changes needed to the conduct of the approach. At 2003:55, the Charlotte final controller directed PI 467 to turn to 290°. Radar data from the CLT terminal radar approach control indicates that PI 467 had descended to 2,400 feet as it began this turn. (See appendix C.)

At 2004:17, the CLT final controller informed PI 467 that it was 3 miles southeast of HAYOU, the final approach fix for the ILS approach to runway 36R. (See figure 1.) He directed the flight to continue its turn until reaching 330° and to maintain 2,400 feet until it was established on the localizer. He then cleared PI 467 for the ILS approach to runway 36R. PI 467 acknowledged the clearance at 2004:26.

At 2005:01, the first officer said, "Standard callouts," while simultaneously the captain said, "Gear down, it's going to be tight." The first officer did not acknowledge the gear down command and the gear was not lowered until 2005:40. PI 467 contacted Charlotte tower at 2005:36, and was told that the surface wind was 100° at 4 knots and that it was cleared to land. At that time, the flaps were set to 5°. At 2005:54, the captain called for "flaps 10" and then called for the next two flap settings of 15 and 25.

At 2066:22, the captain commented to the first officer, "Yeah-George didn't do me any favors there," and two seconds later he added, "we'll get back on it in a second." After the accident, the captain said that he was referring to the autopilot, to which pilots often refer with the colloquialism "George." He added that he prefers to use the autopilot on an ILS approach, but on PI 467 he could not establish autopilot control of the airplane.

At 2006:37, the first officer said:

> "I'm going to start some lights for you now on the an recalls been checked the speed brake is manual—landing gear is down and three green, and flaps—to go."

The captain called for the final setting of flaps 30 simultaneous with the first officer's saying "to go." It could not be determined if the captain verbally responded to the first officer's callout that the speed brake was in manual. The first officer called 100 feet above minimums at 2007:03 and, at the same time, the ground proximity warning system (GPWS) alerted "Glideslope." The first officer called "at minimums" at 2007:09 and, at the same time, the GPWS alerted "Whoop whoop pull up." The sound of touchdown was recorded at 2007:19 and, 5 seconds later, the first officer said, "Good show."

The captain stated after the accident that he knew that the turn to the final approach course, which the controller gave to PI 467 when he cleared it for the approach, was "a little late in coming," but that he believed that such "close in" turns were common at Charlotte. Moreover, he said he was aware that there was ". . . a hell of a tailwind." Since the winds at 6,000 feet msl were "significantly different," from the winds on the ground, he said that he planned the approach from ". . . the standpoint of a possible windshear." He said that he added 20 knots of airspeed, the maximum allowable under Piedmont procedures, to the Vref speed of 131 knots. He added that, although the airspeed fluctuated as much as 10 knots during the approach, the approach was "stable" as well as "safe."

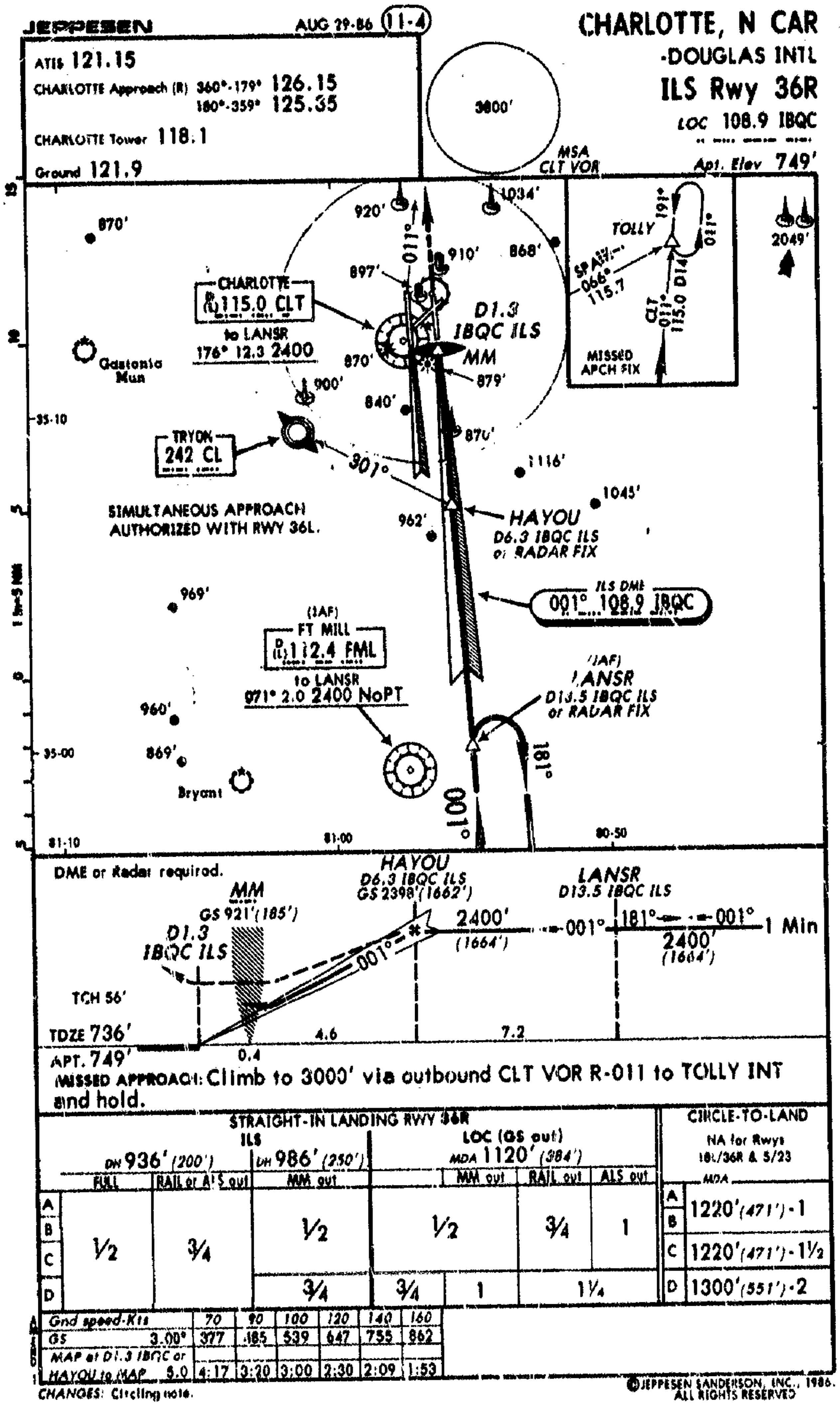

Figure 1.—ILS Approach to runway 36R—Charlotte Douglas International Airport.
(Reprinted by permission of Jeppesen- Sanderson, Inc.
Not to be used for navigation.)

The first officer confirmed that, although Piedmont procedures require that the airplane be configured for landing at the final approach fix, "it goes without saying that this wasn't the way it was done . . ." on PI 467. (See appendix D.)

According to witnesses, PI 467 touched down at a point over 3,000 feet from the approach end of the runway. One witness, a ramp service agent, placed the touchdown across a light from a prominent sign on the airport at a point about 3,100 feet from the threshold. The local controller stated that the touchdown occurred near the D3 intersection on the runway, also about 3,000 feet from the approach end.

The captain told Safety Board investigators that following touchdown:

> "I had my hands on the throttles. There's a detent. I cracked the thrust reversers to the detent to open them. As I did that, the speed brake had not deployed automatically. I manually deployed the speed brake, went directly back to the thrust reversers, and . . . I did not get full reverse . . . I applied the brakes immediately after I deployed the speed brake . . . And when the wheel brakes were applied, there was no sensation of stopping, not a sensation of antiskid, a cycle, there was nothing. And I was still trying to pull full reverse . . . I didn't get full reverse . . . (and) without full reverse, I lost high air speeds where they're most effective and that's where I lost most of my stopping (capability)."

The captain also stated that after landing, he pushed the control column forward, although he did not indicate the extent of the pressure applied. The captain added that, since it appeared to him that the antiskid system was not operating properly, he released the brakes in order to get wheel spin up, which would then activate the antiskid system. He was aware that Piedmont procedures required that steady pressure be applied to the brakes in order for the antiskid system to be effective. He stated that nevertheless: "I released the brakes after what I thought was an adequate time and reapplied the brakes, and any pumping situation might have been my nervousness on the brake pedals . . . "

After touchdown, the airplane continued its rollout and, at 2007:43 the first officer said, "We're gonna get the lights on the overrun." Two seconds later, the airplane struck the localizer antenna array for runway 36R, located about 300 feet from the departure end of the runway; struck a concrete culvert used for drainage, located 18 feet from the localizer; and continued through a chain link fence. It traveled about 440 feet beyond the departure end of runway 36R and came to rest upon the edge of the Norfolk Southern Railroad tracks, which were perpendicular to the runway. (See figures 2 and 3.)

The accident occurred during darkness at 35°12'37" north latitude and 80°56'37" west longitude.

The flight attendants initiated an emergency evacuation immediately. Damage to the forward electronics equipment compartment, sustained during the impact sequence, made the public address system inoperable. As a result, no communication was possible from the flightcrew regarding evacuation. Flight attendants shouted evacuation instructions to the passengers. The flight attendants described the evacuation as orderly. Passengers exited the airplane within 1 1/2 minutes.

Passengers and flight attendants generally described the flight as routine until touchdown. Several passengers stated that they believed the airplane landed "fast," and then accelerated slightly. Most did not recall sensing deceleration however, several

Figure 2.—Concrete culvert area and rear view of airplane.

Figure 3.—Left side of airplane nose against railroad track.

passengers reported that some time after touchdown they heard engine sounds characteristic of reverse thrust. They then felt what one passenger described as a "terrific" bump, followed by several strong bumps, after which the airplane came to a stop. None of the passengers who were seated over the wings and who were looking out during the approach and landing observed wing structure movement characteristic of ground spoiler deployment.

The flight attendants' descriptions of the accident were similar to those of the passengers. They sensed no deceleration until the bumps were felt. They believed that maximum reverse thrust was employed as the airplane left the runway.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others	Total
Fatal	0	0	0	0
Serious	0	3	0	3
Minor	3	28	0	31
None	2	83	0	85
Total	5	114	0	119

1.3 Damage to Aircraft

The airplane was destroyed by the accident. Its value was placed at $5 million.

1.4 Other Damage

The localizer antenna array located beyond the departure end of runway 36R was destroyed.

1.5 Personnel Information

The flightcrew consisted of a captain, a first officer, and three flight attendants. All were properly certificated and met the requirements for a flight conducted under 14 CFR 121. Both pilots had been off duty at least 3 days before the accident, and each described himself as well-rested. (See appendix E.)

Before joining Piedmont on May 1, 1980, the captain had flown with the U.S. Air Force, becoming an aircraft commander on the C-141 transport. He flew the YS-11 and B-737 as a first officer with Piedmont. In April 1984, he upgraded to captain on the F-28, and in September 1985, he transitioned to captain on the B-737. At the time of the accident, he had accrued about 10,000 total flight hours, about 2,500 of which were in the B-737 with about 500 hours of those as captain.

Before joining Piedmont on June 21, 1984, the first officer had served as a first officer in Fairchild Metroliner and C-402 airplanes in scheduled 14 CFR 135 commuter type operations, as well as first officer in DC-6, DC-7, and CE-500 airplanes. He had flown as a second officer with Piedmont on the B-727 for about 13 months before he upgraded to the position of first officer on the B-737 in August 1985. He had accrued about 4,100 flight hours at the time of the accident, including about 500 hours in the B-737.

Both the captain and the first officer stated that before the accident each had flown into Charlotte, a major hub for the airline, on "numerous" occasions.

1.6 Aircraft Information

1.6.1 General Airplane Information

The airplane, serial No. 19073, a Boeing 737-222, was manufactured on November 11, 1968, by the Boeing Commercial Airplane Company. It was operated by United Airlines from that time until June 1973. It was placed into service and continuously operated by Piedmont since July 31, 1973. (See appendix F.)

The takeoff weight of the airplane was 103,812 pounds and its center of gravity (CG) was 21 percent mean aerodynamic chord (MAC). Both were within acceptable limits throughout the flight. The estimated landing weight of the airplane was 95,112 pounds and the CG was about 20 percent MAC. The maximum allowable landing weight for a B-737 landing on runway 36R at CLT, under wet or slippery conditions, was 98,000 pounds.

The airplane's maintenance records were reviewed for the period from January 1, 1986 to October 15, 1986. The last service check was completed on the day of the accident, and an A check was completed on October 22, 1986. A discrepancy concerning excessive stiffness in the thrust reverser levers was recorded on October 2, 1986; it was corrected by lubricating the thrust reverser cables and control mechanism.

1.6.2 Airplane Systems

The Boeing 737-222 is equipped with several logic systems designed to prevent deployment of engine thrust reversers and ground spoilers in flight, touchdown with wheel brakes applied, and wheel skid during braking. The logic systems receive data that indicate that the airplane is on the ground when the strut is compressed 5 inches or more, or that it is in the air when the strut is within 1/2 inch of full extension. This signal is supplied from an air/ground safety sensor which is mounted in the right main landing gear wheel well. It is activated by a push/pull cable connected to the oleo strut which also actuates a hydraulic system interconnect valve in the ground spoiler system. At a strut compression between 1 1/2 inches and 3 inches, the hydraulic system interconnect valve provides hydraulic pressure to the ground spoiler actuators.

To deploy the thrust reverser deflectors, the landing gear selector must be in the "Gear Down" position. In addition, the right main gear strut must be compressed at least 5 inches and at least one engine must be operating. If these conditions are met, the appropriate movement of the reverse thrust levers on the throttle will result in deployment of thrust reverser deflectors. An interlock is also provided which prevents movement of the thrust levers beyond idle reverse until full deployment of the deflectors is achieved.

Rapid deployment of the ground spoilers following touchdown is critical since they "spoil" or reduce up to 70 percent of the lift generated by the wings, as well as increase drag. The loss of lift transfers airplane weight to the wheels, which compresses the struts and permits brake and antiskid system operation on the inboard wheels.

On the Boeing 737, the spoilers are composed of eight spoiler panels, four on each wing. (See figure 4.) The outboard and inboard panels on each wing can only be activated on the ground to a maximum deflection of 40° and 60° up, respectively. The

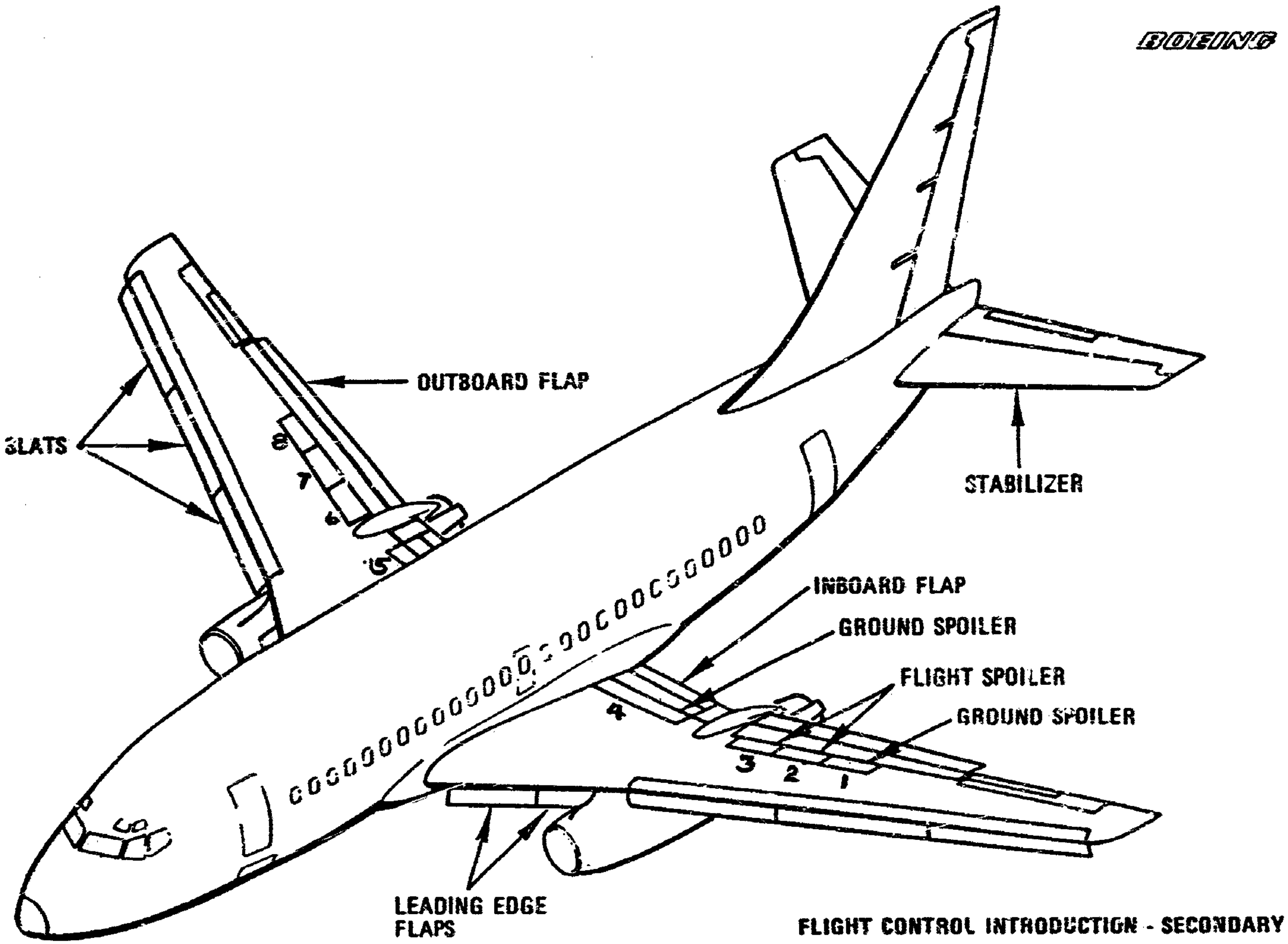

Figure 4.—Boeing 737-222.

two center panels of each wing also can be used in flight as speed brakes where the panels can be deflected to a maximum of 40°. These panels are used also in conjunction with the ailerons, when the airplane is airborne, for lateral control.

The spoilers can be deployed automatically or manually after landing. With the speed brake lever in the "Armed" position before touchdown, the ground spoilers will deploy automatically if an antiskid switch is on and if a combination of two left wheels, two right wheels, or both inboard or outboard wheels are rotating approximately 60 knots and both thrust levers are at idle. With these conditions met, an electric actuator will drive the speed brake lever to the UP position. The ground spoilers will then deploy when the right main gear strut is compressed between 1 1/2 and 3 inches. The Boeing Commercial Airplane Company determined that a load of about 5,250 and 9,125 pounds on the right main gear strut is needed to compress the strut 1 1/2 and 3 inches, respectively.

Pilots can manually deploy the spoilers following touchdown by moving the speed brake lever aft to the "Up" position. When that occurs, flight spoilers will extend in proportion to the lever position and ground spoilers will extend, provided the right main gear strut has been compressed between 1 1/2 and 3 inches. The speed brake lever electric actuator, which powers the speed brake lever, will follow the lever when the "armed" detent is passed, with the power levers at or near idle and a speed of 60 knots or more is achieved on any combination of two main gear wheels. The spoilers on the B-737 retract when the lever is moved to the "Down" detent at any time. However, N75‿N was modified in accordance with a Boeing service bulletin which prevented the speed brake lever actuator from being driven to the "Down" detent until either power lever is advanced beyond idle or the No. 3 Speed Brake Test Switch is moved to the "Test" position.

The antiskid system automatically modulates hydraulic pressure to the individual wheel brakes of the two right and two left main gear wheels to prevent wheel skidding and thereby, increases effectiveness on wet or slippery runways, when skidding potential is increased. The antiskid system also provides touchdown protection to the inboard wheels by preventing brake application at touchdown. Thus, brake actuation can only occur after right main gear strut compression occurs, signaling ground contact by the air/ground safety sensor. For maximum effectiveness of the antiskid system, the pilot must apply constant pressure on the brake pedals. (See appendix D.)

The system provides locked wheel protection after landing to each wheel. It is disarmed at wheel speeds below 12 mph and rearmed and applied to both wheels of each pair of main gear wheels (outboard-to-outboard and inboard-to-inboard) when either paired wheel spins up to at least 30 mph. In this mode, if rotation speed on one paired wheel drops below 10 mph while the other is above 30 mph, brake pressure on the slower wheel will be completely released.

The antiskid system receives wheel speed signals from sensors on each wheel. It measures and compares these signals and provides an electrical signal to brake control valves on each wheel brake to modulate hydraulic pressure to the brakes. This portion of the antiskid system remains effective for each main gear wheel so long as a wheel rotation-speed signal of more than 12 mph is sensed by the speed sensor in that wheel. A rapid (approximately 0.45 second or less) 8 mph decrease in wheel rotation-speed will cause the antiskid control to provide a signal to the brake control valve of that wheel. This will release the applied brake pressure which will remain released until the speed sensor output again increases and the signal is terminated. At the same time, the skid detector also provides a signal to the modulator, which causes a limiting signal to the brake control valve, which reduces the applied brake pressure to below the pressure which caused the initial wheel skid. This limit signal then slowly decreases, which increases braking pressure until another skid occurs, at which time the cycle is repeated.

Release of brake pedal pressure also results in release of the antiskid features, which will be reactivated only when brake pressure is reapplied. Since the system requires time to match the wheel speeds, releasing and reapplying the brakes will prolong the time required for the antiskid to increase braking effectiveness. The time required for the antiskid system to function varies according to the amount of ground friction. On a runway with a low coefficient of friction of 0.10, the antiskid will activate in 0.4 second. By contrast, on a runway with a coefficient of friction of 0.50, 4.5 seconds will be needed to reactivate the antiskid system.

The GPWS will alert when one of the following conditions is met: excessive rate of descent below 2,450 feet above ground level (agl), excessive closure rate with terrain below 1,800 feet agl, altitude loss after takeoff before reaching 700 feet agl, insufficient terrain clearance and not in a landing configuration below 500 feet agl, and excessive deviation below the glideslope below 1,000 feet agl.

1.7 Meteorological Information

The following surface observations were made by the National Weather Service (NWS) at its facility located about 4,100 feet north of the approach end of runway 36R at CLT.

> 1950 Record: Measured ceiling—500 feet overcast; visibility—1/2 mile; moderate rain, fog; temperature—60° F; dewpoint—59° F; wind—60° at 10 knots; altimeter setting—30.03 inHg.
>
> 2002-Special: Measured ceiling—400 feet overcast; visibility—2 miles; light rain, fog; wind—060° at 8 knots; altimeter setting—30.03 inHg; ceiling ragged.
>
> 2011-Local: Measured ceiling—400 feet overcast; visibility—2 miles; light rain, fog; wind—090° at 8 knots; temperature and dewpoint—60° F; altimeter setting—30.03 inHg; ceiling ragged; aircraft mishap.

On October 25, 1987, the NWS measured 0.67 inch of rainfall at CLT between 0745 and 1945. An additional 0.08 inch of rain fell between 1945 and 2015, as recorded by airport rain gauges. The NWS tipping rain gauge measured 0.02 inch of rail between 2006 and 2008. Federal Meteorological Handbook No. 1 classifies an hourly rainfall rate of less than 0.1 inch as light. Similarly, a rainfall rate of between 0.11 and 0.3 is classified as moderate and a rate over 0.3 inch per hour is classified as heavy.

The CLT wind gust recorder measured the wind velocity at 8 knots at 1955, 2000, and 2010. The maximum wind velocity, 12 knots, was recorded at 1957.

Piedmont flight 565, a Boeing 737-300 equipped with an inertial reference system 2/, landed on runway 36L about 2010. The captain of the flight informed Safety Board investigators that he had noted the wind was 222° at 38 knots over the

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2/ A system using ring laser gyros and an internal computer, which, with other systems, provides precise, real-time navigational information, as well as information on wind direction and speed.

outer marker. He stated that while descending to 500 feet agl the wind direction had changed to 200°, 180°, and 1[illegible] At 500 feet agl, the wind was 090° at 12 knots.

The NWS-CLT terminal forecast in effect at the time of the accident indicated a ceiling of 600 feet overcast; visibility—1 mile; light rain, fog; wind—080° at 8 knots; occasional ceiling 300 feet overcast; visibility—1/2 mile; light rain; fog.

To obtain an estimate of the winds that PI 467 encountered while on final approach, the Safety Board compared air speed data from the airplane with ground speed data from the CLT air traffic control radar. The results indicate that when at 2,400 feet msl, the flight encountered an approximate 30-knot tailwind at HAYOU, the final approach fix. There was almost no longitudinal wind as the flight descended through 1,900 feet msl. PI 467 encountered a 10-knot tailwind as it descended from 1,500 feet msl to 1,400 feet msl. From 1,300 feet msl to touchdown, the longitudinal wind was about zero.

At 1957:17, a pilot of a Boeing 727 that had just landed on runway 36R reported to the ground controller that his antiskid had just cycled twice. The controller, who was not a pilot, did not understand the meaning of the report and did not communicate the information to other controllers or pilots. The Airman's Information Manual advises pilots, when making braking action reports to air traffic control, to characterize the quality of the braking action as good, fair, poor, or nil. Federal Aviation Administration (FAA) air traffic control procedures require controllers to broadcast that "braking action advisories are in effect" when they receive a report that braking action is either poor or nil.

1.8 Aids to Navigation

Runway 36R at CLT is served by an ILS system. (See figure 1.) All navigation aids used in the ILS approach, except for the localizer, were found to be operational after the accident. An FAA flight check of the glide slope following the accident indicated that the glide slope was operating within prescribed tolerances. The localizer could not be flight checked since it was destroyed in the accident; however, no problems with the localizer were reported by the flightcrews who landed on the runway before PI 467.

1.9 Communications

There were no known communications difficulties at the time of the accident.

1.10 Aerodrome Information

Charlotte Douglas International Airport is located 4.3 miles west of the city of Charlotte, North Carolina. The airport elevation is 749 feet msl. It consists of three runways, 36R/18L, 36L/18R, and 5/23, all of which are hard surfaced. ILS approach aids were available to runways 5, 18R, 36L, and 36R. In addition, distance measuring equipment (DME) was available for the ILS approach to runway 36R. Runway 5/23 was 7,501 x 150 feet, runway 36L/18R was 10,000 x 150 feet, and runway 36R/18L was 7,845 x 150 feet. Runway 18L had a displaced landing threshold located 635 feet south of the approach end of the runway. Runway 36R/18L was grooved and equipped with a medium intensity approach light system with runway alignment indicator lights (MALSR) and centerline lighting. The runway was partly reconstructed in 1983 to strengthen it for an expected increase in jet transport traffic. This included adding layers of asphaltic concrete to the runway and grooving its entire length. (See Section 1.16.1, Runway Condition, for additional information.)

The airport was a fully certificated airport under the provisions of 14 CFR 139 and an Index C, crash, fire, and rescue (CFR) facility. 3/ The FAA inspected the airport in July 1986. No discrepancies regarding the condition of runway 36R were reported.

1.11 Flight Recorders

The aircraft was equipped with a Fairchild digital flight recorder (DFR), model F800, serial No. 194; and a Fairchild cockpit voice recorder (CVR), model A-100, serial No. 50202. Following the accident, both recorders were retrieved from the aircraft and read out. The DFR, which digitally records airspeed, heading, vertical acceleration, altitude and microphone actuation, was read out at the manufacturer's facility. The CVR was read out at the Safety Board's laboratory in its Washington headquarters.

The vertical acceleration trace on the DFR showed a constant 1.2 G reading when the airplane was in level flight where there would be no discernable vertical acceleration. For airplane performance evaluations, 0.2 G was subtracted from the recorded value.

An examination of DFR altitude and airspeed data indicated that the values were not consistent with other known information about the flight, as well as data predicted from B-737-222 operating information for this flight and flights that preceded it. For example, the airport touchdown zone elevation indicated on the DFR was 1,116 feet, over 470 feet higher than the known elevation.

To determine the source of the error, the Safety Board performed a variety of checks of the recorder and its own independent pitot-static system. Potential error sources were ruled out except for the effects of moisture in the portion of the pitot-static system that had been damaged in the accident.

The Safety Board then applied corrections to the airspeed data by applying the known static pressure value that existed during the landing roll. The corrected airspeed values were consistent with known values obtained from flightcrew statements and information on the CVR transcript. Similarly, a correction was applied to airspeed data obtained during the airborne portion of the flight. The static pressure corrections were based on a comparison of altitude data obtained from the DFR with known altitude information from the CLT air traffic control radar.

1.12 Wreckage and Impact Information

The airplane wreckage was confined to the area between the localizer antenna array, located north of the departure end of runway 36R, and the railroad tracks. Most of the damage to the airplane occurred to its underside, resulting mostly from contact with the concrete culvert located beyond the runway. (See figures 5 and 6.)

The lower forward fuselage, from the nose aft to about 5 feet behind the forward exit, was destroyed. The remainder of the lower fuselage, aft to the wing root

3/ 14 CFR 139.49 requires, for scheduled air carrier service with aircraft between 127 and 160 feet long, that at a minimum, the following equipment be maintained at the airport: one lightweight vehicle providing at least 500 pounds of dry chemical extinguishing agents or 450 pounds of dry chemical and 50 gallons of water for aqueous film-forming foam (AFFF) production, and two self-propelled fire extinguishing vehicles.

Figure 5.—Underside of forward fuselage.

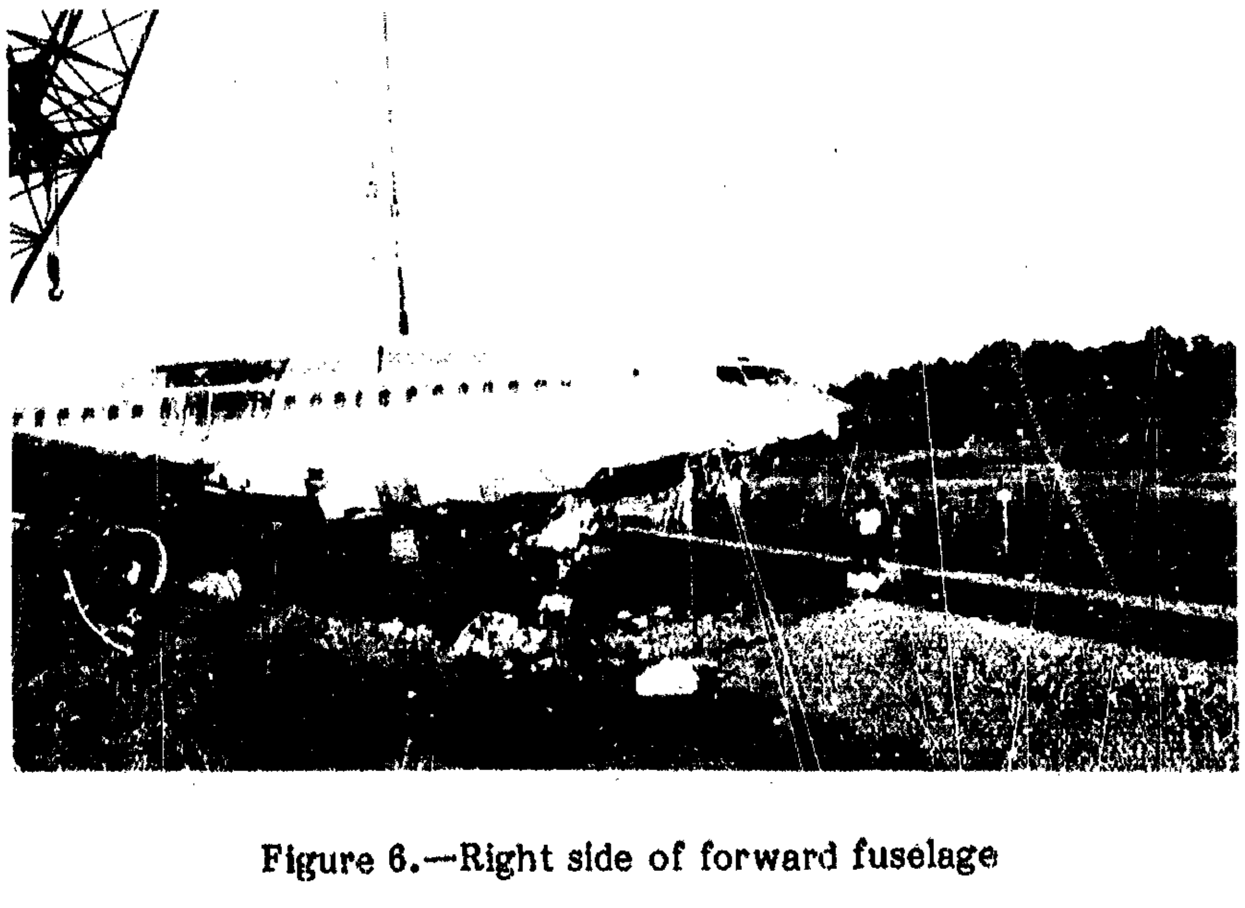

Figure 6.—Right side of forward fuselage

trailing edges, suffered decreasing degrees of damage. The keel beam was fractured aft of the wing center, and there was compression buckling of the fuselage skin forward of the aft exit. The empennage was undamaged.

There was minor impact damage to both wings. The leading and trailing edge devices of both wings, which also showed minor damage, were configured similarly; the leading edge slats were extended and the flaps were extended 30°. The spoiler panels on both wings were retracted.

The three landing gear assemblies were separated from the fuselage. The left main gear assembly was displaced aft of the wheel well and the trunnion attachments had been pulled from their fittings. The nose gear assembly and most of its support structure came to rest beneath the airplane near the forward baggage compartment. The right main gear was displaced aft and outboard.

The wear indicators on all four brake assemblies appeared normal. There was extensive separation of hydraulic lines in the right and left main landing gear well areas. The anti-skid system was removed from the aircraft and examined at the manufacturer's facility. No preexisting damage was noted.

The four main landing gear tires were H40 x 14.5-19 tires manufactured by the Goodyear Aerospace Corporation. The Nos. 1 and 2 tires were new when installed and the Nos. 3 and 4 tires had been recapped. Examination of the tires revealed that the Nos. 1, 2, and 3 tires had deflated; the pressure in the No. 4 tire was 164 psi. The tread depth on all tires was about equal at 10/32-inch.

Small areas of reverted rubber 4/ were found on the four main gear tires. The area on the left outboard tire was elliptical in shape and measured 4 x 7 inches. A semicircular area on the left inboard tire measured about 6 x 9 inches. The right inboard tire contained a teardrop-shaped reverted rubber area, which measured 10 inches and 3 1/2 inches in the widest and narrowest points, respectively. The area on the right outboard tire was elliptically shaped and measured 6 x 10 inches.

Examination of the surface of runway 36R revealed pieces of reverted rubber about 2,200 feet from the threshold. These pieces were tested for comparison with the material in the No. 2 tire and found to be not similar. The surface of about the last 200 feet of the runway contained several intermittent, white streaks that were approximately equal to the width of PI 467's main gear tires. About the last 100 feet of the runway contained four distinctive white streaks that were aligned with the depressions in the overrun made by PI 467's four main gear tires.

The extensive damage to the lower forward fuselage of the aircraft precluded an accurate assessment of the integrity of the flight control cables. However, the positions of cockpit controls matched the control surface positions on the wing and tail surfaces. The elevator and aileron trim tab settings were in the neutral positions. The spoilers were in the stowed or retracted positions. The spoiler handle which could be moved slightly, was in the down or stowed detent. The horizontal stabilizer was turned 6° nose up.

4/ Reverted rubber is indicative of the absence of wheel rotation on a wet surface. As a result, friction heat between the tire and the runway surface generates steam. The steam pressure lifts the tire off the runway surface while the heat causes the rubber to "revert" to its original state. (See appendix G.)

The thrust reversers of both engines were fully deployed. The forward mount of the No. 1 engine was attached; however, the aft mount was broken. A substantial amount of grass and weeds had been ingested into the engine. In addition, several fan blades were twisted and curled opposite the direction of rotation. The last stages of the turbine appeared undamaged.

The No. 2 engine was separated from its mounts and was found resting about 3 feet outboard of its normally installed position. A substantial amount of dirt, rocks, and grass had been ingested into the engine. The fan and compressor were damaged but there was no gross blade distortion. The inlet guide vanes exhibited moderate damage; however, the last stages of the turbine appeared intact.

1.13 Medical and Pathological Information

Thirty-three passengers, the 2 flightcrew members, and 2 of the 3 flight attendants were examined at local hospitals following the accident. Two of these passengers and one of the flight attendants did not sustain injuries. Of the 28 passengers who received minor injuries, 27 were treated for contusions to the head and contusions and sprains of the upper and lower extremities; all 27 were treated and released the same day. One passenger, a 77-year-old female, suffered a back sprain and remained in the hospital for 5 days. According to the hospital, she was admitted for observation primarily because of her advanced age, not because of her injuries. The flightcrew and one flight attendant were treated for minor sprains and were released the same day, following treatment.

Three passengers who received serious injuries were admitted to a local hospital. Two of the passengers suffered compression fractures of vertebrae and remained in the hospital 2 days after the accident. One passenger was treated for aggravation of a previous spinal injury and was released the next day. Two of the minor injuries were evacuation-related.

Eighty-one passengers and 1 flight attendant were not examined and were considered to have been uninjured.

1.14 Fire

No fire erupted as a result of the accident. A small amount of fuel flowed to the ground from the fuel line to the separated No. 2 engine. However, the fuel collected in a puddle of water which had accumulated from the day's rainfall.

1.15 Survival Aspects

Most of the damage to the interior of the airplane resulted from floor damage in the front of the airplane rearward to approximately 11 feet aft of the forward entry door. The front row, triple-passenger seat on the right side was completely detached from the floor. The corresponding seat on the left side and both triple-passenger seats in the second row were partially detached. Seat tracks in the forward part of the cabin were deformed as much as 11° from the floor damage. The fittings that attach the forward flight attendant's seat to the seat pan failed, and as a result, the seat was able to be rotated to the floor. The seat fittings were examined at the Safety Board's metallurgical laboratory in Washington. The examination revealed that the fittings contained fatigue areas that penetrated about .07 inch, representing about 5 percent of the cross-sectional areas. The remaining portions of the fractures exhibited typical bending overstress characteristics. The remainder of the cabin was relatively undamaged.

According to passengers and the flight attendants the evacuation was orderly and completed in about 1 1/2 minutes. The cabin emergency lighting functioned properly. The flight attendants recognized that an evacuation would be necessary. They notified the flightcrew by the bell evacuation signal that they were initiating an evacuation. The three flight attendants remained at their assigned exits. The right rear exit was not used in the evacuation since the flight attendants had observed most of the passengers exiting through the front. However, the remaining three exits were used in the evacuation.

Passengers seated adjacent to the two overwing exits opened them and exited the airplane. One elderly passenger needed assistance in evacuating the airplane. The flight attendants said that the evacuation might have been accomplished in less than 1 1/2 minutes had this passenger not required assistance. Several passengers commented that two passengers who appeared to be intoxicated required additional efforts over what was generally required in the evacuation. They had slept through the accident and were sleeping through the evacuation when some passengers physically shook them to wake them up. The flightcrew exited the airplane through the cockpit windows.

The CLT ground controller initiated the emergency response when he noted that the airplane would most likely be unable to stop on the runway. Nine airport firefighters in four vehicles responded to the emergency. At 2009:48, the captain on the lead CFR vehicle, who also noted that the airplane probably would be unable to stop, initiated a preplanned, mutual assistance response by informing the Charlotte Fire Department (CFD) dispatcher of the accident. The CFD dispatcher, according to the mutual assistance plan, informed fire, police, ambulance, hospitals, and fire department personnel from the city of Charlotte and surrounding Mecklenburg County, of the accident. An additional 10 rescue units, including 7 pieces of firefighting equipment, a mobile command post, 1 rescue unit, and 1 foam applicator were dispatched to the site. Aqueous film-forming foam was applied almost immediately after the arrival of the foam applicator.

The CFD dispatcher was unaware of the number of people on board PI 467 and was unsure of the proper number of ambulances to dispatch to the site. Three ambulances were dispatched immediately and arrived at the site within 15 minutes of the accident. A fourth, which was dispatched 42 minutes after the accident, arrived on scene 15 minutes later. Additionally, several rescue and transport units, which were sent to the site from neighboring localities, provided on-scene treatment and hospital transport to the injured.

The Norfolk Southern Railway System, which owned the tracks near runway 36R/18L, informed the Safety Board that 14 freight and 2 passenger trains operated daily on the tracks. Although they were not on the notification list used in the mutual assistance plan, 7 minutes after the accident an airport firefighter asked the CFD dispatcher to inform the railroad of the accident. One minute later, the railroad was notified and asked to keep the tracks clear of trains until the evacuation was completed. They immediately complied with the request.

1.16 Tests and Research

On the nights of October 28 and 29, a variety of assessments were made of the overall quality of runway 36R/18L. These included examining the runway surface for deviations from acceptable standards, flooding segments to measure standing water depths, and assessing runway friction using two independent measuring devices. (See appendix H.)

1.16.1 Runway Condition

At the request of the Safety Board, the FAA provided a survey team to evaluate the physical characteristics of runway 36R/18L and to conduct measurements of runway surface friction under dry and wet conditions. The evaluation and measurements were conducted over a 2-night period, beginning on October 28, 1986.

According to the survey team, the pavement of the first one-third of runway 36R was within FAA-recommended standards except for heavy deposits of rubber in the touchdown zone. The last two-thirds of the runway exhibited variances from the recommended transverse slope of 1.5 percent; the slopes ranged from 0.5 to 1.05 percent. There were longitudinal depressions about 12 1/2 feet on either side of the runway centerline for nearly the full length of the runway. The depressions were 1/8- to 3/8-inch deep and were 10 to 40 inches wide. The transverse grooves in the depressions were filled with asphalt. Water was sprayed over three portions of the runway and allowed to stabilize. The measured depths of the pooled water on the longitudinal depressions ranged from 0.09 to 0.18 inch and the widths ranged from 12 to 18 inches. The depths of the runway surface texture ranged from 0.0039 to 0.0095 inch. The recommended depth is 0.025 inch. The last 1,940 feet of runway 36R had three ungrooved asphalt patches near or straddling the runway centerline which totalled 487 feet of runway length. There were no significant rubber deposits in the touchdown zone of runway 18L.

Examination of the runway after a heavy rain disclosed the accumulation of water in the longitudinal depressions. Also, due to shallow transverse slopes in the last 1,000 feet, the water tended to spread from the depressions toward the center of the runway, particularly in the last 500 feet.

1.16.2 Runway Friction

Two independent devices were used to measure runway friction, the Mark IV Mu Meter and the M6800 Runway Friction Tester. Both were operated 12 1/2 and 30 feet of each side of the runway centerline, beginning 268 feet north of the runway threshold and ending 284 feet south of the runway departure end. The tests were conducted at speeds of 40 and 60 mph, using the self-contained water systems of each device to wet the surface and a separate water tanker to flood selected runway portions. In addition, the Mu Meter measured friction on dry pavement.

The measurements from each device indicated that the major portion of the runway met FAA standards for adequate friction. The Mu values 5/ averaged from 56 to 78. However, there were two runway areas where the Mu values were lower and the friction unacceptable: the runway touchdown area where rubber deposits reduced the pavement friction quality and the final 1,500 feet of the runway. The lower Mu values were attributed to a lack of grooving in some areas and the flat transverse slopes.

5/ Runway friction is expressed as a value of Mu, ranging from 0 to 100, or low to high friction. AC 150/5320-12A states: "When the averaged Mu value on the wet runway pavement surface is less than 50 but above 40 for a distance of 500 feet, and the adjacent 500 feet segments are above 50, no corrective action is required." Thus, values above 50 indicate acceptable friction.

The Charlotte Airport Authority was made aware of the runway 36R variance from recommended standards. It reported the deficiencies to the FAA which issue a Notice to Airmen (NOTAM) describing the deficiencies in the runway. The Airport Authority also hired contractors to repair the runway deficiencies. The repairs were scheduled to be completed in October 1987.

1.17 Other Information

1.17.1 Piedmont Procedures

According to Piedmont's B-737 Operations manual, the aircraft's airspeed and flaps are to be set at the following points along the "normal" ILS pattern: on initial entry, airspeed at 210 knots; on base, flaps at position 1 and airspeed at 190 knots; before the turn to final, flaps at position 5 and airspeed at 170 knots; and after intercepting the localizer, landing gear lowered, flaps at position 15 and airspeed at 150. Just before passing the locator at the outer marker (LOM) 6/ or final approach fix (HAYOU in the ILS approach to runway 36R), the final flap setting of position 30 or 40 is selected and the airspeed of about 140 knots is established. (See appendix D.)

Piedmont's manager of Boeing flight training said that he did not believe, insofar as the normal ILS pattern was portrayed, that every approach was to be flown as portrayed in the operations manual. "There are," he stated, "just with an ATC instruction to hold 180 knots to the outer marker; [examples which] if we were to hold every pilot to this, we would have to not accept hold instructions of those kinds."

The principal operations inspector (POI) assigned to Piedmont stated that the FAA considers adherence to the aircraft configuration and airspeeds depicted in appendix D to be acceptable performance in flying ILS approaches in training settings. "Line flying," he added, ". . . [may] possibly [be] modified as required by ATC or whatever variable may come into play, but we'll rest then upon the pilot's good judgment to carry the approach out or not carry the approach out."

The POI stated that, had he been riding on the cockpit observer's seat on PI 467, despite the fact that FAA inspectors normally would be hesitant to speak up "until safety becomes a direct factor," he would have "strongly suggested that the pilot consider a missed approach long before this approach was completed" due, he said, to "the airspeed and the glideslope maintenance." He added that, in his opinion, the approach flown by PI 467 was not a stable approach.

The operations manual, also states that: "The recommended approach speed wind correction is 1/2 the steady headwind component plus all of the gust value, based on tower reported winds. The maximum wind correction should not normally exceed 20 knots. In all cases, the gust correction should be maintained to touchdown while the steady wind correction should be bled off as the aircraft approaches touchdown." (See appendix D.)

Pilots not flying the airplane, the first officer on PI 467, are required by the operations manual to use standard call outs, "including any significant deviation especially when less than 500 feet above field elevation. Call out significant deviations from programmed airspeed, descent rate and instrument indications." These include:

6/ The LOM is comparable to the final approach fix in the ILS runway 36R approach to CLT.

Airspeed below Vref or 10 knots above intended approach speed.

If rate of descent exceeds 800 FPM (feet per minute).

Localizer displaced more than 1/3 dot. Glideslope displacement greater than 1 dot.

During instrument approaches in instrument meteorological conditions, pilots are required to perform a missed approach when one of the following conditions is met:

A radio or flight instrument failure occurs below 500 feet agl.

The localizer and/or the glide slope show full deflection, below 500 feet agl when conducting an ILS approach.

When there is a significant disagreement among the instrument readings.

The POI said that, "While nowhere in (the operations manual) does it say specifically that the captain, assuming he's flying the approach, will name an airspeed and then verbally say to the first officer, 'This is the target speed and Vref is 130 knots. I will fly this approach at 150 knots,' it does not detail that here. I guess my assumption has been through the years . . . that that was implied. However, it is not spelled out per se."

During the final approach, Piedmont procedures require the pilot flying to arm the speedbrake and check that the speedbrake armed (green) light is illuminated. The pilot not flying is then required to check the recall system or system annunciator panel.

On a wet or slippery runway, the operations manual directs pilots to aim for a touchdown 1,000 feet from the approach end of the runway. After touchdown, the pilot flying is required to: "check that the speedbrakes deploy immediately after main gear touchdown, if they do not deploy automatically they are to be deployed manually; immediately lower the nose . . . immediately select reverse thrust, (and) . . . smoothly apply moderate-to-firm, steady breaking (sic) until a safe stop is assured."

The operations manual advises that ground spoiler deployment is critical since the ground spoilers will spoil or eliminate about 70 percent of the lift above the wings. Further, the manual states: "Do not modulate the brake pedals during brake application, but keep a steadily increasing pressure applied allowing the antiskid system to function at its optimum."

Piedmont distributes to all flightcrew members, on a bimonthly basis, the publication "Operations Update," which, while not required reading, was described by a Piedmont official as the most popular airline publication among Piedmont flightcrews and therefore, widely read by them. It contains information about the company and general operational and specific information on each aircraft type in its fleet. Five months before the accident, the April/May 1986 issue contained information on a previous runway overrun accident. (See appendix G.) The article cites three factors that contributed to the accident, including a touchdown considerably beyond the runway threshold and an airspeed that was excessive for conditions. The article states that the combination of factors "resulted in the accident."

In addition, the article discusses hydroplaning and lists procedures to minimize the possibility of hydroplaning. The article advised that the "strict adherence to established operating procedures relative to approach and landing . . . are important courses to follow."

1.17.2 Aircraft Performance

The Safety Board compared parameters of the approach and touchdown of PI 467 with corresponding parameters of three preceding flights and one subsequent flight into CLT. In addition, several performance characteristics of PI 467 during its entry into the CLT airspace and subsequent touchdown and rollout on runway 36R were examined.

The flights that preceded PI 467 to runway 36R, the type of airplane, the estimated maximum weights, and landing times, are presented below:

PI Flight No.	Airplane	Estimated Maximum Weight (lbs)	Approximate Landing Time
73	B727-200	150,000	1956
105	B727-200	154,500	2000
579	B737-300	114,000	2002
309	B737-200	98,000	2005

Radar data obtained from CLT air traffic control indicate that the groundspeeds of these flights at the final approach fix and at 500 feet agl, respectively, were: PI 73, 191 and 145 knots; PI 105, 156 and 141 knots; PI 579, 179 and 141 knots; PI 309, 181 and 158 knots; and PI 467, 214 and 170 knots. At those ground speeds PI 467 would have required a descent rate of 1,135 ft./min. to intercept the glide slope at HAYOU. To maintain the glide slope at 500 feet agl, PI 467 would have needed a descent rate of about 900 ft./min. Recorded radar data indicated that PI 467 averaged a descent rate of 990 ft./min. during the 16 seconds before touchdown. The Piedmont recommended descent rates, at those points in the approach, were 750 ft./min. and 720 ft./min., respectively.

The Safety Board examined the DFRs of PI 579 and PI 105 to determine the distances required by those aircraft following touchdown to stop on runway 36R. PI 579 stopped in 3,450 feet and PI 105 stopped in 2,895 feet.

Following the accident, the Safety Board attempted to replicate the landing and rollout of PI 467 using a Phase II, Boeing 737, simulator at Piedmont's training center in Winston-Salem, North Carolina. The environmental conditions and airplane weight, speeds, configuration, and touchdown point on the runway were matched to known variables corresponding to PI 467. Runway friction was set at wet-ice. The obtained stopping distance approximated that of PI 467 when full wheel braking was applied and reverse thrust was used, but without the ground spoilers deployed. With ground spoiler deployment the stopping distance was within the available runway whether brakes only or reverse thrust only, was used.

The Boeing Commercial Airplane Company calculated the stopping distance capabilities of a Boeing 737 on a wet, grooved runway with the weight, configuration, and speeds similar to those experienced by PI 467. The calculated stopping distances were 2,200 feet with spoilers deployed and reverse thrust and 3,480 feet with reverse thrust but without any spoilers deployed. The calculations included an approximate 3-second delay in developing reverse thrust from thrust reverser lever activation.

The Boeing Company also provided data on the weight applied on the main landing gear struts of a B 737-200, under similar conditions to those of PI 467, as a function of air speed, with 30° of trailing edge flaps extended, the CG at 19.57 percent MAC, and the elevators in a neutral (hands off) position. These data showed that without spoiler extension, the load on the main gear struts at 147 knots was zero because the lift generated is approximately equal to that of the airplane's weight. The weight on both main gear struts increases to about 8,000 pounds at 140 knots, to 16,000 pounds at 130 knots, and to 25,000 pounds at 120 knots. When the control column is pushed forward to a one-half full nose down elevator position, the loads on both main gear struts decrease to about 2,000, 14,000, and 22,500 pounds at 140, 130, and 120 knots, respectively. In addition, a load of about 18,250 pounds is needed on normally serviced main landing gear struts to compress them 3 inches.

Due to the corrections that were applied to the DFR, as well as the lack of complete precision in measuring airspeed, the derived airspeeds contain an approximate 5-knot error. That is, the actual airspeed could be as much as 5 knots higher or 5 knots lower than the derived airspeed. The examination of the DFR indicates that the derived airspeed of PI 467 was about 214 knots when it was cleared for the approach. (See figure 7.) The airspeed was about 194 knots crossing HAYOU. When PI 467 crossed the threshold, the airspeed was about 165 knots, and at touchdown, it was about 147 knots. The airspeed was about 72 knots when the airplane departed the runway.

The groundspeed of the airplane during the 24-second period that it was on the runway was examined, assuming a zero longitudinal wind component, to determine its ground roll and touchdown point. By integrating the airspeed history between the times of touchdown and departure, a ground roll of 4,595 feet was obtained before PI 467 departed the runway. Subtracting this distance from the runway length of 7,845 feet results in a distance of 3,250 feet, the distance from the approach end of runway 36R upon where PI 467 most likely touched down. This also corresponds to the approximate touchdown point described by witnesses.

1.17.3 Airport Certification

To qualify for an airport operating certificate, an airport must, according to 14 CFR 139.45, demonstrate that there are no "potentially hazardous ruts, depressions, humps, or other surface variations," on each safety area of the airport. In addition, 14 CFR 139.45(3) requires that there be an extended runway safety area, along the extended runway centerline, that begins 200 feet from the end of the "usable runway" and extends "outward in conformance with FAA criteria in effect at the time of construction of the runway." Further, 14 CFR 139.83(a) requires the operator of a certified airport to act promptly to prevent ponding on any runway pavement surface area that was due to inadequate drainage.

1.17.4 Research on Antiskid System Performance

In 1979 the National Aeronautics and Space Administration (NASA) conducted tests of an aircraft velocity-rate-controlled, pressure-bias-modulated antiskid system, a type similar to that with which PI 467 was equipped. 7/ In this system, in which

7/ "Behavior of Aircraft Anti-skid Braking Systems on Dry and Wet Runway Surfaces—A Velocity-Rate-Controlled, Pressure-Bias-Modulated System," NASA Technical Note TN D-8332, Stubbs, Sandy M., and Tanner, John A., NASA Langley Research Center, Hampton Roads, Virginia, December 1976.

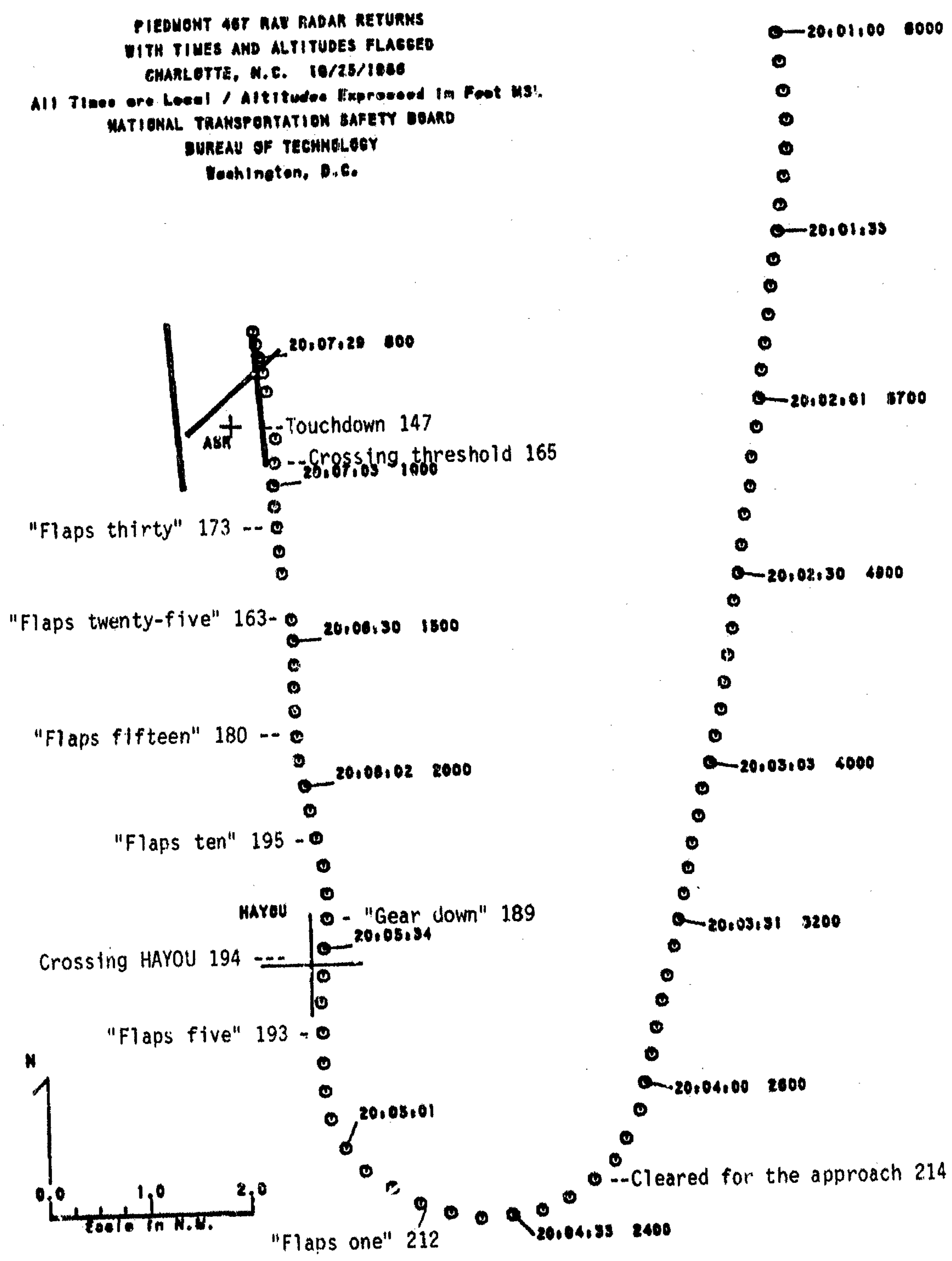

Figure 7.—Airspeeds and airplane configuration at selected points in the approach of PI 467

deceleration was compared to a preset velocity rate threshold of about 30 radian/sec2 (50 ft/sec2), if the braking effort resulted in a wheel deceleration greater than the threshold value, a skid signal (d.c. voltage) was transmitted to the antiskid control valve to reduce brake pressure to a low value, possibly zero. The antiskid system needed about 40 milliseconds to react to a wheel spindown. When the wheel recovered from the skid, the skid signal voltage was reduced as a function of the magnitude, duration, and number of preceding skids. In addition, the rate of reapplication of brake pressure was modulated as a function of the same parameters.

The results indicated that at a speed of 98 knots, rotational speed was reduced to about zero in about 0.2 second when the airplane transitioned from a dry pavement to a flooded one. Further, brake pressure was released almost completely by the antiskid system and the coefficient of friction was reduced from about 0.5 to 0.05. Following brake pressure release, wheel rotational speed fluctuated and was reduced to near zero for several seconds when the test was terminated due to limitations in the test facility.

FAA-sponsored tests 8/ in 1973 with a Lockheed L-1011 and a B-737 demonstrated that rotational spinup of the main gear wheels could require a much as 2 seconds following a normal landing at Vref on a wet (0.01 to 0.03 inch water), ungrooved, concrete runway. Further, the tests showed that if the wheel brakes were applied when the wheel speed was low relative to the speed of the airplane, the wheel speed would remain low and and would not reach synchronous speed with the airplane for more than 25 seconds. The delay was attributed to the skid control logic circuit's assumption of the relatively low reference speeds at the time the brakes were first applied. Consequently, low wheel spin up accelerations (low friction between tire and pavement) following brake release during each braking cycle combined with the low reference speed, prevented wheel spin up from reaching synchronous speed until the airplane had slowed sufficiently to cause higher wheel spin up accelerations (increased friction between tire and pavement).

Other NASA tests 9/ in 1971 with a B-727 demonstrated that wheel lockup can occur on a smooth concrete runway, covered with 0.049 inch of water. The wheel lockup resulted in reverted rubber hydroplaning with effective braking friction coefficient ranging from about 0.05 at 70 knots to 0.03 at 115 knots.

1.17.5 Cockpit Resource Management

Piedmont Airlines did not provide, nor was it required to provide, training to its crewmembers in crew coordination or cockpit resource management. However, about 2 years before the accident, the airline ceased offering to its captains a 1- to 2-day program in behavioral principles that was part of their upgrade training. Since it was not required training, there was no record available to indicate whether the captain had participated in the program.

8/ "Concorde Landing Requirement Evaluation Tests,' Report No. FAA-FS-160-74-2, U.S. Department of Transportation, FAA, Washington, D.C., August 1974.
9/ Preliminary Test Results of the Joint FAA-USAF-NASA Runway Research Program, Part I-Tracking Measurements of Several Runways Under Wet and Dry Conditions with a Boeing 727, a Diagonal-Braked Vehicle, and a Mu-Meter," NASA TM X-73909, 1977.

2. ANALYSIS

2.1 General

The flightcrew and the flight attendants were properly certificated and were qualified to perform their duties in accordance with applicable Federal aviation regulations. There was no evidence that the performance of the flightcrew was adversely affected by behavioral or physiological factors. Piedmont Airlines carried out the maintenance on N752N in accordance with FAA approved regulations. Although on October 2, 1986, the thrust reverser levers were reported to be difficult to operate, there were no further reports of difficulty following lubrication of the thrust reverser cables and controls. Instrument meteorological conditions prevailed, along with a slight tail wind shearing to calm winds from the outer marker to the runway, but there was no evidence that meteorological factors precluded the ability of PI 467 to land safely.

There was also no evidence of preexisting damage to the airplane structure, systems, or powerplants. In addition, there was no indication, based on an examination of the airplane systems, that before the accident the airplane's airborne and ground-based performance was compromised. Although postimpact damage precluded functional tests of the airplane braking and antiskid systems, the Safety Board examined components of the antiskid system; all were found free of preexisting defects. Therefore, the Safety Board concludes that the airworthiness of the airplane was not a factor in the accident.

The investigation examined the quality of the air traffic control services that CLT approach control and the CLT tower provided to PI 467. The results indicate that air traffic control services for the flight were carried out in accordance with FAA air traffic control practices and procedures. CLT approach turned the flight onto its final approach course within an acceptable distance from the final approach fix when PI 467 was 3 miles south of HAYOU. Further, the controller informed the flight that the base leg would be "close in," and the flightcrew acknowledged the clearance. Therefore, the Safety Board concludes that air traffic control services for the flight did not contribute to the accident.

Rather, the evidence indicates that a combination of operational and runway environmental factors contributed to the accident. These include excessive approach and landing speeds for the prevailing conditions, nonadherence to required airspeeds and airplane configurations during the approach, touchdown over 3,200 feet beyond the approach end of the runway, lack of timely ground spoiler deployment following touchdown, and hydroplaning which reduced the airplane braking capability. The Safety Board believes that each factor, individually, may not have caused the accident; however, in combination, they led to the inability of the flightcrew to stop the airplane on the runway.

Therefore, the Safety Board focused on the actions of the captain and the first officer to determine how their operation of the flight contributed to the accident, and on the runway environmental conditions to determine their effects on the airplane stopping capability.

Since the flight was, by all accounts, routine until it arrived in the Charlotte area, the Safety Board began its analysis of the accident sequence from that point in the flight. In addition, the Safety Board examined factors affecting the survivability of the accident to determine what measures, if any, could have been taken to reduce the severity of the accident.

2.2 The Approach

The Safety Board believes that after PI 467 entered the Charlotte approach control airspace, the flightcrew failed to follow certain required company procedures and did not monitor critical flight parameters. As a result, there was a diminution in the margin of safety which led directly to the failure of the captain to land within the proper area of the runway at a proper airspeed and then perform the procedures necessary to stop on the available runway.

Before PI 467 crossed the final approach fix, HAYOU, at 2005:31, the captain did not reduce the airspeed to a value appropriate for the approach, nor did he configure the airplane as required nor did the first officer call this to the attention of the captain. Piedmont procedures specified that before crossing the LOM the final landing flap setting should have been selected and the airspeed should have been reduced to a level appropriate for that flap setting. On this flight, the final flap setting was 30° and the final approach airspeed or Vref was 131 knots. The CVR indicates that the final flap setting was not accomplished until the airplane was on the glide slope, well inside the final approach fix. Further, the first officer did not lower the gear until 2005:39, and the captain did not select the final 30° flap setting until 2006:48, when the airplane was less than 1 mile from the runway threshold and 2 seconds before the first officer made the 500 feet (agl) call. Moreover, the airspeed was not reduced to 131 knots until after landing. Thus, the approach of PI 467 was carried out in a manner well outside the parameters established in Piedmont's procedures.

The Safety Board believes that because the airplane was not configured for the landing until 500 feet above touchdown, the captain was "behind" the airplane. That is, he was setting flaps, lowering the landing gear, and trying to reduce the airspeed after the flight was descending on the glide slope and well inside the final approach fix. Had the captain slowed the airplane and configured it as required before reaching HAYOU, he could have stabilized the approach and controlled the airspeed with the needed precision. Instead, the airplane crossed HAYOU at 194 KIAS, crossed the threshold about 165 KIAS, and touched down about 147 KIAS, considerably higher than the Vref speed of 131 KIAS, over 3,200 feet from the runway threshold and over 2,000 feet beyond the company recommended touchdown point. Under these circumstances, the margin of safety was reduced considerably, that is, the captain's ability to stop the airplane on the remaining runway depended on his ability to optimally use the airplane decelerative devices, with no margin for error allowed in the use of those devices.

Despite the captain's assertions that he added 20 knots to Vref because of his concern for a wind shear condition, the Safety Board believes that, if correct, he failed to properly interpret and apply guidance provided on the subject in the company operations manual. (See appendix D.) From that guidance, with surface wind reports, the lack of significant convective activity, and his knowledge of the tailwind on the approach, the captain should have known that the existing wind shear involved that of a tail wind shearing to a light crosswind or no wind. Under these conditions, significant speed additions are not needed and may compound airplane controllability because this type of wind shear tends to increase indicated airspeed during descent, through the reducing tailwind shear. Moreover, the four Piedmont flights that landed during the approximate 11-minute period before PI 467's landing, flew through similar wind conditions without any significant speed additions and without any reported difficulties in stopping. Finally, the operations manual stated that "if the airplane is below 500 feet AGL and the approach becomes unstable, a go-around should be initiated immediately." The Safety Board believes that given the unstable condition of the captain's approach below 500 feet above the runway, he should have promptly adhered to company guidance and should have executed a missed approach.

Moreover, the evidence indicates that the captain and the first officer were aware that the approach was unstable, yet they continued the approach instead of executing a go-around. The captain knew that the turn to the final approach course was going to be close to HAYOU and he accepted it. He was aware that the likelihood of encountering a tailwind on final approach was high. Further, he received several indications that the approach was not procedurally correct. At 2005:02, he told the first officer, "it's going to be tight," presumably in reference to configuring the airplane properly and capturing the glide slope and localizer. At 2006:22, when he told the first officer that "George didn't do me any favors there," he recognized that the autopilot was not capturing the glide slope. This was most likely caused by the excessive descent rate which exceeded the autopilot capabilities to maintain the glide slope path, due to the high air speed and substantial tailwind.

Moreover, the first officer informed the captain at 2006:37 that the speedbrake lever was in manual, i.e., down detent, contrary to Piedmont's requirement that the speed brake lever be armed before landing. The captain's response to that call is unclear on the CVR. Thus, it could not be determined whether he armed the speed brake lever. However, the failure of the ground spoilers to deploy immediately after landing suggests that they were not armed.

The GPWS alerted twice thereafter, further indicating that the approach was unstable and not in accordance with company procedures. Since the runway was in sight when the first GPWS alert sounded, and since the first officer called minimums when the second alert sounded, the captain probably recognized that terrain clearance was adequate and, as a result, he believed that he could safely ignore the alert. However, the Safety Board believes that the GPWS was alerting, not because of inadequate terrain clearance, but because of an excessive descent rate close to the ground. Because the airspeed was considerably higher than required at that point and because the airplane had only just been configured for the landing, the captain should have recognized that the approach was not stabilized at the appropriate airspeed, descent rate, and power setting, and consequently, that the margin of safety for landing on a wet runway had been reduced to an unacceptably low level.

Because 5 months before the accident Piedmont's flightcrew publication, "Operations Update," had discussed the role of proper airspeed management and proper touchdown point to avoid a runway overrun, the Safety Board believes that the captain and the first officer should have been acutely aware that proper airspeed management was critical. Nonetheless, there is no evidence that such airspeed management was present. Rather, the evidence indicates that the airspeed throughout the approach was excessive for the existing runway conditions. As a result, the captain's failure to stabilize the approach compromised his ability to stop the airplane on the runway. Therefore, the Safety Board concludes it was the major factor in establishing the conditions for the accident.

2.3 Landing and Rollout

The evidence indicates that, despite the unstabilized nature of the approach and the touchdown that was at a point considerably beyond the recommended touchdown point, on a runway that contained areas of standing water, the airplane could have been stopped on the remaining runway had the captain made optimal use of the airplane decelerative devices, i.e., spoilers, thrust reversers, brakes and antiskid system.

However, the evidence suggests that, despite repeated guidance in the Piedmont operations manual on the need to arm spoilers and, if not armed, deploy them upon touchdown before the other decelerative devices, the spoilers were not armed and were not deployed. This can be readily accounted for by the rushed nature with which the approach was conducted and the extent to which required procedures were not followed, both on the approach and upon touchdown, as well as by witness statements and supportive evidence from the Piedmont B-737 simulator. However, the captain stated that he did arm the speedbrakes before landing but that they failed to deploy automatically. As a result, the Safety Board closely examined the airplane performance following touchdown on runway 36R to determine the consequences to its performance following speedbrake arming, given the environmental and airplane conditions at the time.

The captain stated that immediately following touchdown, he attempted to deploy the thrust reversers, without success. He said that he then moved the speed brake lever to the "Up" position to manually deploy the spoilers, and then immediately applied the wheel brakes. After the airplane left the runway, according to the captain, he configured it for an evacuation, in compliance with emergency procedures, by retracting the spoilers and by moving the speed brake lever to the "Down" detent.

After the accident, the speed brake lever was found in the "Down" detent and the speed brake lever actuator was found in the retracted position. However, the evidence suggested by the position of the cockpit controls as to whether the spoilers had deployed is inconclusive for several reasons. Damage to the underside of the airplane precluded a determination of the amount of right main gear strut compression needed to operate the air/ground safety sensor switches and to open the ground spoiler interlock valve. Consequently, the rigging tolerance of 1 1/2 inch plus 1 1/2 inch minus 0 inch for the interlock valve, and the rigging tolerance of 5 inches for the air/ground safety sensor could not be verified, and it could not be conclusively determined as to whether the spoilers functioned as designed.

The damage to the airplane underside also prevented a determination of possible actions of the speed brake electric actuator electrical circuits. Ordinarily, once extended, the actuator will not retract simply by moving the speed brake lever to the "Down" detent. The thrust levers in the forward thrust regime must also be advanced. However, if a wheel rotational speed of 60 knots or more was never achieved on any combination of two main gear wheels throughout the landing roll, the spoilers would not have automatically deployed and the actuator, automatically extended. In addition, during the crash sequence, an action in the actuator's electrical circuits could have caused the actuator to retract. Thus, the retracted position of the actuator was inconclusive as to its relationship to spoiler deployment.

Since it is likely that a wheel rotational speed of 60 knots or more on any combination of two main gear wheels was obtained at some point during the landing roll, the possibility that the speed brake lever was never moved from the "Down" detent was examined to determine the effect on the airplane stopping performance.

According to data supplied by Boeing, on a wet, grooved runway without spoiler extension, the airplane could have been stopped in about 3,500 feet provided full reverse thrust was obtained within 3 seconds of touchdown. However, significant reverse thrust was not obtained until about 12 seconds after touchdown when the airplane had slowed to about 112 KIAS, at which time less than 1,900 feet of runway remained. (See figure 8.) Consequently, although the frictional qualities of the last 1,500 feet of

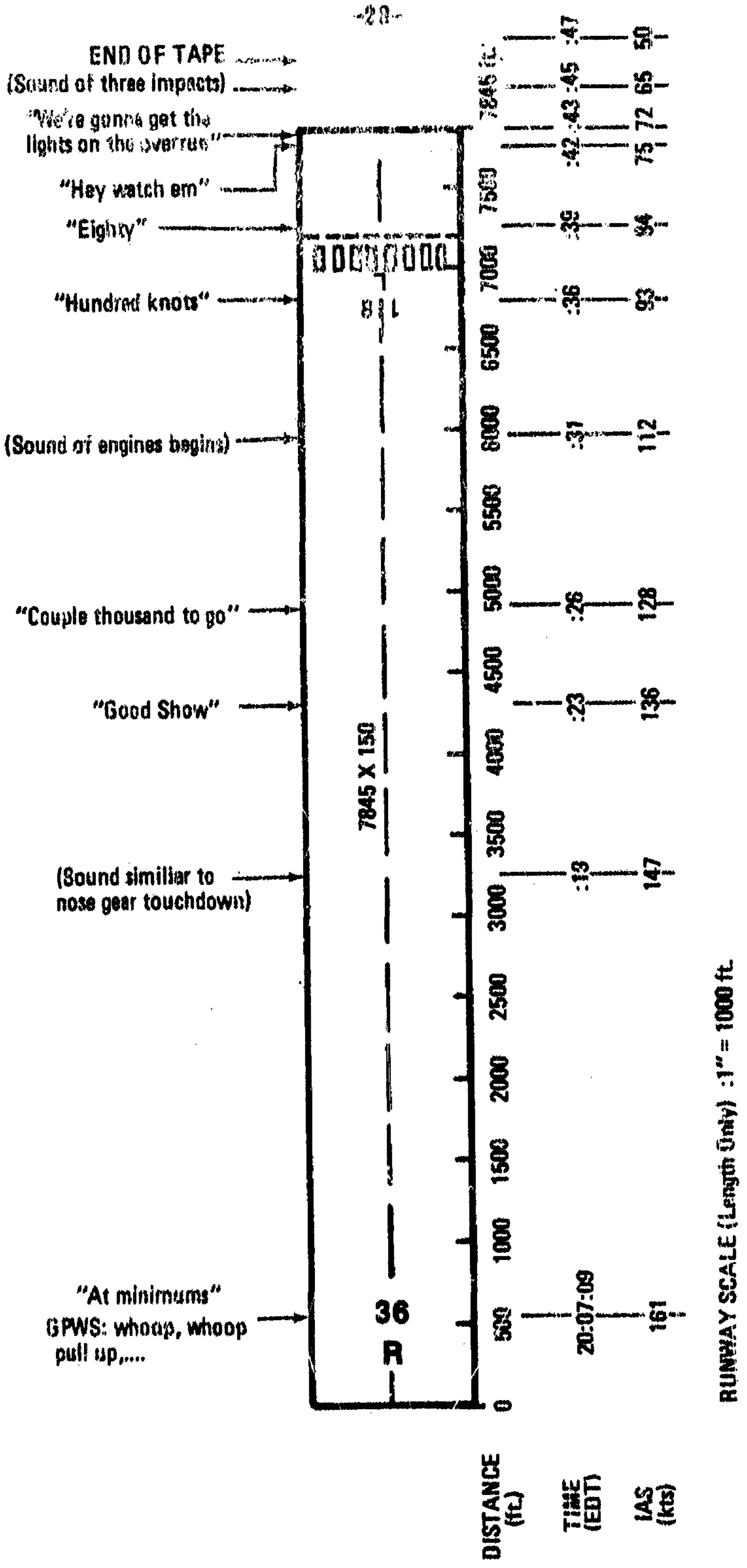

Figure 8.--Speeds of PI 467 at selected points on the runway.

runway 36R were substandard, the lack of any spoiler extension could account for the delay in obtaining reverse thrust, the airplane poor stopping performance with the last 1,900 feet of runway, and its departure from the runway at a speed in excess of J KIAS.

Nevertheless, although the lack of spoiler extension alone could account for the captain's inability to stop the airplane on the runway, given the runway condition and the fact that the touchdown was at a point loca' d over 3,200 feet from the runway threshold, the Safety Board examined other factors which also could have adversely affected the airplane stopping capability. These factors relate to the performance of the airplane deceleration devices during a high speed landing and to the evidence of reverted rubber hydroplaning.

As shown in figure 9, the almost simultaneous sounds of nose wheel contact, with an increase in the G-trace to about 1.43 G, indicate that the airplane nose wheel and the wheels of one or both main gear struts contacted the runway almost simultaneously. The main gear contact was followed by about 3 seconds of oscillation in vertical acceleration, at slightly less than 1.0 G. Thus, following touchdown, very little of the airplane weight transferred to the main gear struts. This situation would have been exacerbated by the captain's stated application of forward pressure on the control column following touchdown, in order to hold the nose wheel on the runway. Boeing Company data indicate that at an increased airspeed of 15 knots above Vref, the lift generated by PI 467, while in a 3-point ground attitude was approximately equal to the airplane weight. Thus, there would have been little or no weight on the main gear wheels following initial touchdown, a condition which could have been maintained for 4 to 6 seconds with forward displacement of the control column. Since the airplane touched down in heavy rain on a runway that had been exposed to over 2/3 inch of rain during the day, it is possible that initially there would have been insufficient friction between the tires and the runway to obtain a wheel speed of 60 knots or more (the speed required by combination of any two wheels to cause automatic spoiler deployment and automatic movement of the speed brake lever actuator to the "Up" position). Further, the lack of any significant weight on the main gear struts would have prevented the strut compression needed to close the air/ground safety sensor switches which would have precluded the immediate selection of reverse thrust. This condition would be consistent with the captain's stated difficulty in deploying reverse thrust.

In addition, if between the time the captain stated that he attempted first to deploy reverse thrust and then manually deployed the spoilers, or immediately thereafter, he had applied wheel brakes, wheel braking could have begun before the outboard main gear wheels reached synchronous speed with the airplane due to the lack of significant weight on the main gear wheels.

As demonstrated in FAA-sponsored research with a Lockheed L-1011 and a Boeing 737, achieving a main gear wheel spin up that is synchronous with the airplane can take as long as 2 seconds, following a normal landing at Vref on a smooth, wet runway. Consequently, even with satisfactory transverse grooving in the area of the runway where PI 467 touched down, the combination of heavy rain and minimal wheel loading could have delayed wheel spin up extensively.

During the 6 seconds after touchdown, the airplane slowed from about 147 knots to about 135 knots, a deceleration of about 2 ft/sec2. Since the brakes on the inboard wheels would not have been available immediately due to locked wheel protection, the performance of PI 467 in the first 6 seconds after touchdown suggests that the outboard wheels may have locked up within 3 to 4 seconds after touchdown, most likely due to the captain's application of wheel brakes before synchronous speed was achieved.

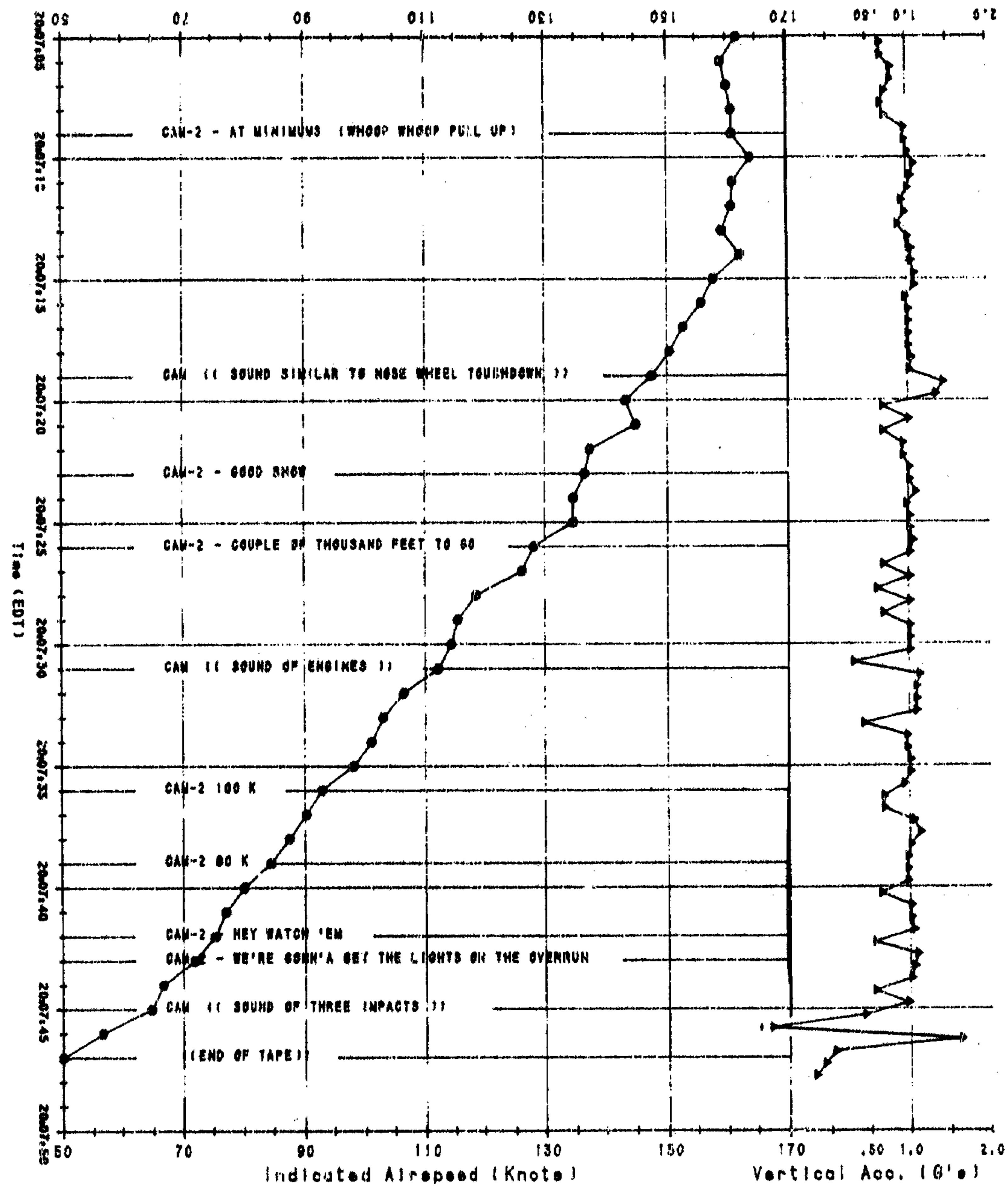

Figure 9.--Vertical acceleration and speeds of PI 467 following touchdown.

During that 6-second period, the airplane rolled about 1,400 feet. As the NASA research with pressure-bias-modulated antiskid systems demonstrated, on an ungrooved, wet runway, brake application before synchronous speed is reached can result in a locked wheel condition. This can prolong the time required for the wheels to reach synchronous speed by as much as 25 seconds. Under locked wheel conditions, the effective braking coefficients are less than 0.05, at speeds over 70 knots.

At 2007:24, the airplane began a rapid deceleration compared to a previous 6-second period of slight acceleration. Its airspeed decreased about 20 knots from 135 to 115 seconds, for a deceleration rate of about 8.5 ft/sec2. Since significant reverse thrust was not generated until about 2007:31, during the 4-second period from 2007:24 to 2007:28, sufficient weight was probably transferred to the main struts, apparently by extension of the flight spoilers, to allow the air/ground safety sensor to sense ground operation. This would have permitted deployment of the thrust reverser deflectors and the application of the inboard wheel brakes as well as deployment of the ground spoiler panels. However, by the time significant reverse thrust was generated, as evidenced by the engine sounds recorded on the CVR, less than 1,900 feet of runway remained.

Since the last 1,500 feet of runway 36R contained a crown that was insufficient to promote adequate drainage, collapsed and uneven transverse grooving, and less than recommended friction qualities, the 1,900 feet of runway remaining was insufficient to stop the airplane from a speed of 112 KIAS, even with all decelerative devices operating. The actual performance of PI 467 during the last 12 seconds indicates that comparatively little deceleration (3.33 ft/sec2) was obtained. The airplane left the runway at a speed of abut 72 KIAS.

It is also apparent from the skid marks on the last 100 feet of runway 36R and from the condition of the four main gear tires that the airplane experienced reverted rubber hydroplaning before it left the runway. To achieve reverted rubber hydroplaning, wheel/tire rotational speed must be reduced essentially to zero so that the tires skid along the runway surface. Since there was no evidence of preexisting defects in the antiskid braking system, wheel/tire rotational speed could be reduced by one of two ways; either by disengaging the antiskid system or by having the rotational speed already reduced to zero before rubber reversion took place. Since there was no indication that the captain disengaged the antiskid system, the Safety Board believes that wheel/tire rotational speed was reduced essentially to zero by a combination of dynamic and viscous hydroplaning that preceded the reverted rubber hydroplaning. Further, the evidence indicates that the poor frictional qualities of the last 1,500 feet of runway 36R and the pooled water on the runway surface contributed to the dynamic and viscous hydroplaning.

In summary, given the many variables that affected PI 467's stopping performance on runway 36R, the Safety Board could not determine conclusively whether or not the spoilers were extended following touchdown. However, irrespective of whether the spoilers were extended, the excessive speed of the airplane as it entered the last 1,500 feet of runway led to the hydroplaning that precluded effective braking action. Consequently, the Safety Board concludes that the accident was directly related to the manner in which the captain flew the approach and executed the landing.

2.4 Crew Coordination

The Safety Board believes that, while the decision to continue the approach belonged to the captain only, the first officer participated in the decision-making process in the information he provided the captain. The first officer recited the landing checklist and stated that the speed brakes were in the manual mode of operation. He also called out the approach lights when they became visible.

The first officer's statement about the speed brake lever being in manual, contained the clear implication that it was not armed as required. This was, the Safety Board believes, a subtle reminder to the captain that the required approach and landing procedures were not being adhered to. At the same time, the first officer did not point out to the captain that the airplane was still not configured for landing when it was well inside the final approach fix, and he did not call out to the captain that the airspeed was excessive throughout the approach. Therefore, the Safety Board concludes that the first officer's lack of assertiveness in providing the captain with needed information and the captain's failure to respond to the "subtle" callout of the speed brakes in manual are indicative of deficient crew coordination, also known as cockpit resource management, and that this deficiency contributed to the accident.

The Safety Board is aware of the difficulty that first officers face in attempting to provide captains with needed information at critical points in a flight, when such attempts could be distracting. More important, perhaps, is the difficulty they may face when attempting to influence the pilot-in-command to reconsider and possibly alter a decision. Thus, it would have been very difficult, once inside the final approach fix, for the first officer to suggest to the captain that the approach was not stabilized and, as a result, they should go around. Such a suggestion could, if presented inappropriately, distract the captain and could potentially endanger the safety of flight.

As a result of its investigation of an airplane accident involving a Lockheed Electra L-188C in Reno, Nevada, on January 21, 1985, 10/ the Safety Board recommended that the FAA:

> A-86-19
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> Provide to all operators, guidance on topics and training in cockpit resource management so that operators can provide such training to their flightcrew members, until such time as the FAA's formal study of the topic is completed.

On December 19, 1986, the FAA informed the Safety Board that its study on cockpit resource management was expected to be completed in November 1987. As a result, the Safety Board has classified Safety Recommendation A-86-19 as "Open—Acceptable Action" until it can review the results of the study. Until that time, the Safety Board reiterates Safety Recommendation A-86-19 and urges the FAA to provide guidance on cockpit resource management to all operators. It is hoped that operators will then implement such courses and provide training in the topic to all flightcrew members.

2.5 Runway Condition

The Safety Board believes that two factors increased the severity of the accident: the lack of adequate runway friction in the final 1,500 feet of the runway and the location of the concrete culvert 18 feet beyond the localizer antenna array, which was itself, located 300 feet beyond the departure end of the runway.

The lack of acceptable friction in portions of the runway increased the severity of the accident because the airplane departed the runway at a higher speed than it probably would have had there been adequate grooving and drainage in the departure end of the runway. The evidence indicates that PI 467 experienced hydroplaning before it

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10/ Aircraft Accident Report—"Galaxy Airlines, Inc., Lockheed Electra L-188C, N5532, Reno, Nevada, January 21, 1985" (NTSB/AAR-86/01).

departed the runway, as indicated by the reverted rubber marks found on the four main landing gear tires and the "steam clean" marks found on the departure end of the runway. Although runway friction was, according to FAA-recommended standards, not acceptable only near its departure end, the Safety Board concludes that the runway condition was not a primary cause of the accident because of the excessive speed of the airplane as it entered the last 1,500 feet of the runway; but the poor friction did contribute to the severity of the accident.

Although the Safety Board concludes that the condition of runway 18L/36R did not contribute to the cause of the accident, the evidence indicates that the runway did not meet the maintenance standards recommended in FAA Advisory Circular (AC) 150/5320-12A, dated July 11, 1986. The circular also indicates that the Charlotte Airport Authority did not comply with 14 CFR 139.83 regarding the prevention of ponding on runway pavement areas. The Safety Board believes that as part of the FAA annual certification inspection of airports, such defects should be identified and corrected.

Currently, airports that are certificated under 14 CFR Part 139 are responsible for their own "self-inspection" program that, among other things, requires them to ensure that the airport pavement surface is adequately maintained. The Charlotte Airport Operations Manual (AOM) was examined subsequent to the accident. It stated that "the runways have been designed to provide 1 1/2 percent crown . . . all of the runways are grooved full length and width to facilitate runoff." Because of the deficiencies that were found in the condition of runway 36R (i.e., it did not have 1 1/2 percent crown in over half the length, the grooving was substantially collapsed in the last 1,500 feet, there were ruts (which were conducive to ponding) for almost the entire length, and the measured friction over the last 1,500 feet was substandard), the Safety Board believes that the airport operator failed to maintain the runway surface to standards specified in the AOM or to the criteria recommended in AC 150/5320-12A.

Subsequent to the World Airways DC-10 overrun at Boston-Logan International Airport on January 23, 1982, 11/ the Safety Board recommended that the FAA:

A-82-153

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.

A-82-154

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.

11/ Aircraft Accident Report--"World Airways, Inc., Flight 30H, McDonnell Douglas DC-10-30, Boston-Logan International Airport, Boston, Massachusetts, January 23, 1982" (NTSB-AAR-82-15).

On January 14, 1987, the FAA responded to these safety recommendations stating that "... the FAA does not believe that measuring dry runway coefficient of friction during certification inspections would be cost-effective nor would any significant safety improvement result" and indicated that no further action was contemplated.

In light of the frictional deficiencies that were found on portions of runway 36R at Charlotte Airport, the Safety Board believes that the concepts at issue in Safety Recommendations A-82-153 and -154 still have considerable merit. However, because the recent response indicates that FAA does not intend to take further action on these recommendations and because the Safety Board is issuing new safety recommendations concerning these issues, Safety Recommendations A-82-153 and -154 have been classified as "Closed—Unacceptable/Superseded."

Despite the FAA's position with regard to annual measurements of runway friction, the Safety Board also believes that the deteriorated condition of runway 36R at Charlotte Airport is indicative of failures on the part of the airport operator and the FAA inspectors to identify and correct other runway conditions that could adversely affect the safety of air carrier operations during inclement weather conditions. Further, the Safety Board believes that the recently revised AC 150/5320-12A should serve as a basis for an aggressive runway inspection and maintenance program.

2.6 Survival Aspects

After it left the runway, the airplane struck and broke off the localizer antenna array from its frangible moorings. However, about 18 feet beyond the antenna was a concrete culvert which caused almost all the damage to the airplane and injuries to those who were injured. The Safety Board believes that the presence of the concrete culvert created a more destructive and severe accident than what it otherwise would have been without the culvert.

The Safety Board expressed its concern about runway safety areas following a Texas International Airlines DC-9 accident at the Stapleton International Airport, Denver, Colorado on November 16, 1976. The airplane overran the runway during a rejected takeoff. Subsequent to the accident, the Safety Board recommended that the FAA:

> A-77-16
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> Amend 14 CFR 139.45 to require, after a reasonable date, that extended runway safety area criteria be applied retroactively to all certificated airports. At those airports which cannot meet the full criteria, the extended runway safety area should be as close to the full 1,000-foot length as possible.

The FAA's initial response, dated July 11, 1977, stated that this recommendation would place an economic burden on airport operators. They did propose, however, an amendment to 14 CFR Part 139 that would require extended safety areas concurrently with construction of new airports, runways, and major runway extensions at existing airports. On October 23, 1985, the FAA published Notice of Proposed Rulemaking (NPRM) No. 85-22, "Revision of Airport Certification Rules," published at 50 FR 43094. In its response to the NPRM, the Safety Board supported the proposed section 139.307, "Safety Area," which would require that safety areas conform to the criteria in effect at the time of an expansion of a runway, or at the time of certification. While the

Safety Board continued to stress that criteria for runway safety areas should be made mandatory at all certificated airports regardless of the date of construction, it was sensitive to the practical and economic difficulties of implementing such a requirement.

Because the final disposition of the NPRM is not certain, the Safety Board has maintained Safety Recommendation A-77-16 as "Open- Acceptable Action." However, as a result of the extensive elapsed time since the Safety Board issued this recommendation, and the lack of completed action by the FAA, the Safety Board has changed its classification to "Open—Unacceptable Action," and urges the FAA to complete the rulemaking process as soon as possible.

In lieu of regulatory guidance concerning extended runway safety areas, Advisory Circular (AC) 150/5335-4, Change 2 to Airport Design Standards—Airports Served by Air Carriers" emphasizes the need for establishment of extended runway safety areas. The AC states that "for existing runways . . . extended runway safety zones should be provided wherever physically feasible and economically possible . . . " The AC states that the extended runway safety area is a rectangular area centered on the extended runway centerline. It begins at the end of the runway safety area and extends 300 feet to a point 1,000 feet from the runway end. Its width is the same as the runway safety area. It further stipulates that "the extended runway safety area should be cleared and free of structures, objects, abrupt surface irregularities, ditches, soft spots, and ponding areas. All objects, which, because of their function, must be maintained within the extended runway safety area, should be constructed with frangibly mounted supporting structures of minimum practical heights."

With respect to the extended runway safety area at the departure end of runway 36R at Charlotte Airport, the Safety Board takes a critical view of the location of a concrete culvert on the extended runway centerline 318 feet beyond the runway end. In fact, this culvert was allowed to exist 18 feet behind a localizer antenna that was made frangible at considerable expense.

The Safety Board reiterates its position that, unless physically impossible or economically impossible, the extended runway safety area should be maintained beyond the end of the runway. In the case of Charlotte Airport, although it would be impractical to move the railroad tracks located approximately 450 feet beyond the end of runway 36R, the concrete culvert probably could have been placed out of the extended runway safety area or could have been covered at little expense. Therefore, the Safety Board believes that the FAA should require airport managers to repair and/or remove, at the earliest opportunity, obstacles, such as concrete culverts, that are adjacent to airport areas.

The Safety Board is concerned that, due to the preexisting fatigue cracks, the forward flight attendant's seat could have failed had the cracks continued to be undetected under normal use loads, in addition to the type of high loads produced in this accident. This could pose a danger to flight attendants and, as a result, threaten the ability of flight attendants to assist in an emergency. As a result, the Safety Board believes that the FAA should issue an airworthiness directive for a one-time inspection of the seat pan roller assembly of this type of seat (Trans Aero Industries, part No. 90835) for evidence of fatigue cracks.

The investigation revealed several deficiencies in the CFR response to the emergency. The limited number of ambulances, only three, that was dispatched to the accident site, was not a factor in the survivability of this accident because of the limited number of injuries that were sustained. However, had there been more injuries, this could have adversely affected the survivability. Moreover, the ambulance dispatcher's lack of knowledge of the number of people on board PI 467 is a further indication of this deficiency. In addition, the lack of immediate communication about the accident to the Norfolk Southern Railroad and the need to halt rail traffic also indicates a deficiency in the emergency response.

The investigation also revealed that a potential hazard to the evacuation existed because of reports of passengers who were considered to be intoxicated. It is clear that intoxicated passengers can pose a danger to themselves and others on an aircraft at all times, particularly in an emergency. As a result of its investigation into the accident involving an Embraer EMB-110P1 in Alpena, Michigan, on March 13, 1986, 12/ the Safety Board recommended that the FAA:

A-87-14

Issue an Operations Bulletin to Principal Operations Inspectors of carriers operating under 14 CFR Part 135 informing them of the need to improve passenger screening to prevent intoxicated passengers from boarding aircraft.

On June 2, 1987, the FAA informed the Safety Board that an Air Carrier Operations Bulletin (ACOB) was being developed which would address the issue of intoxicated passengers. The Safety Board has therefore classified Safety Recommendation A-87-14 as "Open—Acceptable Action," pending its review of the ACOB.

However, this accident demonstrates that operators of aircraft operating with flight attendants on board also must be vigilant to the potential dangers presented by intoxicated passengers. In an emergency where there is a need for passengers to exit the airplane quickly, such passengers can hamper a rapid evacuation. They also can become unruly and interfere with the duties of flightcrew members, thereby creating an emergency situation. Although the investigation was unable to determine whether the particular passengers were served alcohol while on board PI 467, the Safety Board believes that all flight attendants must be vigilant in preventing passengers from being given additional alcohol to the point where they reach intoxication. Therefore, the Safety Board urges the FAA to issue an operations bulletin to principal operations inspectors of air carriers operating aircraft with flight attendants informing them of the need to cease providing alcohol to passengers who are in, or appear that they are about to be in, an intoxicated state.

3. CONCLUSIONS

3.1 Findings

1. The flightcrew and the flight attendants were properly certificated and qualified for the flight.

2. The airplane was properly maintained for the flight.

12/ Aircraft Accident Report—"Simmons Airlines Flight 1746, Embraer Bandeirante, EMB-110P1, Near Alpena, Michigan, March 13, 1986" (NTSB/AAR-87/02).

3. Air traffic control services provided to this flight were in accordance with acceptable procedures.

4. Weather factors did not contribute to the accident.

5. There was no evidence of preexisting damage to the airplane structure, systems, or powerplants that could have contributed to the accident.

6. The airplane was not configured for landing until just before touchdown, contrary to Piedmont operating procedures.

7. The GPWS alert just before touchdown indicated an excessive rate of descent.

8. The approach was flown contrary to Piedmont operating procedures.

9. The captain should have elected to discontinue the approach because it was not carried out in accordance with Piedmont operating procedures and because the airplane was not configured for landing until just before touchdown.

10. Crew coordination was deficient due to the first officer's failure to call the captain's attention to aspects of the approach that were not in accordance with Piedmont operating procedures.

11. The airplane touched down over 3,200 feet from the approach end of the runway, at an airspeed that was excessive for the prevailing runway surface conditions.

12. The spoilers were not deployed immediately after touchdown which adversely affected the airplane stopping performance.

13. The captain probably applied wheel brakes prematurely after touchdown which may have resulted in the loss of brake effectiveness on the outboard wheels.

14. The concrete culvert located beyond the departure end of the runway caused most of the damage to the airplane.

15. The friction on runway 36R was generally acceptable; however, in the last 1,500 feet, it was unacceptable and this contributed to the severity of the accident.

16. The airplane hydroplaned during the substantial portions of the last 1,500 feet of roll on runway 36R.

17. The evacuation was effective and completed within 1 1/2 minutes.

18. The emergency response to the accident was deficient in the limited number of ambulances dispatched to the site.

19. Two passengers were reported to have been intoxicated at the time of the accident, and they could have adversely affected the evacuation.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the captain's failure to stabilize the approach and his failure to discontinue the approach to a landing that was conducted at an excessive speed beyond the normal touchdown point on a wet runway. Contributing to the accident was the captain's failure to optimally use the airplane decelerative devices. Also contributing to the accident was the lack of effective crew coordination during the approach. Contributing to the severity of the accident was the poor frictional quality of the last 1,500 feet of the runway and the obstruction presented by a concrete culvert located 318 feet beyond the departure end of the runway.

4. RECOMMENDATIONS

As a result of its investigation, the Safety Board made the following recommendations:

—to the Federal Aviation Administration:

Require airport managers to repair areas and/or remove obstacles, such as concrete culverts, that are adjacent to airport operating areas. Such repairs should be performed at the earliest opportunity. (Class II, Priority Action) (A-87-107)

Issue an operations bulletin to principal operations inspectors of air carriers operating aircraft with flight attendants informing them of the need to cease providing alcohol to passengers who are in, or appear that they are about to be in, an intoxicated state. (Class II, Priority Action) (A-87-108)

Issue an airworthiness directive for a one-time inspection of the seat pan roller assembly of the flight attendant seat, Trans Aero Industries, part No. 90835, for evidence of fatigue cracks. (Class II, Priority Action) (A-87-109)

During annual inspections of full certificate airports, emphasize the identification of deficient runway conditions and use approved friction-measuring devices to measure the dry runway coefficients of friction; encourage the airport operator to correct (or provide appropriate notice to users) runway conditions that do not meet the criteria recommended in Advisory Circular 150/5320-12A. (Class II, Priority Action) (A-87-110)

During annual inspections of full certificate airports, verify that airport operations manuals address runway pavement inspection and maintenance criteria as recommended in Advisory Circular (AC) 150/5320-12A, and that airport operators are taking actions needed, including appropriate measurements of dry runway coefficients of friction with approved devices, to maintain runways to the criteria recommended in AC 150/5320-12A. (Class II, Priority Action) (A-87-111)

—to the American Association of Airport Executives and the Airport Operators Council International, Inc.:

Inform its membership of the circumstances of the aircraft accident at Charlotte Douglas International Airport on October 25, 1986, and request its membership to repair areas and/or remove obstacles, such as concrete culverts, that are adjacent to airport operating areas. Such repairs should be performed at the earliest opportunity. (Class II, Priority Action) (A-87-112)

Inform its membership of the circumstances of the aircraft accident at Charlotte Douglas International Airport on October 25, 1986, and request its membership to identify deficient runway conditions, to use approved friction-measuring devices to measure the dry runway coefficients of friction and to correct (or provide appropriate notice to users) runway conditions that do not meet the criteria recommended in Advisory Circular 150/5320-12A. (Class II, Priority Action) (A-87-113)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ JOHN K. LAUBER
Member

/s/ JOSEPH T. NALL
Member

/s/ JAMES L. KOLSTAD
Member

September 1, 1987

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The National Transportation Safety "oard was notified of the accident about 2030 eastern daylight time on October 25, 1986. An investigative team was dispatched from its Washington headquarters to the scene the following morning. Investigative groups were established for operations, air traffic control, meteorology, airworthiness, survival factors, human performance, maintenance records, cockpit voice recorder, and flight data recorder. In addition, specialists in aircraft performance, sound spectral examination, and engineering applications participated in the investigation.

Parties to the investigation were the FAA, Piedmont Airlines, the Boeing Commercial Airplane Company, Charlotte Douglas International Airport, the Association of Flight Attendants, the Transport Workers Union, and the Airline Pilots Association.

2. Public Hearing

There was no public hearing. A deposition of the flightcrew was conducted in Winston-Salem, North Carolina on February 5, 1987. A deposition of the FAA principal operations inspector assigned to the airline was conducted on March 18, 1987, also in Winston-Salem.

APPENDIX B

COCKPIT VOICE RECORDER TRANSCRIPT

TRANSCRIPT OF A FAIRCHILD A-100 COCKPIT VOICE RECORDER S/N 50202 REMOVED FROM THE PIEDMONT BOEING 737-200 WHICH WAS INVOLVED IN AN ACCIDENT AT CHARLOTTE, NORTH CAROLINA, ON OCTOBER 25, 1986

LEGEND

CAM	Cockpit area microphone voice or sound source
RDO	Radio transmission from accident aircraft
-1	Voice identified as Captain
-2	Voice identified as First Officer
-3	Voice identified as Flight Engineer
-?	Voice unidentified
ATIS	Air Traffic Information Service
APP	Charlotte Approach
TWR	Charlotte Tower
GPWS	Ground Proximity Warning System
XXX	Other aircraft
UNK	Unknown
*	Unintelligible word
#	Nonpertinent word
@	Expletive deleted
%	Break in continuity
( )	Questionable text
(( ))	Editorial insertion
---	Pause
NOTE:	All times are expressed in eastern standard time.

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	**CONTENT**	**TIME & SOURCE**	**CONTENT**
		ATIS	Charlotte Douglas International Airport information juliet. Two two five zero observation. Charlotte weather measured five hundred overcast, visibility one half, light rain and fog, temperature six zero, dew point five niner, wind one zero zero at six, the altimeter three zero zero four, simultaneous ILS approaches in use landing runway three six left and three six right Notice to Airmen runway five ILS is out of service migratory bird actively in the vicinity of the Charlotte Airport. Two cranes are operating one and one half mile southeast of runway three six right unlit. All departing IFR aircraft contract clearance delivery one two one point four prior to taxiing. Air carrier please advise your gate number. On initial, advise you have juliet
		20:00:45 RDO-2	Ah Piedmont four sixty seven with you at six thousand now
		20:00:49 APP	Piedmont four sixty seven Charlotte Approach expect ILS approach three six right number three to follow a company seven thirty seven further descent clearance in about six miles
		20:00:57 RDO-2	Okay plan a descent in about six miles runway three six left Piedmont four sixty seven

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
CAM-1	Right *		
		20:01:02 APP	It'll be ILS three six right Piedmont four sixty seven turn right heading one niner five vectors for a close in base leg
		20:01:09 RDO-2	Piedmont four sixty seven one ninety five plan three six right sorry
		20:01:18 APP	(Air) craft on this frequency Charlotte measured ceiling four hundred overcast visibility two light rain and fog temperature dew point remain the same, winds zero niner zero at eight altimeter three zero zero one, aircraft acknowledge with an ident please
20:01:24 CAM-1	All right		
CAM-2	* * *		
20:01:31 CAM-1	Three zero zero one		
20:01:33 CAM-2	Okay --- oh one on the right		

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
CAM-1	That's a pretty smart controller, that was a good way to do that, you know		
		20:01:35 APP	Piedmont three oh nine turn right heading two seven zero
		20:01:38 P309	Two seventy Piedmont three oh nine and we're descending to two point four
20:01:46 CAM-2	Yeah yeah covers his tail	20:01:46 APP	Piedmont four sixty seven descend and maintain two thousand four hundred please
		20:01:48 RDO-2	Down to two point four Piedmont four sixty seven
20:01:52 CAM	((Sound of power reduction))		
		20:01:58 APP	Piedmont three oh nine four miles southeast of Hayou turn right heading three three zero maintain two thousand four hundred till established cleared ILS approach three six right
		20:02:05 APP	Okay heading three thirty cleared ILS runway three six right approach Piedmont three oh nine

APPENDIX B

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	CONTENT
20:02:31 CAM-1	Good *		
		20:02:42 APP	Piedmont three oh nine turn further right to zero two zero for your intercept and just for your information on the final approach course there is a wind right to left at twenty to twenty five knots
		20:02:51 P309	Thank you
20:03:03 CAM-2	And ah I see the temperature		
20:03:07 CAM-2	Just for the record		
		20:03:08 P120	Piedmont one twenty six thousand
		20:03:10 APP	Piedmont one twenty Charlotte Approach expect the ILS approach runway three six right number three to follow company seven thirty seven southeast of the field further descent clearance in about five miles
20:03:15 CAM-1	Yeah yeah it's no problem		

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
CAM-2	I saw the * the temperature there		
		20:03:19 P120	Piedmont one twenty
		20:03:21 APP	Piedmont three oh nine contact the tower one eighteen one good day
		20:03:23 PI309	Good night
20:03:30 CAM	((Sound of altitude alert))		
CAM	((Sound similar to main stabilizer trim))		
20:03:31 CAM-2	Thousand to go		
20:03:32 CAM-1	(Yup)		
		20:03:55 APP	Piedmont four sixty seven turn right two niner zero
		20:03:58 RDO-2	Two nine zero on the heading Piedmont four sixty seven

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
		20:04:05 APP	Piedmont one twenty turn right heading one niner zero please, descend and maintain two thousand four hundred
20:04:08 CAM-?	Yeah		
		20:04:11 P120	Down to twenty four hundred and one ninety on the heading Piedmont one thirty --- one twenty
20:04:14 CAM	((Sound of Morse Code IBQC))		
		20:04:17 APP	Piedmont four sixty seven three miles south-east of Hayou continue right turn heading three three zero for intercept maintain two thousand four hundred till established on the localizer cleared ILS approach runway three six right
20:04:20 CAM-2	Identified		
		20:04:26 RDO-2	Okay three three oh on the heading and two point four on the altitude cleared for the three six right approach for Piedmont four sixty seven thank you

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
20:04:38 CAM-2	Can I come on over or not yet		
20:04:39 CAM-1	Yeah boy come on		
CAM-2	Okay, will be right over here one oh eight point five		
CAM-1	Flapers one ((simultaneous with "point five" above))		
CAM-2	Ah checkin' and ah		
20:04:45 CAM-1	Flapers one		
20:04:46 CAM-2	Flaps one		
CAM	((Sound similar to flap handle movement))		
20:04:49 CAM	((Sound of Morse Code IBQC))		
20:04:58 CAM-2	Identified on this side		
20:05:01 CAM-2	Standard callouts ((simultaneous with "gear down" below))		

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	CONTENT
20:05:02 CAM-1	Gear down it's going to be tight		
20:05:03 CAM-2	Glideslope ah --- glideslope and localizer both alive		
		20:05:08 APP	Piedmont four sixty seven contact the tower one one eight point one good day
		20:05:13 RDO-2	Eighteen one Piedmont four sixty seven good day
		20:05:16 APP	Piedmont three six
20:05:17 CAM-2	Okay --- * * *		
20:05:19 CAM-1	Flaps five		
20:05:22 CAM-2	Flaps five		
CAM	((Sound similar to flap handle movement))		
20:05:28 CAM-2	Tower		

INTRA-COCKPIT TIME & SOURCE	INTRA-COCKPIT CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	AIR-GROUND COMMUNICATIONS CONTENT
		20:05:29 RDO-2	Tower Piedmont four sixty seven is with you we're at two point four on the right side approach
		20:05:36 TWR	Piedmont four sixty seven Charlotte Tower runway three six right cleared to land wind one zero zero at four
20:05:39 CAM-?	Gear down		
CAM	((Sound similar to gear handle operation and no smoke chime))		
20:05:40 CAM	((Sound similar to gear extension))		
		20:05:42 RDO-2	Cleared to land Piedmont four sixty seven
20:05:48 CAM-2	And captured *		
CAM	((Sound similar to main stabilizer trim))		
20:05:54 CAM-1	Flaps ten		
20:05:55 CAM-2	Flaps ten		

INTRA-COCKPIT TIME & SOURCE	CONTENT	AIR-GROUND COMMUNICATIONS TIME & SOURCE	CONTENT
20:05:56 CAM	((Altitude alert sound four tones))		
20:05:57 CAM-2	I'll take care of that		
20:06:00 CAM-1	And going down to nine thirty six		
		20:06:04 TWR	Piedmont four sixty seven turn left when ah correction three oh nine turn left when able ground point niner when leaving the runway
CAM-?	* * (I'll say that)		
20:06:09 CAM-1	Flaps fifteen		
20:06:10 CAM-2	Flaps fifteen		
		20:06:15 PI309	Three oh nine
20:06:16 CAM-2	Indicating		
20:06:16 CAM	((Sound of altitude alert))		
		20:06:18 C82	Carolina eighty two three six left ready

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
20:06:20 CAM-2	A thousand above the field	20:06:20 APP	Carolina eighty two contact the tower one two six point four
20:06:22 CAM-1	Yeah --- George didn't do me any favors there	20:06:22 RDO-?	Okay
20:06:24 CAM-1	We'll get back on it in a second		
20:06:26 CAM-2	Not to worry		
20:06:28 CAM-2	Ah get that outta my *		
20:06:33 CAM-1	Flaps twenty five		
20:06:34 CAM-2	Flaps twenty five		
CAM	((Sound similar to flap handle, simultaneous with "flaps" above))		
20:06:37 CAM-2	I'm going to start some lights for you now on the, ah, recall's been checked, the speed brake is manual --- landing gear is down and three green, and flaps --- to go		

INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
CAM-1	* ((simultaneous with "to go" above))		
20:06:48 CAM-1	Flaps thirty		
20:06:50 CAM-2	Flaps coming into thirty		
CAM	((Sound similar to movement of flap handle))		
20:06:52 CAM-2	Okay beginning to get the rabbit you're five hundred above the field		
20:06:55 CAM-2	Little bit of wind guess you got a		
CAM-1	Better get on the wipers		
20:06:58 CAM-2	Okay get you on the wipers now		
20:07:00 CAM	((Sound of windshield wipers))		

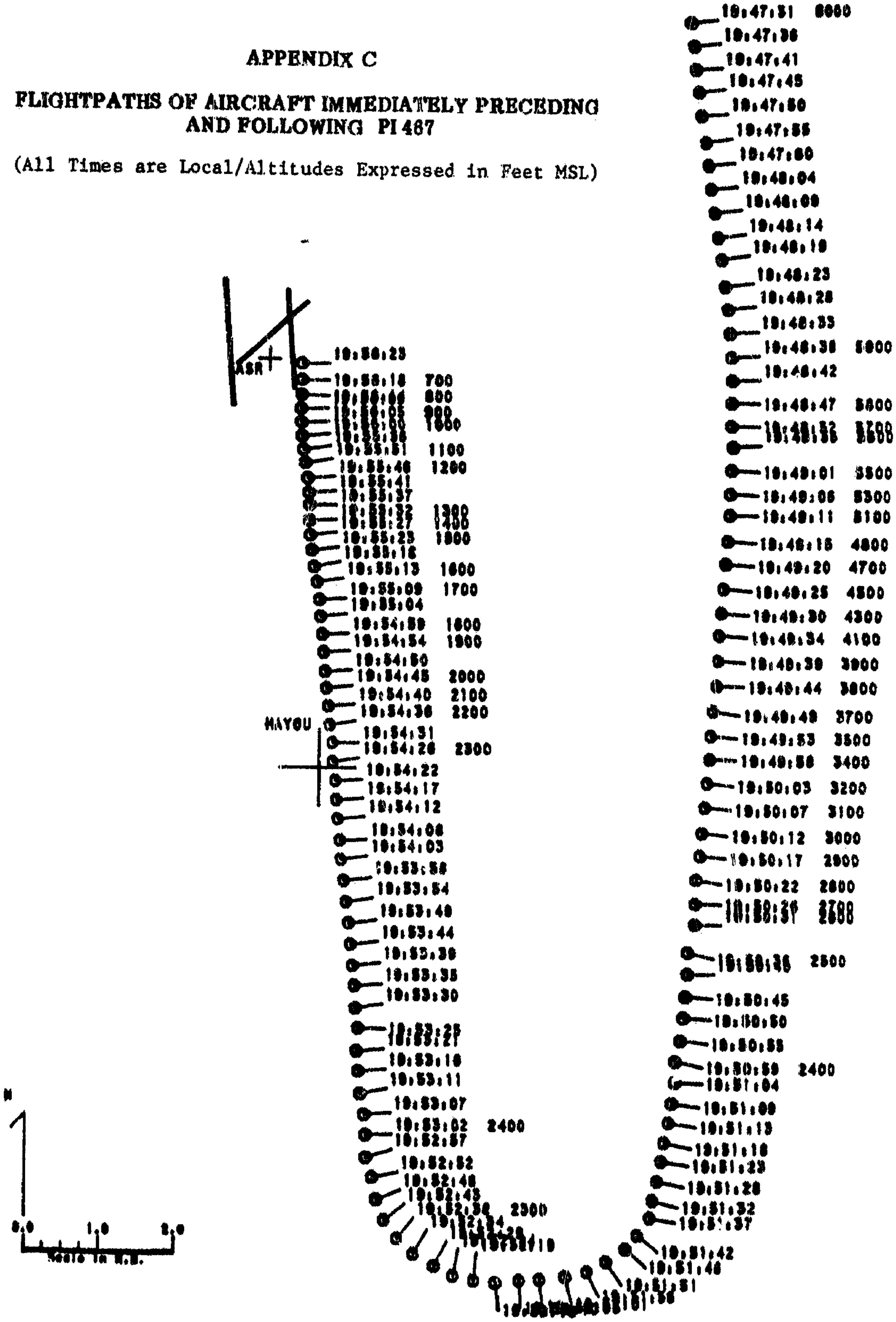
INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
20:07:03 CAM-2	You're a hundred above minimums		
CAM-GPWS	Glideslope ((at "a hundred" above))		
20:07:09 CAM-2	At minimums		
20:07:09 CAM-GPWS	Whoop whoop pull up, whoop whoop pull up, whoop whoop pull up		
CAM-2	Ya hear that ((simultaneous with second "whoop whoop" above))		
20:07:19 CAM	((Sound similar to nose gear touchdown))		
20:07:23 CAM-2	Good show		
20:07:25 CAM-2	Couple of thousand feet to go		
20:07:31 CAM	((Sound of engines begins))		
20:07:36 CAM-2	Hundred knots		

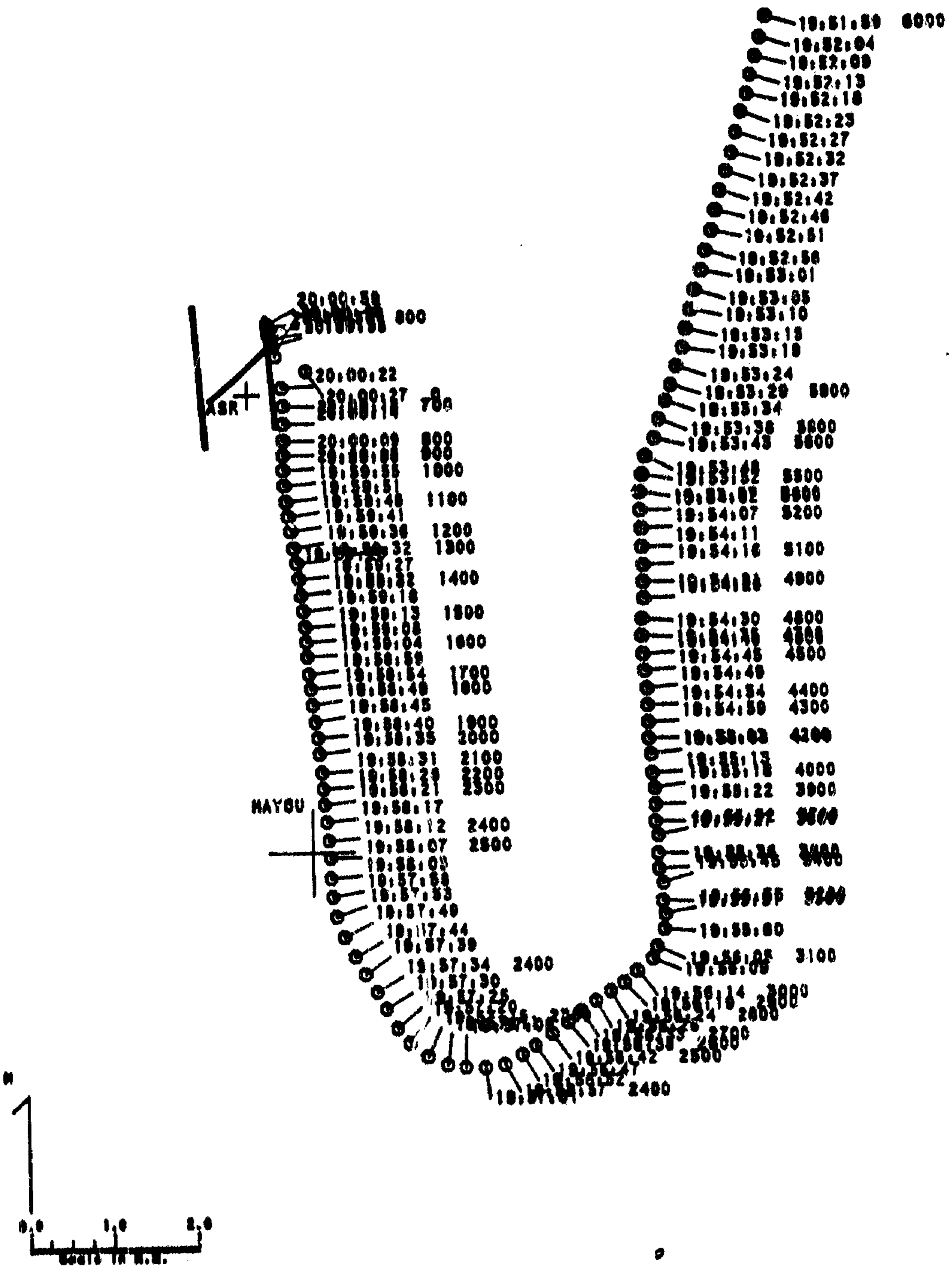
INTRA-COCKPIT		AIR-GROUND COMMUNICATIONS	
TIME & SOURCE	CONTENT	TIME & SOURCE	CONTENT
20:07:39 CAM-2	Eighty		
20:07:42 CAM-2	Hey watch em		
20:07:43 CAM-2	We're gonna get the lights on the overrun		
20:07:45 CAM	((Sound of three impacts))		
20:07:47	((End of Tape))		

APPENDIX C

FLIGHTPATHS OF AIRCRAFT IMMEDIATELY PRECEDING AND FOLLOWING PI 467

(All Times are Local/Altitudes Expressed in Feet MSL)

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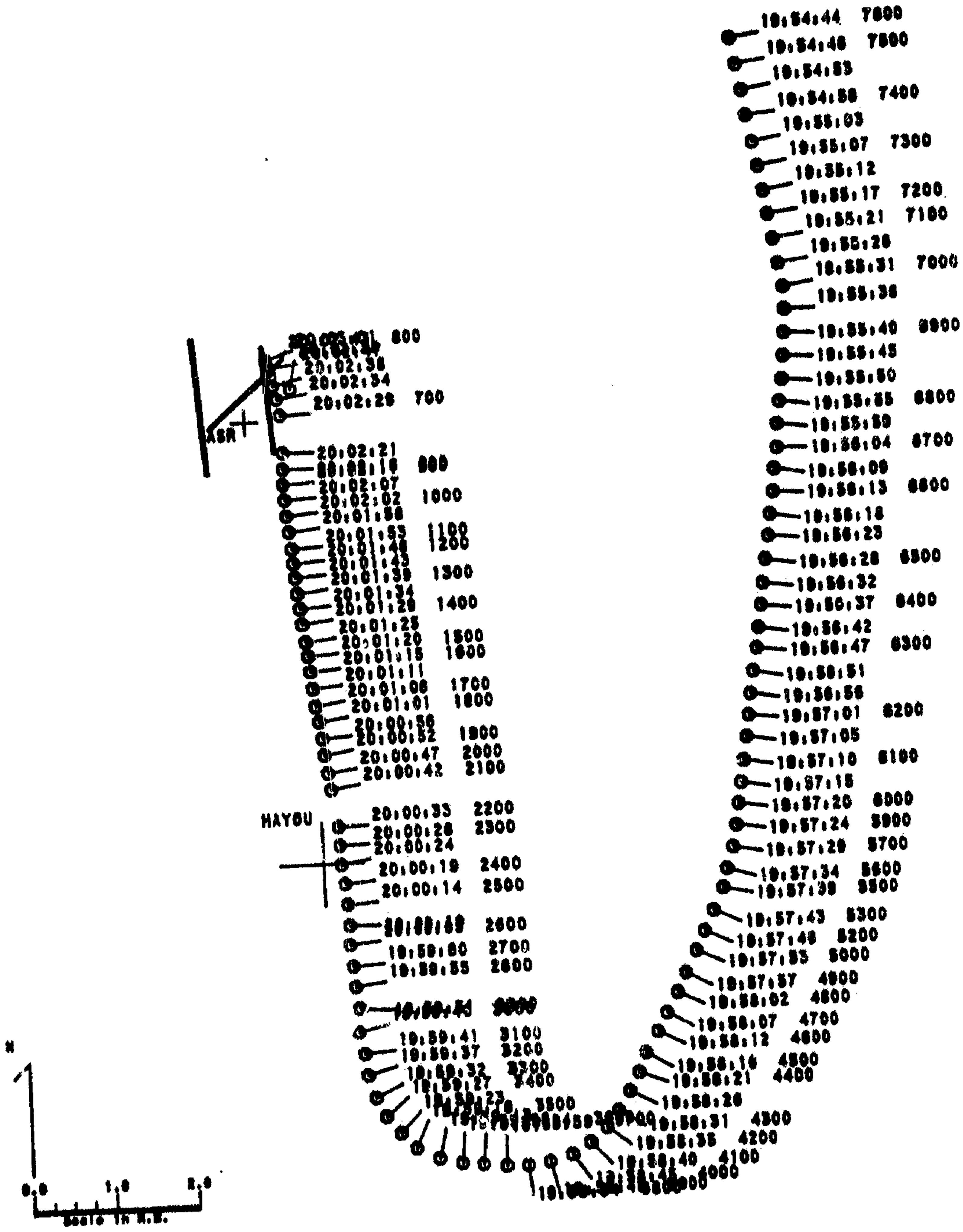
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19:55:26
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19:55:50
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19:56:09
19:56:13 6600
19:56:18
19:56:23
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19:56:37 6400
19:56:42
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19:56:51
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19:57:01 6200
19:57:05
19:57:10 6100
19:57:15
19:57:20 6000
19:57:24 5900
19:57:29 5700
19:57:34 5600
19:57:39 5500
19:57:43 5300
19:57:48 5200
19:57:53 5000
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19:58:12 4600
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19:58:21 4400
19:58:26
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19:59:41 3100
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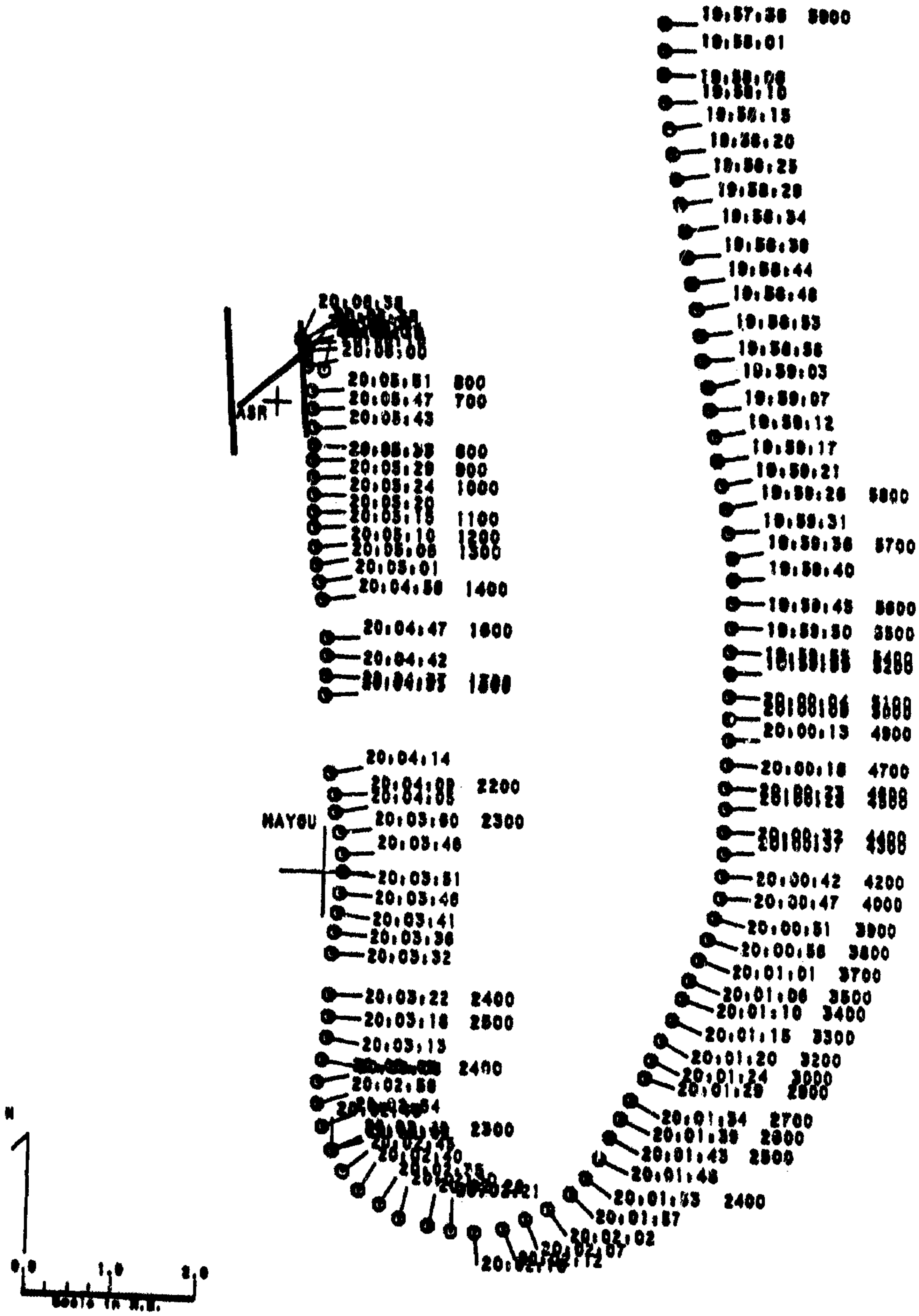
Scale in N.M.

APPENDIX C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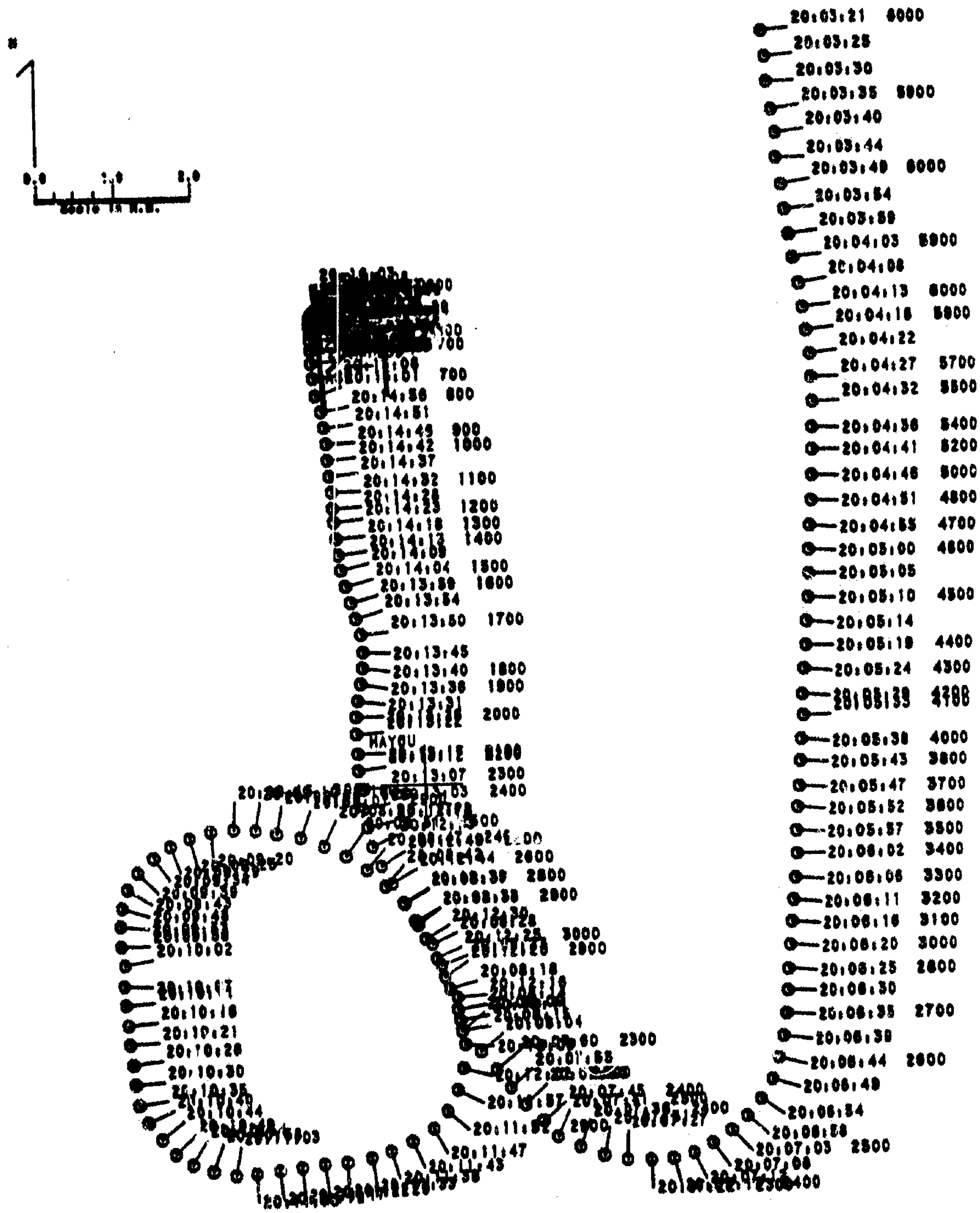
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20:06:25 2800
20:06:30
20:06:35 2700
20:06:39
20:06:44 2600
20:06:49
20:06:54
20:07:03 2500
HAYOU

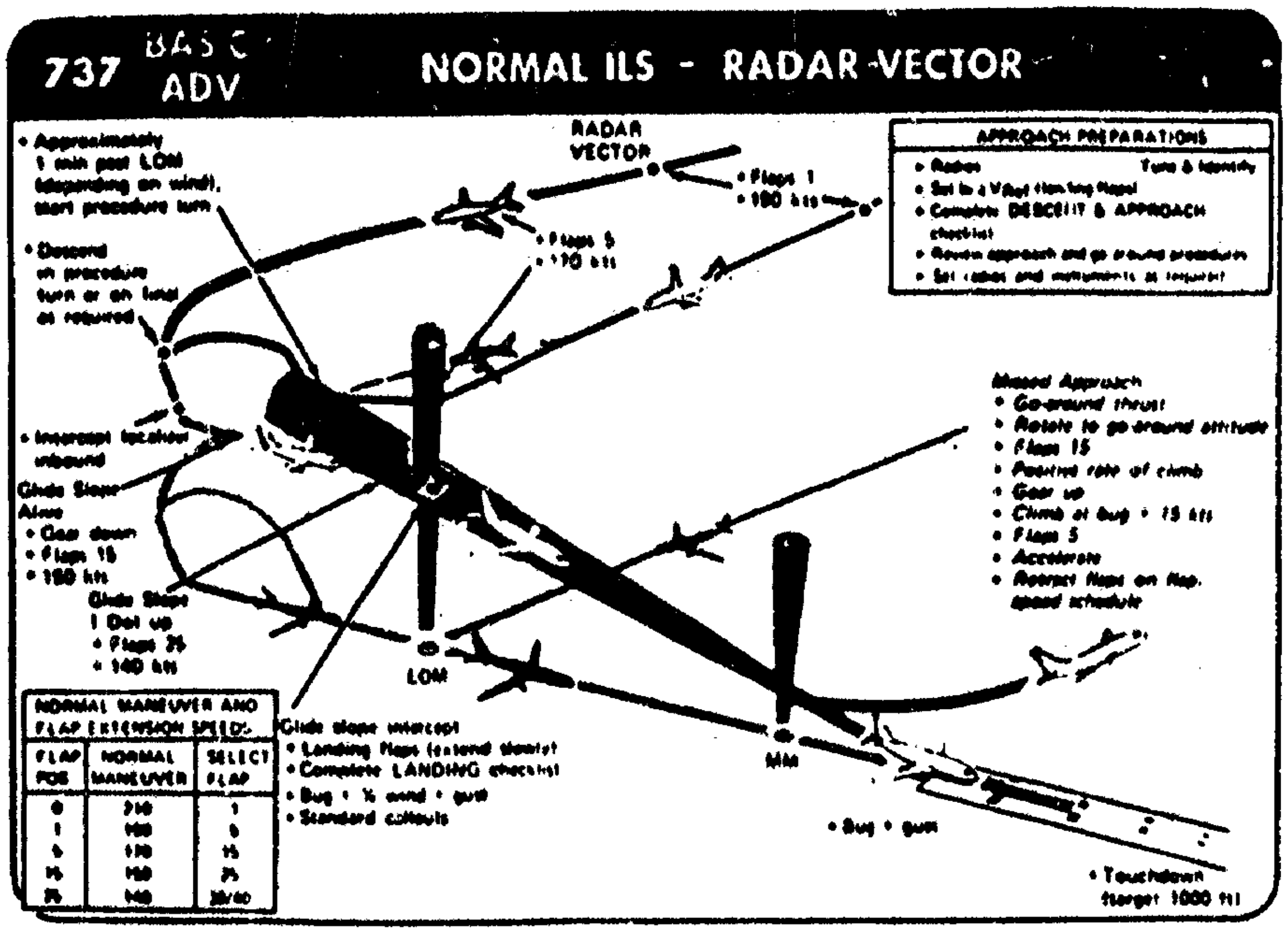
APPENDIX D

SELECTED PROCEDURES FROM PIEDMONT'S B-737 OPERATIONS MANUAL

APPENDIX 4C
Page 2

PIEDMONT

FLIGHT OPERATIONS TRAINING MANUAL PAGE



DESCENT-APPROACH

DESCENT PROCEDURES (Cont'd)

Prior to and during the final approach the following tasks are accomplished, in the relative sequence given, to properly configure the airplane for landing.

PILOT FLYING	PILOT NOT FLYING
Call for flap extension on the flap/speed schedule in accordance with the landing approach requirements.	Position flap lever as directed. Monitor flap extension and leading edge device operation. Execute standard callouts.
Prior to crossing the fix outbound or entering downwind cross-check all flight and navigation instruments, observe all warning flags retracted and all radios tuned to correct frequencies. Complete the approach briefing.	
Call "Gear Down" in accordance with the landing approach requirements. Check landing gear down and locked.	Position landing gear lever DOWN. Observe lights for proper landing gear extension and ANTI-SKID INOP lights extinguished. Auto Brake as required.
Arm speedbrake and check green light illuminated.	Check recall system.
Call for "Landing Checklist down to FLAPS."	Read Landing Checklist down to FLAPS.
Call for landing flap position, and "Complete the Landing Check-list."	Position flap lever as directed and complete the Landing Checklist and state "LANDING Checklist complete."
Check flap position indication and landing flap position and green LE FLAPS EXT light illuminated.	Windshield wipers and landing lights as required.

- The recommended approach speed wind correction is 1/2 the steady headwind component plus all of the gust value, based on tower reported winds. The maximum wind correction should not normally exceed 20 knots. In all cases, the gust correction should be maintained to touchdown while the steady wind correction should be bled off as the aircraft approaches touchdown.

- It is recognized that the actual wind encountered on the approach may vary from that reported by the tower due to terrain or climatic phenomenon. However, unless actual conditions are known, i.e., reported wind shears or known terrain induced turbulence areas, it can be considered reasonable for convenience of operation and to avoid additional cockpit workload to adjust the approach speed by the "1/2 steady wind plus gust" values as reported by the Tower. Headwind corrections are made for any steady wind in the forward 180° arc + 90° on each side of the runway heading.

- When the wind is reported calm or light and variable, and no wind shear exists, Vref + 5 knots is the recommended airspeed on final, bleeding off the 5 knots as the aircraft approaches touchdown.

LANDING

LANDING TECHNIQUES

Flap Extension

Using flaps as speed brakes is not recommended.

The following procedures and maneuvering speeds are used for extending flaps:

FLAP EXTENSION/ MANEUVERING SPEED

NORMAL MANEUVER AND FLAP EXTENSION SPEEDS			
FLAP POSITION	MANEUVERING BELOW 117,000 LB	MANEUVERING ABOVE 117,000 LB	SELECT FLAP
0	210	220	1
1	190	200	5
5	170	180	10/15
10	160	170	15
15	150/VREF	160/VREF	25/30/40
25	140	150	30/40
30	VREF	VREF	—
40	VREF	VREF	---

The only procedures currently in use while Flap 10 during approach are for the One Engine Inoperative non-precision approach (VOR/NDB). Full maneuvering capability is available down to a speed of 150 knots has been selected to provide a more desirable pitch attitude during the approach.

Initial pattern entry: at 210 knots select flaps 1.

At 190 knots, select flaps 5.

Reduce speed to 170 knots.

Lower landing gear passing abeam of end of runway. Select flaps 15.

When landing with flaps 15 and Vref 15 is greater than 150 knots, maintain the higher speed with flaps 15 while maneuvering.

At 150 knots, select flaps 25.

At 140, select landing flap.

Complete LANDING checklist.

Crosswind

The crab, sideslip, or a combination of both are accepted methods for correcting for a crosswind during approach and landing. Regardless of which method is used, there is sufficient rudder and aileron control available to execute crosswind landings.

LANDING

AMPLIFIED LANDING CHECKLIST

The "Landing Checklist down to FLAPS" should be called for by the flying pilot after landing gear has been extended.

Recall .... CHECKED

Pressing and releasing either system annunciator panel will recall any existing abnormal system condition by illuminating the system annunciator light.

Speed Brakes .... ARMED, GREEN LIGHT

Check speed brake lever in armed position and check green SPEED BRAKE ARMED light illuminated.

Gear .... DOWN, 3 GREEN

Check gear lever down, 3 gear indicator lights green and ANTI-SKID INOP light(s) extinguished.

Call for landing flap position and "Complete the landing checklist".

FLAPS .... ____, GREEN LIGHT

Check flaps lever and indicator at flaps ____ and the green LE FLAPS EXT light illuminated.

LANDING Checklist .... COMPLETE

Non-flying pilot will state "The Landing Checklist is complete".

ENGINE FAILURE ON FINAL APPROACH

Loss of an engine on final approach with the airplane in the 2-engine landing configuration is an extremely remote possibility. However, should this situation arise, there is a possibility that the airplane would not be able to maintain a normal glide slope with landing flaps under the most adverse conditions of high headwinds and climb performance limited gross weights. The following is therefore given as a guide to the pilot:

Upon recognition of engine failure, immediately prepare for go-around. Increase thrust on the operative engine, retract flaps to position 15, and accelerate to bug +15 knots, which is at least equal to Vref for flaps 15. The decision on whether to go-around or continue the approach is based on the Captain's judgment, depending mainly on airplane position at engine failure recognition and weather conditions.

If the decision to go-around is made, rotate to go-around attitude and retract gear at positive rate of climb. With gear up and speed at bug +5 knots, subsequent procedure will be the same as for engine failure after V1 on a flaps 15 takeoff.

If the decision to continue the approach is made, follow the 1-engine inoperative landing procedures, adjust power to maintain glide slope and accelerate to bug +15 knots until just prior to touchdown. In the event of a go-around, maintain bug +15 and continue as with normal 1-engine inoperative go-around.

At touchdown use normal stopping technique.

LANDING

LANDING ROLL PROCEDURE

After touchdown and during landing roll, the following procedures are accomplished during normal deceleration.

PILOT FLYING	PILOT NOT FLYING
Thrust Levers - IDLE	
300 Autopilot - DISENGAGE and control airplane manually. 300 Autothrottle disengages automatically. 200 PMS autothrottle must be disengaged prior to 50' AGL.	Ensure autothrottle disengaged.
Check Speed Brake Lever (Ground Spoilers) - FULL UP	Check Speed Brake Lever - - FULL UP
If autobrakes are used and the DISARM/INOP light illuminates - BRAKE MANUALLY	
Reverse Thrust - INITIATE Without delay raise both reverse thrust levers to the interlock, then to reverse thrust detent No. 2. Modulate reverse thrust as required and avoid exceeding engine limits. Conditions permitting, limit reverse thrust to 1.4 EPR (300: 62%) for passenger comfort.	Monitor REVERSER UNLOCKED lights for normal indication. Engine Instruments - Monitor Advise Captain of any engine limit being approached, exceeded or any other abnormalities.
By approx. 60 knts, gradually reduce reverse thrust so as to be at no more than IDLE reverse when reaching taxi speed.	Call out "60 Knots".
At approx. normal taxi speed, slowly move the reverse thrust levers to the full down position.	Call out "60 Knots".
Release autobrakes by applying a light pedal force.	

WARNING: AFTER REVERSE THRUST HAS BEEN INITIATED, A FULL STOP LANDING MUST BE MADE.

200 CAUTION: LOWERING OF THE NOSE SHOULD BE INITIATED BEFORE ACTUATING REVERSE THRUST TO PREVENT THE REVERSER DOORS FROM CONTACTING THE RUNWAY.

ADVERSE WEATHER

HOT WEATHER OPERATION (Cont'd)

Brake Cooling

Flight crews should be aware of brake temperature buildup when operating a series of short flight sectors and attempt to maintain cool brakes by additional in-flight cooling prior to each landing to prevent ground delays resulting from overheated brakes and possible loss of main wheel fuse plugs at enroute stops. A series of short flight sectors without additional in-flight brake cooling can cause excessive brake temperatures as the energy absorbed by the brakes from each landing is accumulative.

Extending the gear a few minutes early in the approach will provide sufficient cooling for a landing with cool tires and brakes. In flight cooling time can be determinedfrom the "Brake Cooling Schedule" in the Performance Section of the Operations Manual.

Close adherence to recommended landing rollout procedures will ensure minimum brake temperature buildup.

LANDING ON WET OR SLIPPERY RUNWAYS

Operate the airplane during the approach in a way that will minimize stopping requirements after touchdown without running the risk of landing short.

Plan for a touchdown 1,000 feet from the approach end of the usable runway. While it is important not to land long, it is more important not to land short of the runway.

Maintain close control over approach speeds and maintain speed recommended for the existing conditions. The recommended wind additives (1/2 steady wind plus full gust to a maximum of 20 knots) provide adequate safety margins for both the approach and the landing roll.

Control glide slope path to accomplish touchdown on the runway at 1,000 feet from the approach end of the runway. The airplane should be flown firmly onto the runway at the aiming point even if speed is excessive. If an unsatisfactory approach is likely to cause touchdown far down the runway, go around and make a second approach. Once the airplane has been landed and the stopping effort begun, attempting a go-around is not recommended.

If the wing anti-ice system is inoperative and large ice formations remain on wing leading edge or leading edge flaps, 10 knots may be added (at pilot's discretion) to the reference speed to maintain normal handling characteristics.

Crosswind

In crosswind conditions, the crosswind crab angle should be maintained to touchdown on very slippery runways. Allowing the airplane to touchdown without removing the crab angle will reduce drift toward the downwind side of the runway on wet or icy runways. Auto spoilers and auto-brakes (if installed) will operate sooner when all main gear touch down simultaneously, thus establishing main gear crab effect sooner and reducing pilot workload.

ADVERSE WEATHER

LANDING ON WET OR SLIPPERY RUNWAYS (Cont'd)

Manual Brake Stopping

Without auto-braking, immediately after nose gear touchdown, apply brakes smoothly and symmetrically with moderate-to-firm pedal pressure and hold until a safe stop is assured. Do not cycle the brake pedals. The brakes and thrust reversers should be applied together. Due to the 3 to 5 seconds delay before buildup of full effective reverse thrust, brakes will normally be operating before reverse thrust.

The anti-skid system will stop the airplane for all runway conditions in a shorter distance than is possible with either anti-skid OFF or brake pedal modulation. The anti-skid system adapts pilot-applied brake pressure to runway conditions by sensing an impending skid condition and adjusting the brake pressure to each individual wheel for maximum braking effort. When brakes are applied on a slippery runway, several skid cycles may occur before the anti-skid system establishes the right amount of brake pressure for the most effective braking.

If the pilot modulates the brake pedals, the anti-skid system is forced to readjust the brake pressure to reestablish optimum braking. During this readjustment time, braking efficiency and runway are lost.

Due to the low available braking co-efficient of friction on extremely slippery runways at high speeds, the pilot is confronted with a rather gradual increase in deceleration and may interpret the lack of an abrupt sensation of deceleration as a total anti-skid failure. His natural response might be to pump the brakes or turn the anti-skid OFF. Either action will degrade braking effectiveness.

Avoid large, abrupt steering and rudder pedal inputs that may lead to overcontrol and skidding. Rudder control is relatively effective down to 60-40 knots. Maintain directional control and wings level with appropriate control inputs. The optimum nose wheel steering angle varies with runway condition and airplane speed and is about 1 to 2 degrees for a very slippery runway. Keep forward pressure on the control column to improve nose wheel steering effectiveness.

Reverse Thrust and Crosswind

The reverse thrust side force and a crosswind can cause the airplane to drift to the downwind side of the runway if the airplane is allowed to weathervane into the wind. As the airplane starts to weathervane into the wind, the reverse thrust side force component adds to the crosswind component and drifts the airplane to the downwind side of the runway. Main gear tire cornering forces available to counteract this drift will be reduced when the anti-skid system is operating at maximum braking effectiveness for existing conditions. To correct back to the centerline, reduce reverse thrust to reverse idle and release the brakes. This will minimize the reverse thrust side force component without the requirement to go through a full reverser actuating cycle, and provide the total tire cornering forces for realignment with the runway centerline. Use rudder, steering and differential braking, as required to prevent overcorrecting past the runway centerline. When reestablished on the runway centerline, reapply steady brakes and reverse thrust as required to stop the airplane.

LANDING ON WET OR SLIPPERY RUNWAYS (Cont'd)

The following chart summarizes the recommended procedure for landing the 737 on wet or slippery runways:

PHASE	RECOMMENDED PROCEDURE	REMARKS
Approach	1. Fly final approach with the airplane positioned on the glide path, runway centerline and at the speed recommended for existing conditions. 2. If installed, arm autobrake system by selecting MED/"3". 3. Arm speedbrakes. 4. Do not be misled by the relative bearing of the runway due to crab angle when breaking out of the overcast. 5. Consider a go-around if zero drift conditions cannot be established prior to flare.	
Flare	1. Do not float or allow drift to build up during flare. 2. Use crab to reduce bank angle and lateral control required and to improve capability in crosswind on slippery runways.	
Touchdown	1. Accomplish a firm touchdown, as near centerline as possible.	A firm touchdown will imp[illegible] wheel spinup on slip[illegible] runways.
	2. Get the wheels on the runway at approximately 1,000 feet from the approach end of the runway. The airplane should be flown firmly onto the runway at the aiming point even if the speed is excessive.	Deceleration on the runway is about three times greater than in the air. Do not allow the airplane to float in the air to bleed off speed.
	3. If a touchdown far down the runway is likely, consider a go-around.	
Transition to Braking Configuration (Expedite All Items)	1. Check that the speedbrakes deploy immediately after main gear touchdown.	If the speedbrake lever fails to actuate automatically, immediately actuate it manually. Speedbrakes release approximately 70% of wing lift.
	2. Immediately lower the nose wheels and hold on the runway with light forward control column pressure.	Decreases lift, increases main gear loading, improves wheel spinup and directional stability. Aerodynamic braking is relatively ineffective.
	3. Immediately select reverse thrust.	Reverse thrust is the most efficient means of deceleration at high speed.
	4. Without auto braking, immediately after gear touchdown, smoothly apply moderate-to-firm, steady breaking until a safe stop is assured. 5. The autobrake system will begin symmetrical braking after wheel spin up. Either pilot can disarm the system and take over manual braking at any time by applying normal pedal braking.	Do not cycle brake pedals.

LOW LEVEL WIND SHEAR
(FAA AC 00-50A)

Wind shear is best described as a change in wind direction and/or speed in a very short distance in the atmosphere. Under certain conditions, the atmosphere is capable of producing some dramatic shears very close to the ground; for example, wind direction changes of 180 degrees and speed changes of 50 knots or more within 200 feet of the ground have been observed. It has been said that wind cannot affect an aircraft once it is flying except for drift and groundspeed. However studies have shown that this is not true if the wind changes faster than the aircraft mass can be accelerated or decelerated.

The most prominent meteorological phenomena that cause significant low level wind shear problems are thunderstorms and certain frontal systems at or near the airport.

METEOROLOGY

Thunderstorms

The winds around a thunderstorm are complex (Figure 1). Wind shear can be found on all sides of a thunderstorm cell and in the downdraft directly under the cell. The wind shift line or gust front associated with thunderstorms can precede the actual storm by 15 nautical miles or more. Consequently, if a thunderstorm is near an airport of intended takeoff or landing, low level wind shear hazards may exist.

Fronts

The winds can be significantly different in the two air masses which meet to form a front. While the direction of the winds above and below a front can be accurately determined, existing procedures do not provide precise, current measurements of the height of the front above the airport. The following is a method for determining the approximate height of the wind shear associated with a front.

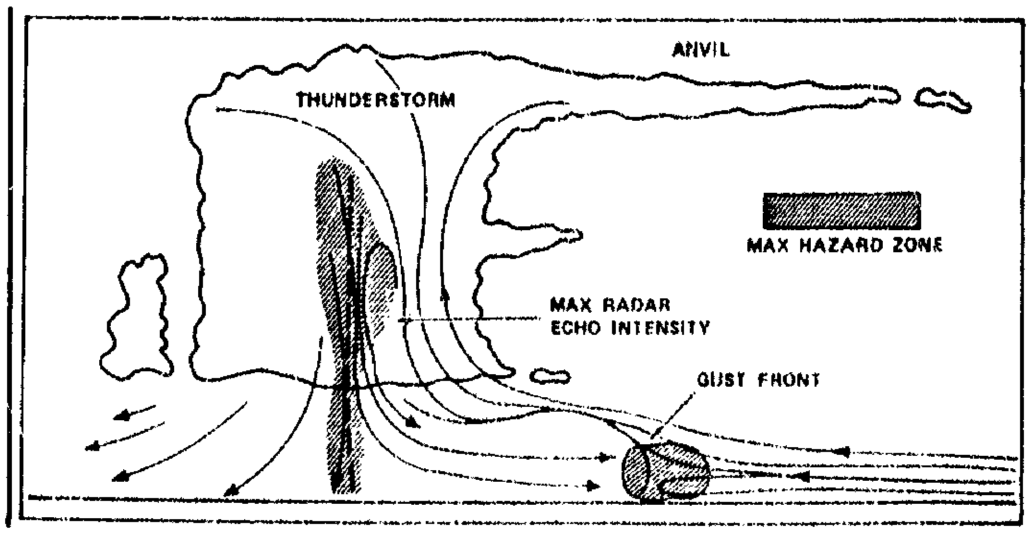


Figure 1.
THUNDERSTORM HAZARD ZONES

LOW LEVEL
WIND SHEAR

Fronts (Cont)

- Wind shear occurs with a cold front just after the front passes the airport and for a short period thereafter. If the front is moving 30 knots or more, the frontal surface will usually be 5,000 feet above the airport about three hours after the frontal passage.
- With a warm front, the most critical period is before the front passes the airport. Warm front shear may exist below 5,000 feet for approximately six hours. The problem ceases to exist after the front passes the airport. Data compiled on wind shear indicates that the amount of shear in warm fronts is much greater than that found in cold fronts.
- Turbulence may or may not exist in wind shear conditions. If the surface wind under the front is strong and gusty, there will be some turbulence associated with wind shear.

Strong Surface Winds.

The combination of strong winds and small hills or large buildings that lie upwind of the approach or departure path can produce localized areas of shear. Observing the local terrain and requesting pilot reports of conditions near the runway are the best means for anticipating wind shear from this source. This type of shear can be particularly hazardous to light airplanes.

Sea Breeze Fronts.

The presence of large bodies of water can create local airflows due to the differences in temperature between the land and water. Changes in wind velocity and direction can occur in relatively short distances in the vicinity of airports situated near large lakes, bays or oceans.

Mountain Waves.

These weather phenomena often create low level wind shear at airports that lie downwind of the wave. Altocumulus standing lenticular (ACSL) clouds usually depict the presence of mountain waves, and they are clues that shear should be anticipated.

DETECTING WIND SHEAR.

Airplanes may not be capable of safely penetrating all intensities of low level wind shear. Pilots should, therefore, learn to detect, predict, and avoid severe wind shear conditions. Severe wind shear does not strike without warning. It can be detected by the following methods:

Analyze the weather during preflight.

- If thunderstorms are observed or forecast at or near the airport, be alert for the possibility of wind shear in the departure or arrival areas.

- Check the surface weather charts for frontal activity. Determine the surface temperature difference immediately across the front and the speed at which the front is moving. A 10° F (6°C) or greater temperature differential, and/or a frontal speed of 30 knots or more, is an indication of the possible existence of significant low level wind shear.

Be aware of pilot reports (PIREPS) of wind shear. Part 1 of the Airman's Information Manual recommends that pilots report any wind shear encounter to Air Traffic Control. This report should be in specific terms and include the loss/gain of airspeed due to the shear and the altitude(s) at which it was encountered. For example: "Denver tower, Cessna 1234 encountered wind shear, loss of 20 knots at 400 feet." This simple report is extremely important so that the pilot of the next airplane in sequence can determine the safety of transiting the same location. Reported shear that causes airspeed losses in excess of 15 to 20 knots should be avoided. Reported shears associated with a thunderstorm should also be avoided due to the speed which some storms move across the ground. The storm movement can cause one aircraft to encounter an airspeed increase which may appear harmless where the next aircraft can encounter a severe airspeed loss.

Assume that severe wind shear is present when the following conditions exist in combination:

- Extreme variations in wind velocity and direction in a relatively short time span.
- Evidence of a gust front such as blowing dust on the airport surface.
- Surface temperature in excess of 80°F.
- Dew point spread of 40°F or more.
- Virga (precipitation that falls from the bases of high altitude cumulus clouds but evaporates before reaching the ground).

Examine the approach or takeoff area with the airplane's radar set to determine if thunderstorm cells are in the vicinity of the airport. A departure or approach should not be flown through or under a thunderstorm cell.

Use the airplane instruments to detect wind shear.

- Pilots flying airplanes equipped with inertial navigation system (INS) should compare the winds at the initial approach altitude (1500-2000' above ground level (AGL)) with the reported runway surface winds to see if there is a wind shear situation between the airplane and the runway.
- If frontal activity does exist, note the surface direction to determine the location of the front with respect to the airport. If the airplane will traverse the front, compare the surface wind direction and speed with the wind direction and speed above the front to determine the potential wind shear during climbout or approach.
- Pilots flying airplanes equipped with a device which reads out groundspeed should compare the airplane's groundspeed with its airspeed. Any rapid changes in the relationship between airspeed and groundspeed represents a wind shear. Some operators have adopted the procedure of not allowing their aircraft to slow below a precomputed minimum groundspeed on approach. The minimum is computed by subtracting the surface headwind component from the true airspeed on approach.

LOW LEVEL
WIND SHEAR

DETECTING WIND SHEAR (CONT)

- Pilots flying airplanes which do not have INS or groundspeed readouts should closely monitor their airplane's performance when wind shear is suspected. When the rate of descent on an ILS approach differs from the nominal values for the aircraft, the pilot should beware of a potential wind shear situation. Since rate of descent on the glide slope is directly related to groundspeed, a high descent rate would indicate a strong tailwind; conversely, a low descent rate denotes a strong headwind. The power needed to hold the glide slope also will be different from typical, no-shear conditions. Less power than normal will be needed to maintain the glide slope when a tailwind is present and more power is needed for a strong headwind. Aircraft pitch attitude is also an important indicator. A pitch attitude which is higher than normal is a good indicator of a strong headwind and vice versa. By observing the aircraft's approach parameters - rate of descent, power, and pitch attitude - the pilot can obtain a feel for the wind he is encountering. Being aware of the wind-correction angle needed to keep the localizer needle centered provides the pilot with an indication of wind direction. Comparing wind direction and velocity at the initial phases of the approach with the reported surface winds provides an excellent clue to the presence of shear before the phenomenon is actually encountered.

Utilize the Low Level Wind Shear System (LLWSAS) at airports where it is available. LLWSAS consists of five or six anemometers around the periphery of the airport, which have their readouts automatically compared with the center field anemometer. If a wind vector difference of 15 knots or more exists between the center field anemometer and any peripheral anemometer, the tower will let the pilot know the winds from both locations. The pilot then may assess the potential for wind shear. An example of a severe wind shear would be the following: "Center field wind is 230 degrees at 7 knots; wind at the north end of Runway 35 is 180 degrees at 60 knots." In this case, a pilot departing on runway 35 would be taking off into an increasing tailwind condition that would result in significant losses of airspeed and, consequently, altitude.

AIRPLANE PERFORMANCE IN WIND SHEAR

The following information provides a basis for understanding the operational procedures recommended in this circular.

Power Compensation

Serious consequences may result on an approach when wind shear is encountered close to the ground after power adjustments have been already made to compensate for wind. Figures 2 and 3 illustrate the situations when power is ap-

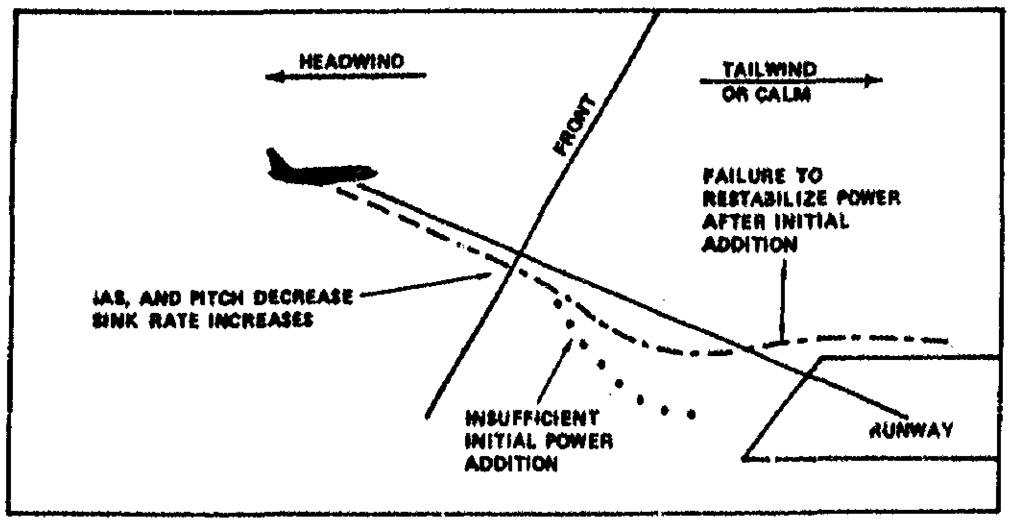


Figure 2.

HEADWIND SHEARING TO TAILWIND OR CALM

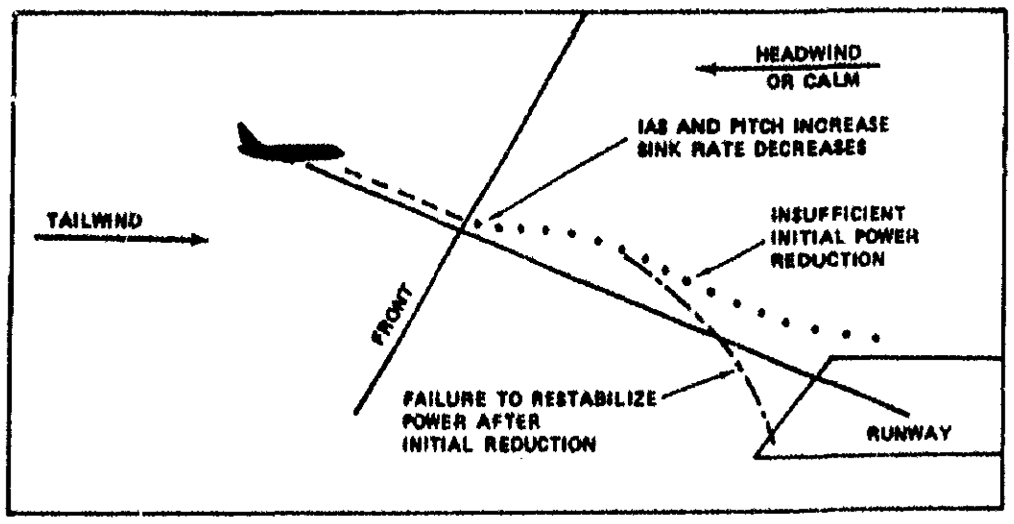


Figure 3.

TAILWIND SHEARING TO HEADWIND OR CALM

LOW LEVEL WIND SHEAR

Power Compensation (Cont)

plied or reduced to compensate for the change in aircraft performance caused by wind shear.

- Consider an aircraft flying a 3° ILS on a stabilized approach at 140 knots indicated airspeed (IAS) with a 20-knot headwind. Assume that the aircraft encounters an instantaneous wind shear where the 20-knot headwind shears away completely. At that instant, several things will happen; the airspeed will drop from 140 to 120 knots, the nose will begin to pitch down, and the aircraft will begin to drop below the glide slope. The aircraft will then be both slow and low in a "power deficient" state. The pilot may then pull the nose up to a point even higher than before the shear in an effort to recapture the glide slope. This will aggravate the airspeed situation even further until the pilot advances the throttles and sufficient time elapses at the higher power setting for the engines to replenish the power deficiency. If the aircraft reaches the ground before the power deficiency is corrected, the landing will be short, slow, and hard. However, if there is sufficient time to regain the proper airspeed and glide slope before reaching the ground, then the "double reverse" problem arises. This is because the throttles are set too high for a stabilized approach in a no-wind condition. So, as soon as the power deficiency is replenished, the throttles should be pulled back even further than they were before the shear (because power required for a 3° ILS in no wind is less than for a 20-knot headwind). If the pilot does not quickly retard the throttles, the aircraft will soon have an excess of power; i.e., it will be high and fast and may not be able to stop in the available runway length (Figure 2).
- When on approach in a tailwind condition that shears into a calm wind or headwind, the reverse of the previous statements is true. Initially, the IAS and pitch will increase and the the aircraft will balloon above the glide slope. Power should initially be reduced to correct this condition or the approach may be high and fast with a danger of overshooting. However, after the initial power reduction is made and the aircraft is back on speed and glide slope, the "double reverse" again comes into play. An appropriate power increase will be necessary to restabilize in the headwind. If this power increase is not accomplished promptly, a high sink rate can develop and the landing may be short and hard (Figure 3). The double reverse problem arises primarily in downdraft and frontal passage shears. Other shears may require a consistent correction throughout the shear.
- The classic thunderstorm "downburst cell" accident is illustrated in Figure 4. There is a strong downdraft in the center of the cell. There is often heavy rain in this vertical flow of air. As the vertical air flow nears the ground it turns 90 degrees and becomes a strong horizontal wind, flowing radially outward from the center. Point A in Figure 4 represents an aircraft which has not entered the cell's flow field. The aircraft is on speed and on glide slope. At Point B the aircraft encounters an increasing headwind. Its airspeed increases, and it balloons above the glide slope. Heavy rain may begin shortly. At Point C the "moment of truth" occurs. If the pilot does not fully appreciate the situation, he may attempt to regain the glide slope and lose excess airspeed by reducing power and pushing the nose down. Then in the short span of time between Points C and D the

headwind ceases, a strong downdraft is entered and a tailwind begins increasing. The engines spool down, the airspeed drops below V_{ref}, and the sink rate becomes excessive. A missed approach initiated from this condition may not be successful. Note that a missed approach initiated at Point C (or sooner) would probably be successful since the aircraft is fast and high at this point. Note also that the pilot of an aircraft equipped with a groundspeed would see the telltale signs of a downburst cell shortly after Point B; i.e., rapidly increasing airspeed with decreasing groundspeed.

Angle of Attack in a Downdraft

Downdrafts of falling air in a thunderstorm (sometimes called a "downburst") have gained attention in the last few years due to their role in wind shear accidents. When an airplane flies into a downdraft, the relative wind shifts so as to come down from above the horizon. This decreases angle of attack, which in turn decreases lift, and the airplane starts to sink rapidly. In order to regain the angle of attack necessary to support the weight of the airplane, the pitch attitude must be significantly increased. Such a pitch attitude may seem uncomfortably high to a pilot. However, a normal pitch attitude will result in a continued sink rate. The wing produces lift based on angle of attack - not pitch attitude. Caution should be observed when a pilot has traversed a downdraft and has pitched up sufficiently to stop the sink rate. If that pilot does not lower the nose of the airplane quickly when it exits the downdraft, the angle of attack will become too large and may approach the stall angle of attack. For these reasons, a flight director which senses angle of attack will be preferable to a flight director which calls for a fixed pitch attitude in a downdraft. However, even an angle of attack based flight director may become ineffective if it has an arbitrary pitch up command limit which is set to low (with respect to the downdraft).

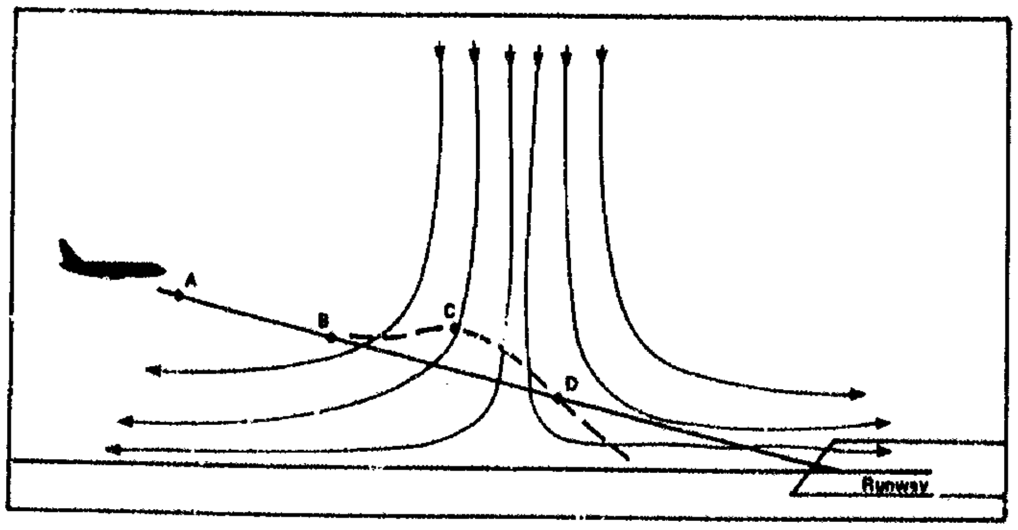


Figure 4.
DOWNDRAFT SHEAR

LOW LEVEL WIND SHEAR

Climb Performance

In the takeoff and landing configurations, jet transports climb best at speeds near V_2 and V_{ref} (reference speed with landing flaps), respectively. Retracting gear and flaps will even further improve climb performance. However, jet transport airplane manufacturers have pointed out that their airplanes still have substantial climb performance (generally in excess of 1000 fpm) at speeds down to stall warning or stick shaker speed, Vss.

Energy Trade

There are only two ways an aircraft can correct for a wind shear. There can be an energy trade or a thrust change. Historically, most pilots have opted for a thrust change since they had no idea how much an energy trade would benefit them. Further information on the energy of flight, therefore, is warranted.

- The energy of motion (kinetic energy) is equal to 1/2 MV^2 where M is the mass of the airplane and V is the velocity. Kinetic energy is directly convertible to energy of vertical displacement (potential energy). More simply put, airspeed can be traded for altitude or vice versa. It is important to note that adding 10 percent to the speed of the airplane results in a 21 percent increase in kinetic energy because of the velocity being squared. This, of course, explains the concern over stopping an aircraft on the available runway when additional speed is added.

- The following table shows the altitude conversion capability of trading 10 or 20 knots of speed for altitude at various initial speeds. Independent of its mass, the capability of the aircraft to trade airspeed for altitude increases as its initial speed increases.

10 Knot Change From - To	Equivalent Altitude, Ft.
150-140	123
140-130	119
130-120	111
120-110	102
110-100	93

20 Knot Change From - To	Equivalent Altitude, Ft.
150-130	247
140-120	230
130-110	212
120-100	195
110-90	177

Trading Altitude for Speed

A pilot caught in a low level wind shear who finds he is slower than the normal airspeed (even though he has gone to max power) could lower the nose and regain speed by trading away altitude. (This is trading potential energy for kinetic energy.) However, data shows that the penalty for doing this is severe; i.e., a large sink rate is built up and a great deal of altitude is lost for a relatively small increase in airspeed. Therefore, at low altitudes this alternative becomes undesirable. It is preferable to maintain the lower airspeed and rely on the airplane's climb performance at these lower speeds than to push the nose over and risk ground contact. Flight directors which attempt to maintain a given speed (such as V_2 + 10, etc.) will automatically call for trading altitude for airspeed if the airplane is below the proper airspeed. Cases have been observed in simulators where following such a flight director will result in the pilot flying the airplane into the ground. It is the pilot - not the flight director - who should decide if trading altitude for speed is desirable.

Trading Speed for Altitude

Conversely, a pilot caught in low level wind shear may pull the nose up and trade speed for altitude; i.e., trade kinetic energy for potential energy. If the speed is above V_2 or V_{ref} (as applicable), then this trade may well be desirable. If at or below V_2 or V_{ref}, such a trade should be attempted only in extreme circumstances. In doing so, the pilot is achieving a temporary increase in climb performance. After he has traded away all the airspeed he desired to trade, he will then be left with a permanent decrease in climb performance. In addition, if ground contact is still inevitable after the trade, there may be no airspeed margin left with which to flare in order to soften the impact. Wind shear simulations have shown, however, that in many cases trading airspeed for altitude (down to V_{ss}) prevented an accident, whereas maintaining V_{ref} resulted in ground impact.

Adding Speed for Wind Shear

The possibility of having to trade speed for altitude in wind shear makes it attractive to carry a great deal of extra speed. However, on landing, if the airspeed margin is not used up in the shear and the airplane touches down at an excessive speed, the airplane may not be able to stop on the available runway. It is generally agreed that if a speed margin in excess of 20 knots above V_{ref} appears to be required, the approach should not be attempted or continued.

Difficulties of Flying Near V_{ss}

A previous paragraph stated that in simulations, wind shear "accidents" had been prevented by trading speed for altitude all the way down to V_{ss}. There are difficulties associated with flying at or near V_{ss} which should be recognized. These include:

- The pilot often does not know V_{ss}.
- The stickshaker mechanism may be miscalibrated (especially on older aircraft).
- The downdraft velocity may vary, which requires a change in pitch attitude to hold speed.
- It is hard to fly a precise airspeed in turbulence, which is often associated with wind shear.
- Turbulence might abruptly decrease the airspeed from V_{ss} to V_s.
- Pilots have historically had little training in maintaining flight at or near V_{ss}.

LOW LEVEL
WIND SHEAR

PROCEDURES FOR COPING WITH WIND SHEAR

The most important elements for the flight crew in coping with a wind shear environment are the crew's awareness of an impending wind shear encounter and the crew's decision to avoid an encounter or to immediately respond if an encounter occurs.

Takeoff

If wind shear is expected on takeoff, the PIREPS and weather should be evaluated to determine if the phenomena can be safely traversed within the capability of the airplane. This is a judgment on the part of the pilot based on many factors. Wind shear is not something to be avoided at all costs, but rather to be assessed and avoided if severe. Some rules of thumb for coping with wind shear on takeoff follow:

- An increasing headwind or decreasing tailwind will cause an increase in indicated airspeed. If the wind shear is great enough, the aircraft will initially pitch up due to the increase in lift. The pilot should not trim the airplane at the initial high pitch attitude. After encountering the shear, if the wind remains constant, aircraft groundspeed will gradually decrease and indicated airspeed will return to its original value. This situation would normally lead to increased aircraft performance so it should not cause a problem if the pilot is aware of how this shear affects the aircraft.

- The worst situation on departure occurs when the aircraft encounters a rapidly increasing tailwind, decreasing headwind, and/or downdraft. Taking off under these circumstances would lead to a decreased performance condition. An increasing tailwind or decreasing headwind, when encountered, will cause a decrease in indicated airspeed. The aircraft will initially pitch down due to the decreased lift in proportion to the airspeed loss. After encountering the shear, if the wind remains constant, aircraft groundspeed will gradually increase and indicated airspeed will return to its original value.

- When the presence of severe wind shear is suspected for departure, the pilot should delay takeoff until conditions are more favorable.

- If the pilot judges the takeoff wind shear condition to be safe for departure, he should select the safest runway available considering runway length, wind directions, speed, and location of storm areas or frontal areas. He should execute a maximum power takeoff using the minimum acceptable flap position. After rotation, the pilot should maintain an airplane body angle which will result in an acceleration to V_2 + 25. This speed and takeoff flaps should be held through 1,000 feet AGL. Above 1,000 feet the normal noise abatement profile should be flown. If preflight planning shows that the airplane is runway length limited, or obstruction clearance is a problem, taking off into even a light shear using the V_2 + 25 procedure should not be attempted. This is because too much of the thrust available for climb is used for acceleration, resulting in the V_2 + 25 flight path falling below the engine-out flight path at V_2. This would give insufficient clearance for an obstacle in close proximity to the departure end of the runway.

LOW LEVEL WIND SHEAR

If severe wind shear is encountered on takeoff, the pilot should immediately confirm that maximum rated thrust is applied and trade the airspeed above V_2 (if any) for an increased rate of climb. Depending on the airplane's gross weight, pitch attitudes of 15 to 22 degrees are to be expected during this energy trade, especially if a downdraft is present. A sudden decrease in headwind will cause a loss in airspeed equal to the amount of wind shear. At this point, the pilot should quickly evaluate his airplane's performance in the shear. He/she should monitor airspeed and vertical velocity to ensure that an excessive rate of descent does not develop. If it becomes apparent that an unacceptable rate of descent cannot be prevented at V_2 speed or ground contact appears to be certain at the current descent rate, the pilot should gradually increase the airplane's pitch attitude to temporarily trade airspeed for climb capability to prevent further altitude loss. The trade should be terminated when stickshaker is encountered. The airplane should be held in an attitude that will maintain an airspeed just above the airspeed where the stickshaker was initially encountered. A general rule is to reduce pitch attitude very slightly when stickshaker is encountered. Further pitch reductions in the shear could result in a large descent rate. As the airplane departs the shear, the pilot should reduce the pitch attitude and establish a normal climb. In several recent wind shear accidents, the National Transportation Safety Board (NTSB) has found that the full performance capability of the airplane was not used following a severe wind shear encounter. Post accident studies have shown that, under similar circumstances, had flight techniques of an emergency nature (such as those outlined above) been used immediately, the airplane could have remained airborne and the accident averted.

__Approach to Landing__

Considerations involved in flying an approach and landing or go-around at an airport where wind shear is a factor are similar to those discused for takeoff.

- When wind shear weather analysis, PIREPS, or an analysis of airplane performance indicates that a loss of airspeed will be experienced on an approach, the pilot should add to the V_{ref} speed as much airspeed as he expects to lose up to a maximum of V_{ref} + 20. If the expected loss of airspeed exceeds 20 knots the approach should not be attempted unless the airplane is specially instrumented and the pilots are specially trained. The pilot should fly a stabilized approach on a normal glidepath (using an electronic glidepath and the autopilot when available). In the shear when airspeed loss is encountered, a prompt and vigorous application of thrust is essential, keeping in mind that if airspeed has been previously added for the approach, the thrust application should be aimed at preventing airspeed loss below V_{ref}. An equally prompt and vigorous reduction in thrust is necessary once the shear has been traversed and normal target speed and glidepath are reestablished to prevent exceeding desired values. Early recognition of the need for thrust is essential. Along with the thrust addition is a need for a nose-up rotation to minimize departure be-

LOW LEVEL
WIND SHEAR

Approach to Landing (Cont)

low the glidepath. If the airplane is below 500 feet AGL and the approach becomes unstable, a go-around should be initiated immediately. Airspeed fluctuations, sink rate, and glide slope deviation should be assessed as part of this decision.

- A pilot's chances of safely negotiating wind shear are better if he/she remains on instruments. Visual references through a rain-splattered windshield and reduced visibility may be inadequate to provide him/her with cues that would indicate deviation from the desired flightpath. At least one pilot should, therefore, maintain a continuous instrument scan until a safe landing is assured.

- Some autothrottle systems may not effectively respond to airspeed changes in a shear. Accordingly, the thrust should be monitored closely if autothrottles are used. Pilots should be alert to override the autothrottles if the response to increased thrust commands is too slow. Conversely, thrust levers should not be allowed to get too low during the late stages of an approach as this will increase the time needed to accelerate the engines.

- Should a go-around be required the pilot should initiate a normal go-around procedure, evaluate the performance of his airplane in the shear, and follow the procedures outlined in the takeoff section of this manual as applicable.

SUMMARY

The following summarizes the critical steps in coping with low level wind shear.

Be Prepared

Use all available forecasts and current weather information to anticipate wind shear. Also, make your own observations of thunderstorms, gust fronts and telltale indicators of wind direction and velocity available to pilots.

Giving and Requesting PIREPS

Giving and requesting PIREPS on wind shear are essential. Request them and report anything you encounter. PIREPS should include:

- Location of shear encounter.
- Altitude of shear encounter.
- Airspeed changes experienced, with a clear statement of:
  - The number of knots involved;
  - Whether it was a gain or loss of airspeed.
- Type of aircraft encountering the shear.

Avoid Known Areas of Severe Shear

When the weather and pilot reports indicate that severe wind shear is likely, delay your takeoff or approach.

LOW LEVEL
WIND SHEAR

Know Your Aircraft

Monitor the aircraft's power and flight parameters to detect the onset of a shear encounter. Know the performance limits of your particular aircraft so that they can be called upon in such an emergency situation.

Act Promptly

Do not allow a high sink rate to develop when attempting to recapture a glide slope or to maintain a given airspeed. When it appears that a shear encounter will result in a substantial rate of descent, promptly apply full power and arrest the descent with a noseup pitch attitude.

APPENDIX E

PERSONNEL INFORMATION

Richard H. Givens-Captain

The captain, 37, was employed by Piedmont Airlines on May 1, 1980. He held airline transport pilot certificate No. 2134896 with CE-500, FK-28, and B-737 type ratings and an airplane multiengine land rating. His first class medical certificate, dated April 10, 1986, contained no waivers or limitations.

At the time of the accident, the captain had accrued approximately 10,000 total flight-hours, of which about 2,500 were accrued in the Boeing 737. In the previous 90 days, 30 days, and 24 hours, the captain had flown 174, 58.9 and 1.7 hours respectively.

Joel K. Horwich-First Officer

The first officer, 29, was employed by Piedmont Airlines on June 21, 1984. He held airline transport pilot rating No. 223803898 with an airplane multiengine land rating. His first class medical certificate, dated January 23, 1986, contained no waivers or limitations.

At the time of the accident, the first officer had accrued about 4,100 total flight-hours, of which about 500 were accrued in the Boeing 737. In the previous 90 days, 30 days, and 24 hours, the first officer had flown 146, 43.8 and 1.7 hours, respectively.

APPENDIX F

AIRCRAFT INFORMATION

The airplane, a Boeing 737-222, United States Registry N752N, Serial No. 19073, was manufactured on November 4, 1968, and placed into service by United Airlines. It was acquired by Piedmont Airlines on June 8, 1973, and placed into service on July 31, 1973. The airframe had accrued 41,714.2 hours total time in 59,033 cycles at the time of the accident.

The airplane was powered by two Pratt & Whitney JT8D-9A engines.

Engines	No. 1	No. 2
Serial No.	P655883B	P655919B
Date Installed	7-15-86	5-19-86
Total Time	30,321	36,139
Total Cycles	43,171	51,936
Time Since Overhaul	635	1,045

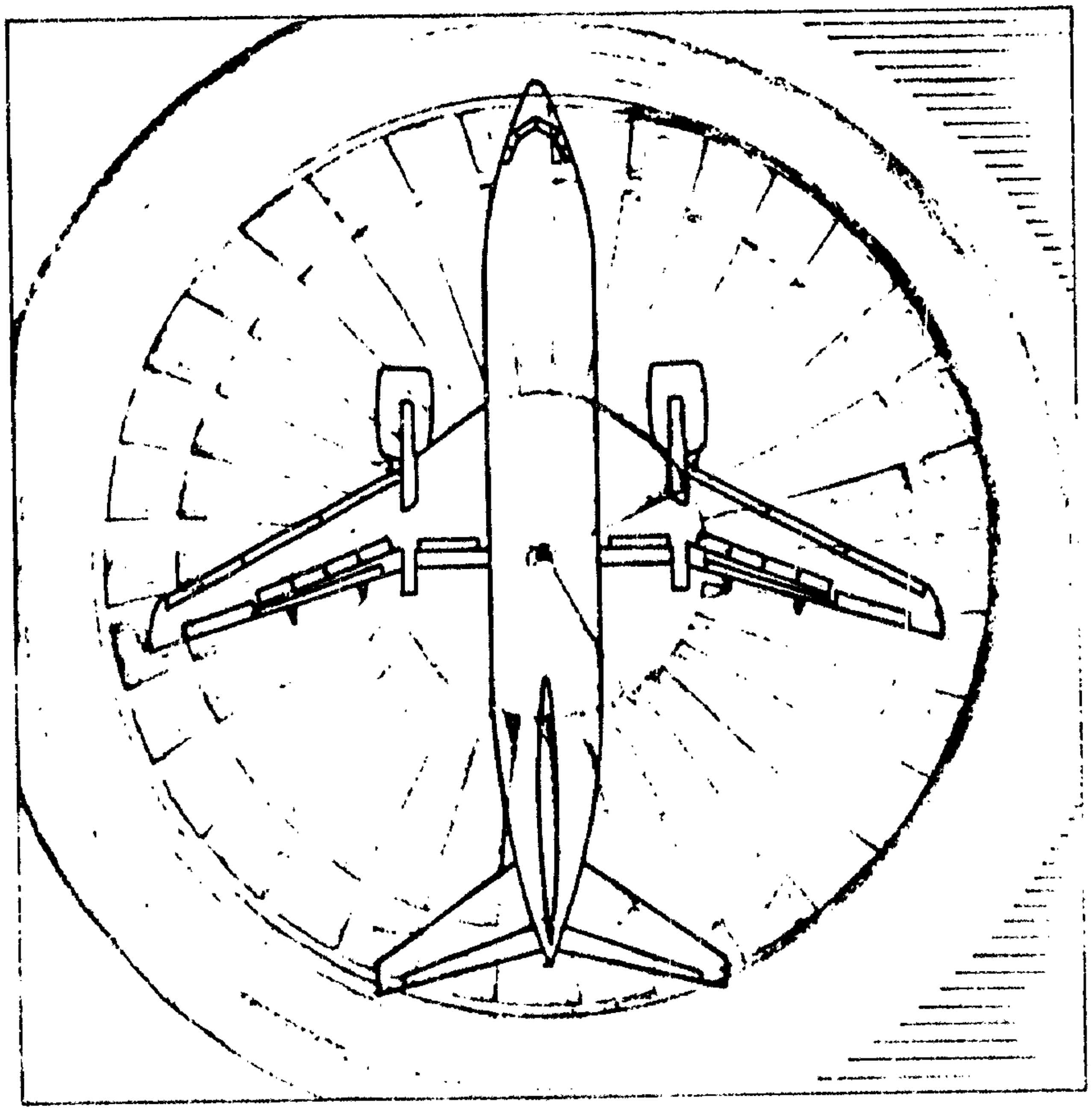
APPENDIX G

SELECTIONS FROM "OPERATIONS UPDATE"

OPERATIONS UPDATE

APRIL/MAY 1986

A PIEDMONT AIRLINES FLIGHT OPERATIONS PUBLICATION •



from the desk of ... FRED D. WOMACK
Director, Flight Operations & Flying Safety

While speaking at an Eastern Airlines Seminar, Robert J. Serling said, "Pride is what the airlines have accomplished, achieving miracles in the face of adversity ... learning from mistakes ... showing initiative in spite of outside lethargy and indifference, and even opposition." Mr. Serling identified one very important element in the safety equation: learning from mistakes.

If one reviews an aircraft accident, he will find that the major cause is often linked to several different contributing factors. Let me give you an example. Some time ago, an accident occurred in which the crew landed the aircraft and ran off the end of the runway. There were three contributing factors: (1) touchdown at the 2,500 foot point on the runway; (2) use of minimum reverse; and (3) airspeed at touchdown 20 knots above "bug" speed.

If any one of these maneuvers had been executed properly, the pilot would have been able to stay on the runway. But the combination of all three resulted in an accident.

Even if one element of the system breaks down, as long as we follow our prescribed safety procedures, the likelihood of an accident is lessened.

As you are aware, one of our aircraft was recently directed to the wrong airport for a visual approach and landing. A safe landing was made on the 3,755 foot long runway. Even though a mistake was made, no accident occurred because the crew flew the airplane in the proper approach and landing profile. The combination for an accident was simply not there. If one would apply the contributing factors of the aforementioned accident, then we surely would have experienced an aircraft exiting the end of the runway and possible damage to equipment or injury to passengers or crew.

I once witnessed a judge explain to a pilot during a hearing, "When I make a mistake, I can take an eraser and erase it. But when an airline pilot makes a mistake, he carries a satchel of responsibility." That, my friends, is the reason your job is so important.

To paraphrase Mr. Serling, pride is what we are accomplishing, day by day, flight by flight. We all take pride in learning, and learning from mistakes, be they ours or someone else's, is part of the safety equation.

* * * * *

HOT BRAKES AND TIRES

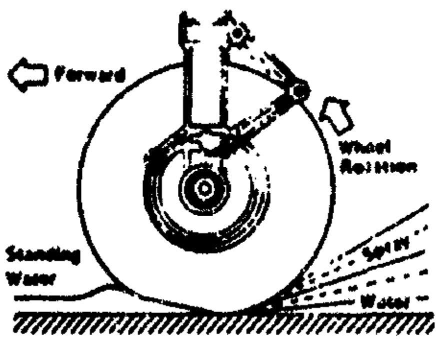
Good pilot techniques can reduce total brake/landing costs by over a million dollars a year, cut delays due to brake and tire changes and add a measure of safety to the operation.

- Remember that spoilers and reverse thrust are most effective at high speed, brakes are most effective at low speed, and those first taxiway turnoffs are expensive.

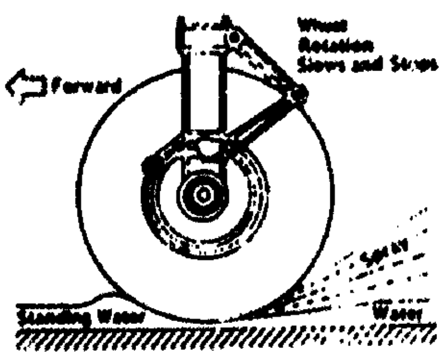
- Engine shutdown procedures for taxi operations have been instituted primarily for fuel conservation. However, one of the important by-products of these procedures is the reduction of brake wear. Less braking is required when engines are shutdown during taxi. Also, remember that slow taxiing will reduce heat buildup.

HYDROPLANING

Hydroplaning? --- that's flying on water, right? That's one answer, but actually, there are three types of hydroplaning that can send you and your aircraft slipping and sliding down the runway. They are: dynamic, viscous, and reverted rubber hydroplaning.



- Dynamic Hydroplaning: In 1956, NASA demonstrated on a tire treadmill that a tire in an unbraked condition will spin down to a complete stop on a flooded surface at some critical ground speed. The spindown is the result of dynamic fluid pressures in the tire-ground contact area. If enough water is present, the tire will completely lift off the pavement surface. This is pretty serious business, which can lead to loss of braking and steering ability. If you are mathematically inclined, you can even find the speed at which your aircraft will hydroplane by multiplying the square root of the tire pressure times nine.



- Viscous Hydroplaning: In later studies, NASA showed that when a surface was thoroughly saturated with water and then the standing water ran off so that the surface was only damp to the touch, traction could be lost at very low speeds. In this case, a thin film of water acts as a lubricating agent, particularly on smooth runway surfaces, and when mixed with rubber deposits and/or dust. Many of our runways are relatively rough-textured; however, every time you land, you leave a little rubber in the texture. A momentary landing skid can generate enough heat to melt a thin layer of each tire that bonds to the surface.

- <u>Reverted Rubber Hydroplaning</u>: In the mid 1960's, studies of low-speed skidding accidents on wet runways demonstrated that water could boil at the point of tire/runway contact. This caused the rubber to <u>revert</u> to its natural latex state and provided a seal over the tire grooves, which delayed water dispersal. The steam produced by the boiling water also acts as a cushion which prevents tire contact with the runway. Light colored streaks indicating a "steam-cleaning" effect can be seen on runways after reverted rubber hydroplaning has occurred.

<u>Minimizing Hydroplaning Effects</u>

- Strict adherence to established operating procedures relative to approach and landing, followed by a "firm" touchdown rather than a "grease job" are important courses of action to follow.

- Spoiler deployment, to get the aircraft weight on the wheels right away, is important. This action helps to prevent delayed wheel spinup. Monitor spoiler operation if spoilers are deployed automatically. See that they are extended immediately after the nose wheel touches the pavement.

- Don't hold the nosewheel off. Land it without delay.

- Apply reverse smoothly and evenly to all engines. Use the maximum recommended if conditions indicate the need. If the aircraft begins to weathervane into a crosswind, ease off on the reverse until the rudder becomes effective.

- <u>After</u> nose wheel has contact the runway and aircraft is tracking, increase reverse thrust. Apply brakes smoothly and symmetrically with moderate to firm steady pedal pressure. If hydroplaning conditions develop, the use of reverse thrust may be the most effective deceleration means available to the pilot. However, improper use of reverse thrust on wet slippery runways can be critical to directional control, especially during crosswind conditions.

- Avoid the use of nosewheel steering as long as possible. It is virtually useless on a wet runway until the speed is quite low. Often its use can create more problems that it corrects. Nose wheel tire pressures are lower than main gear tire pressures on most airplanes, and this allows the nosewheel to hydroplane long after the main gear wheels have stopped.

SUMMARY

- In summary, the key factor in hydroplaning is SPEED. The water skier serves as a good example of total hydroplaning. Just as skis must reach a critical speed before they are fully supported, the aircraft must do likewise to effect total hydroplaning. It can be easily seen that with no tire to runway contact, braking is reduced to practically zero levels. The loss in directional control may also be appreciated if it is realized that when the wheels are not in contact with the runway, any unbalanced forces on the aircraft--such as crosswinds--may induce an out-of-control situation.

* *

APPENDIX H

RUNWAY FRICTION MEASUREMENT

REPORT ON THE FRICTION SURVEY FOR RUNWAY 36R-18L
CHARLOTTE/DOUGLAS INTERNATIONAL AIRPORT
CHARLOTTE, NORTH CAROLINA

PREPARED BY

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OFFICE OF AIRPORT STANDARDS
ENGINEERING AND SPECIFICATIONS DIVISION
WASHINGTON, D.C.

NOVEMBER 14, 1986

CONDUCTED BY THE FEDERAL AVIATION ADMINISTRATION
FOR THE NATIONAL TRANSPORTATION SAFETY BOARD

1.0 BACKGROUND. On Saturday, October 25, 1986, at approximately 08:07 PM, Piedmont Flight 467 skidded off the the end of Runway 36 Right at Charlotte/Douglas International Airport, Charlotte, North Carolina. The Boeing 737-200 aircraft ended nose down on an embankment at the end of the runway, with the nose of the aircraft resting on the ballast of the railroad tracks. Thirty-four of the 118 passengers and crew were injured. There were no fatalities.

The National Transportation Safety Board (NTSB) requested the Federal Aviation Administration (FAA) to conduct an investigation on the friction and drainage characteristics of the 36R-18L runway pavement. On Tuesday, October 28, 1986, the FAA Survey Team arrived at the Charlotte airport. Members of the team included, Hector Diautolo, Harry Jackson and Joe Walaconis, from the FAA Technical Center, located near Atlantic City, New Jersey, Charles Blair from the FAA Southern Region in Atlanta, Georgia and Thomas Morrow, from the Washington Headquarters Office of Airports Standards.

Members from NTSB and the FAA conducted a visual inspection of runway 36R on Tuesday afternoon. The results of this investigation is reported in Paragraph 2.1. Friction surveys were conducted on Tuesday and Wednesday nights. Physical measurements of the runway 36R pavement was conducted on Wednseday night. The results of these tests are discussed in paragraphs 2.0 and 5.0.

2.0 PAVEMENT EVALUATION. A visual inspection and measurement of the runway pavements physical condition was conducted by the survey team. Measurements of water depths and dimensions of depressions, transverse slope, and texture depths were taken. The following paragraphs briefly state the results of the visual inspection and measurements.

2.1 Visual Inspection of Runway 36R-18L. In 1983, Runway 36R-18L was partly reconstructed to strengthen the pavements ability to accept an anticipated increase in aircraft loading. The reconstructed section began at station 19 + 25 and ended at station 38 + 25, as measured south from the 18L threshold. The wearing course was constructed of two 2-inch layers of P-401 asphaltic concrete. After completion of the reconstructed portion of the runway, the remaining portions were overlaid with two 1-1/2 inch layers of P-401 asphaltic concrete. The entire runway was transversely grooved 130 feet wide for the full length. The grooves channels were constructed 1/4 inch wide, 1/4 inch deep, and were spaced every 2 inches, center to center. The length of the runway is 7,845 feet, which includes the 645 foot displaced threshold. The blast pad at the 36R end is approximately 90 feet long.

2.2 Construction Details of Runway 36R-18L. The inspection started from the 36R end of the runway and proceeded down to the 18L end. Generally, the runway pavement was within the FAA standards for the first-third of the runway. However, the next two-thirds of the runway exhibited variances from the design transverse slope, a depressed area along the longitudinal construction joints, displacement of the grooves in the construction joint area, in the direction of aircraft landing on runway 36R, and grooves filled with liquid asphalt.

The depressed areas were located 12-1/2 feet either side of the runway centerline and average approximately 30 inches in width and 3/8 inches in depth. The depressions were observed to be greater on the left side of the runway centerline. The depressed areas may have been caused by improper construction techniques, such as inadequate compaction or poor grade control, or by low stability pavement due to an excess of asphalt cement in the bituminous mix. The appearance of asphalt in the grooves is also an indication of excessive asphalt in the mix since the asphalt will expand onto the surface when the voids within the pavement are filled during periods of extremely hot weather. In addition, the transverse slope of the pavement contains undulations. This could be caused by poor rolling techniques or screed control of the paving machine. The undulated surface caused the grooves to vary in depth. It is surmised that when the grooving machine traveled across the pavement transversely, the higher part of the undulation received the full cut of the groove, whearas, on the lower part of the undulation, the groove was cut at a shallow depth, sometimes just barely cutting the surface. There were no visible areas of subgrade failure along the runway.

The rubber deposit area along the touchdown portion of runway 36R were classified as medium deposits. Microtexture was still evident when rubbing the hand across the rubber coated pavement surface. It is estimated that 60 % of the texture was covered with rubber and therefore received an R6 code rating (reference AC 150/5320-12A). This will be discussed later in greater detail in paragraph 5.0. There were no significant rubber deposits on the approach end of runway 18L.

2.3 Physical Measurements Conducted on Runway 36R-18L. Several measurements were conducted on runway 36R-18L. Measurements were taken at several designated locations along the runway of water depth in depressions, dimensions of the depressions, transverse slope of the pavement, and texture depth of the pavements surface.

2.3.1 Measurement of Water Depths in Depressions. The water depth measurements were taken in longitudinal depressions 12-1/2 feet left of the runway centerline. All locations are relative to the distance "to go" for a landing by an aircraft on Runway 36R. The water tanker was used to spray water over the 12-1/2 foot wide by 300 foot long test section, left of the centerline. A sufficient amount of water was used to accumulate water in the depressed areas. A short period of time was allowed for the water to stabilize in the depressed areas, after which time the water depth measurements were obtained. After the measurements were taken, the friction measuring devices were run through the test section at 40 miles per hour over the depressed areas. After completion of these tests, the same procedure was followed and the friction equipment was run through the test section at 60 miles per hour. The range of width of standing water in the depressed areas was observed to be from 12 to 18 inches, once the water was stabilized. The following table shows the average water depth for each test section.

LOCATION (FEET)	TEST RUN AT 40 MPH WATER DEPTH (INCHES)	TEST RUN AT 60 MPH WATER DEPTH (INCHES)
TEST SECTION A		
1000 TO 0700	0.12	0.18
TEST SECTION B		
3000 TO 2700	0.18	0.18
TEST SECTION C		
4700 TO 4400	0.09	0.11

2.3.2 Dimensions of the Depressions. The dimensions of the longitudinal depressions ranged from 10 to 41 inches throughout the test sections evaluated. The following table summarizes the measurements taken at the designated locations on the runway.

DISTANCE TO GO FROM THE 36R END (FEET)	DISTANCE LEFT OF THE CENTERLINE (FEET)	DISTANCE RIGHT OF THE CENTERLINE (FEET)	WIDTH (INCHES)	DEPTH (INCHES)
4700 TO 4400 BETWEEN D3 & D4	12 —	— 12	24 14	5/16 1/8
3000	12 —	— 12	31 37	3/8 1/4
2000	12 —	— 12	41 30	1/4 3/8
1000	12 —	— 12	38 36	3/8 1/4
200 FROM DEPARTURE END OF PAVEMENT (NON GROOVED)	14 —	— 12	10 33	3/8 1/4

DEPTH MEASUREMENTS TAKEN TO THE CLOSEST 1/16 INCH

2.3.3 Transverse Slope Measurements. Transverse slope measurements were taken at the following locations given in the table below.

DISTANCE TO GO FROM THE 36R END (FEET)	DISTANCE LEFT OF THE CENTERLINE (FEET)	DISTANCE RIGHT OF THE CENTERLINE (FEET)	TRANSVERSE SLOPE (PERCENT)
4700 TO 4400 BETWEEN D3 & D4	16 —	— 16	1.10 1.70
3000	16 —	— 16	0.30 0.75
2000	10 —	— 10	0.65 0.50
1000	10 —	— 10	1.00 0.50
200 FROM DEPARTURE END OF PAVEMENT (NON-GROOVED)	12 —	— 06	0.75 1.05

2.3.4 Texture Depth Measurements. Texture depth measurements were taken at the following locations given in the table below. All measurements were 5 inches in width, taken on non-grooved pavement, and the volume of grease used was o.50 cubic inches. The measurement taken at the runway centerline between the D3 and D4 signs is located in the rubber deposit portion of the runway.

DISTANCE TO GO FROM THE 36R END (FEET)	LOCATION	LENGTH (INCHES)	TEXTURE DEPTH (INCHES)
4700 TO 4400 BETWEEN D3 & D4	LEFT EDGE	13-3/4	0.0073
4700 TO 4400 BETWEEN D3 & D4	CENTERLINE	25-1/2	0.0039
200 FROM DEPARTURE END OF PAVEMENT (NON GROOVED)	12 FEET LEFT OF CENTERLINE	10-1/2	0.0095

3.0 DESCRIPTION OF EQUIPMENT. The Mark IV Mu Meter was used to evaluate the friction properties of runway 36R. The tests were conducted on Tuesday evening and into Wednesday morning, October 28 and 29, 1986. Another friction tester was available to the investigating team, and on Wednesday evening into Thursday morning, October 29 and 30, 1986, the M6800 Runway Friction Tester was used to evaluate the runway friction properties. A brief description for each testing device is given in the following paragraphs.

3.1 Mark IV Mu Meter Trailer. The Mu Meter is a trailer that weighs 540 pounds and measures side-force friction. The trailer consists of two friction measuring wheels and a rear wheel that measures the distance travelled. The friction measuring wheels when set in the test position (toed out) approximate an included angle of 15 degrees and an apparent slip ratio of 13.5 percent. When the trailer is towed by a vehicle over the pavement surface in the toed-out position, the friction measuring wheels tend to pull apart. This tendency is resisted by an electronic load cell placed between the pivoted members which are part of the frame upon which the friction measuring wheels are mounted. A vertical load of 171 pounds is generated by ballast via a shock absorber on each friction measuring wheel. The friction measuring tires were smooth tread, size 16 x 4 x 6 ply, RL2 stencil 100, inflated to a pressure of 10 pounds per square inch. The rear tire is a patterned tire, size 16 x 4 x 6 ply, RL6, inflated at a pressure of 30 pounds per square inch. Two nozzles are mounted in front of each friction measuring wheel. They are designed to provide a 1 mm (0.04 inches) water depth in front of each friction measuring tire. A 350 gallon tank is mounted on the tow vehicle to supply water to the self water system. Pressure regulating valves are used to control the flow rate for the speed used in the survey. The Mu Meter is equiped with a processor unit which provides a continuous trace of friction values for each foot travelled in a survey on a strip chart. The scale used was one inch equals 280 feet. The computer provided friction averages for each 500 foot segment of the runway length. Information concerning the friction survey and observations are entered via a keyboard. The friction surveys were conducted at speeds of 40 and 60 miles per hour. The equipment was calibrated at the beginning of the test program according to the manufacturers instructions.

3.2 M6800 Runway Friction Tester Van. The Runway Friction Tester is a van with front wheel drive and a turbo engine. The friction measuring wheel (5th wheel) is connected to the rear axle by a gear drive maintaining a 13 percent slip ratio. The test mode utilizes a two-axis force transducer which measures the drag force and vertical load. A vertical load of 300 pounds is generated on the friction wheel by weights mounted on a double shock absorber spring assembly. The friction measuring tire is smooth tread, size 16 x 4 x 6 ply, RL2 stencil 100, inflated to a pressure of 30 pounds per square inch. A nozzle is located in front of the friction measuring tire. The nozzle is designed to provide a 1 mm (0.04 inches) of water depth in front of the friction measuring tire. A 150 gallon container is installed in the rear of the van to supply water to the self water system. The self water system assures that the pump revolutions per minute corresponds to the vehicle speed, thus a constant water flow per travelled distance is maintained, independent corrective action to eliminate this situation". In this case it means that there are significant rubber deposits to reduce the pavement microtexture and therefore the rubber deposits should be removed. This paragraph applies only when mu values are 50 or less. The friction value for station 1,000 to 1,500 feet for the 40 miles per hour speed is 51. The friction value for the same location at the 60 miles per hour speed is 33, located 12 feet right of the centerline. The difference of 18 is greater than the minimum 10. Therefore, this paragraph controls.

The friction values for the remaining part of the runway are acceptable, with the exception of the last 1,500 feet, 12 feet left and right of the centerline. Here, the 60 miles per hour speed shows a dramatic drop in friction values when compared to the friction values obtained at the 40 miles per hour speed. This is attributed partly to the ungrooved section in the departure end plus the flat transverse slopes, inadequate groove depths, the 150 foot touchdown marker, and general overall poor microtexture in this area. The last 1,500 feet of friction values are below the minimum 50. The airport operator should look into the cause for this deterioration and take corrective action.

5.2 Friction Measurements Using the Water Tanker Procedure. Tables 5 and 6 as well as Figures H, I and J show the results of the water tanker method. Section A, generally was taken over the 150 foot touchdown marker, which accounts for the low friction values obtained in this section. Sections B and C are above the minimum acceptable value of 50. The drop in friction value between speeds is within the minimum difference of 10. Therefore, the water tanker show the same results as those obtained by the friction equipments self water system.

5.3 Friction Measurements on Dry Runway Pavement Surface. Two test runs were made at the speed of 40 miles per hour, 12 foot left and right of the centerline, starting from the threshold of 36R north 268 feet and ending 284 feet south of the 18L threshold. Then average friction value for the entire length tested was 94 on the right side of the runway centerline and 96 on the left side of the runway centerline. These are expected averages for an asphalt grooved runway. Table 9 and Figure K show the results of the survey.

REPORT ON THE FRICTION SURVEY FOR RUNWAY 36R-18L,
CHARLOTTE/DOUGLAS INTERNATIONAL AIRPORT, CHARLOTTE, NORTH CAROLINA

CONDUCTED BY THE FEDERAL AVIATION ADMINISTRATION
FOR THE NATIONAL TRANSPORTATION SAFETY BOARD
ON OCTOBER 28-30, 1986

TABLE 1 - FRICTION SURVEYS CONDUCTED AT 40 MILES PER HOUR USING A MARK IV MU METER WITH SELF WATER SYSTEM OPERATING, STARTING 268 FEET NORTH OF THE THRESHOLD OF RUNWAY 36R AND ENDING 284 FEET SOUTH OF THE THRESHOLD OF RUNWAY 18L.

DATE - OCTOBER	28	28	28	29
EASTERN TIME	11:32 PM	11:42 PM	11:57 PM	00:04 AM
RUN NUMBER	1	2	3	4
LOCATION OF SURVEY	30 FT RIGHT OF CENTERLINE	12 FT RIGHT OF CENTERLINE	30 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE
DISTANCE FROM 36R	FRICTION VALUES			
0000 FT TO 0500 FT	73	73	75	64
0500 FT TO 1000 FT	74	59	76	63
1000 FT TO 1500 FT	79	61	82	69
1500 FT TO 2000 FT	77	64	83	71
2000 FT TO 2500 FT	75	75	79	77
2500 FT TO 3000 FT	75	76	79	79
3000 FT TO 3500 FT	77	78	79	78
3500 FT TO 4000 FT	74	77	79	78
4000 FT TO 4500 FT	73	78	79	79
4500 FT TO 5000 FT	76	76	78	77
5000 FT TO 5500 FT	77	75	75	73
5500 FT TO 6000 FT	72	77	79	81
6000 FT TO 6500 FT	72	74	79	77
6500 FT TO FT	67	75	72	68
TOTAL LENGTH OF RUNWAY SURVEYED	6906 FT	6919 FT	6915 FT	6898 FT
AVERAGE MU VALUE FOR THE RUNWAY	75	72	78	75
AVERAGE SPEED FOR THE SURVEY	40 MPH	41 MPH	40 MPH	40 MPH

CALIBRATION DATE - 29 OCTOBER 1986 AT 14:55. ZERO KNOB # = 815, MU KNOB # = 750 BY: JCW

REPORT ON THE FRICTION SURVEY FOR RUNWAY 36R-18L,
CHARLOTTE/DOUGLAS INTERNATIONAL AIRPORT, CHARLOTTE, NORTH CAROLINA

CONDUCTED BY THE FEDERAL AVIATION ADMINISTRATION
FOR THE NATIONAL TRANSPORTATION SAFETY BOARD
ON OCTOBER 28-30, 1986

TABLE 2 - FRICTION SURVEYS CONDUCTED AT 60 MILES PER HOUR USING A MARK IV MU METER WITH SELF WATER SYSTEM OPERATING, STARTING 268 FEET NORTH OF THE THRESHOLD OF RUNWAY 36R AND ENDING 284 FEET SOUTH OF THE THRESHOLD OF RUNWAY 18L.

DATE - OCTOBER	29	29	29	29
EASTERN TIME	01:26 AM	02:13 AM	02:20 AM	02:42 AM
RUN NUMBER	1	2	3	4
LOCATION OF SURVEY	30 FT RIGHT OF CENTERLINE	12 FT RIGHT OF CENTERLINE	30 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE
DISTANCE FROM 36R	FRICTION VALUES			
0000 FT TO 0500 FT	75	48	50	44
0500 FT TO 1000 FT	67	41	52	38
1000 FT TO 1500 FT	67	33	52	41
1500 FT TO 2000 FT	72	41	57	46
2000 FT TO 2500 FT	70	58	60	59
2500 FT TO 3000 FT	68	60	59	60
3000 FT TO 3500 FT	67	60	62	62
3500 FT TO 4000 FT	65	61	59	59
4000 FT TO 4500 FT	66	63	61	60
4500 FT TO 5000 FT	66	58	62	51
5000 FT TO 5500 FT	70	53	57	56
5500 FT TO 6000 FT	60	52	58	49
6000 FT TO 6500 FT	57	46	57	44
6500 FT TO FT	50	35	[illegible]	27
TOTAL LENGTH OF RUNWAY SURVEYED	6679 FT	6708 FT	6684 FT	6688 FT
AVERAGE MU VALUE FOR THE RUNWAY	67	52	58	52
AVERAGE SPEED FOR THE SURVEY	60 MPH	59 MPH	60 MPH	60 MPH

CALIBRATION DATE - 28 OCTOBER 1986 AT 14:55. ZERO KNOB # = 815, 160 KNOB # = 760 BY: JCW

REPORT ON THE FRICTION SURVEY FOR RUNWAY 36R-18L,
CHARLOTTE/DOUGLAS INTERNATIONAL AIRPORT, CHARLOTTE, NORTH CAROLINA

CONDUCTED BY THE FEDERAL AVIATION ADMINISTRATION
FOR THE NATIONAL TRANSPORTATION SAFETY BOARD
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TABLE 3 - FRICTION SURVEYS CONDUCTED AT 40 MILES PER HOUR USING THE RUNWAY FRICTION TESTER WITH SELF WATER SYSTEM OPERATING, STARTING 268 FEET NORTH OF THE THRESHOLD OF RUNWAY 36R AND ENDING 284 FEET SOUTH OF THE THRESHOLD OF RUNWAY 18L.

DATE - OCTOBER	30	30	30	30
EASTERN TIME	12:17 AM	12:28 AM	12:53 AM	01:03 AM
RUN NUMBER	1	2	3	4
LOCATION OF SURVEY	30 FT RIGHT OF CENTERLINE	12 FT RIGHT OF CENTERLINE	30 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE
DISTANCE FROM 36R	FRICTION VALUES			
0000 FT TO 0500 FT	78	68	67	58
0500 FT TO 1000 FT	70	64	72	53
1000 FT TO 1500 FT	75	49	70	46
1500 FT TO 2000 FT	74	47	76	52
2000 FT TO 2500 FT	78	61	78	57
2500 FT TO 3000 FT	71	70	74	70
3000 FT TO 3500 FT	71	73	72	70
3500 FT TO 4000 FT	70	71	74	70
4000 FT TO 4500 FT	70	70	75	68
4500 FT TO 5000 FT	71	70	74	66
5000 FT TO 5500 FT	70	66	68	64
5500 FT TO 6000 FT	68	66	67	63
6000 FT TO 6500 FT	64	70	70	72
6500 FT TO 7000 FT	64	62	61	60
AVERAGE MU VALUE FOR THE RUNWAY	72	64	72	62
AVERAGE SPEED FOR THE SURVEY	40.1 MPH	39.9 MPH	40.1 MPH	40.0 MPH

REPORT ON THE FRICTION SURVEY FOR RUNWAY 36R-18L,
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TABLE 4 - FRICTION SURVEYS CONDUCTED AT 60 MILES PER HOUR USING THE RUNWAY FRICTION TESTER WITH SELF WATER SYSTEM OPERATING, STARTING 268 FEET NORTH OF THE THRESHOLD OF RUNWAY 36R AND ENDING 284 FEET SOUTH OF THE THRESHOLD OF RUNWAY 18L.

DATE - OCTOBER	30	30	30	30
EASTERN TIME	01:33 AM	01:51 AM	02:15 AM	02:25 AM
RUN NUMBER	1	2	3	4
LOCATION OF SURVEY	30 FT RIGHT OF CENTERLINE	12 FT RIGHT OF CENTERLINE	30 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE
DISTANCE FROM 36R	FRICTION VALUES			
0000 FT TO 0500 FT	72	69	74	62
0500 FT TO 1000 FT	69	50	81	60
1000 FT TO 1500 FT	67	32	73	48
1500 FT TO 2000 FT	67	36	72	48
2000 FT TO 2500 FT	68	52	75	47
2500 FT TO 3000 FT	62	65	70	64
3000 FT TO 3500 FT	64	66	66	64
3500 FT TO 4000 FT	65	64	67	62
4000 FT TO 4500 FT	62	63	64	64
4500 FT TO 5000 FT	62	62	63	62
5000 FT TO 5500 FT	62	58	66	50
5500 FT TO 6000 FT	57	58	60	56
6000 FT TO 6500 FT	57	61	64	68
6500 FT TO 7000 FT	---	48	62	58
AVERAGE MU VALUE FOR THE RUNWAY	64	56	68	58
AVERAGE SPEED FOR THE SURVEY	58.3 MPH	58.5 MPH	57.5 MPH	57.8 MPH

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REPORT ON THE FRICTION SURVEY FOR RUNWAY 36R-18L,
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TABLE 5 - FRICTION SURVEYS CONDUCTED ON RUNWAY 36R NORTH AT THE SPEEDS INDICATED, WITH THE MARK IV MU METER, USING THE WATER TANKER PROCEDURE, STARTING AND ENDING AT THE POSITIONS INDICATED

DATE - OCTOBER	29	29	29	29	29	29	29
EASTERN TIME	03:47 AM	03:57 AM	04:21 AM	04:26 AM	04:44 AM	04:48 AM	04:53 AM
RUN NUMBER	1	2	3	4	5	6	7
AVERAGE SPEED	40 MPH	60 MPH	41 MPH	61 MPH	40 MPH	59 MPH	20 MPH
LOCATION OF SURVEY	12 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE
FRICTION VALUES MEASURED IN EACH SECTION							
DISTANCE TO GO FROM RUNWAY 36R	1000 FT TO 0700 FT SECTION A		3000 FT TO 2700 FT SECTION B		4700 FT TO 4400 FT SECTION C		
0100 FT TO 0200 FT	40	35	60	55	56	45	70

TABLE 6 - FRICTION SURVEYS CONDUCTED ON RUNWAY 36R NORTH AT THE SPEEDS INDICATED, WITH THE RUNWAY FRICTION TESTER, USING THE WATER TANKER PROCEDURE, STARTING AND ENDING AT THE POSITIONS INDICATED

DATE - OCTOBER	29	29	29	29	29	29	29
EASTERN TIME	03:49 AM	03:59 AM	04:23 AM	04:28 AM	04:46 AM	04:50 AM	04:55 AM
RUN NUMBER	1	2	3	4	5	6	7
AVERAGE SPEED	40.3 MPH	60.7 MPH	---- ----	61.6 MPH	40.4 MPH	64.5 MPH	21.2 MPH
LOCATION OF SURVEY	12 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE
FRICTION VALUES MEASURED IN EACH SECTION							
DISTANCE TO GO FROM RUNWAY 36R	1000 FT TO 0700 FT SECTION A		3000 FT TO 2700 FT SECTION B		4700 FT TO 4400 FT SECTION C		
0100 FT TO 0200 FT	34	30	----	52	45	40	60

REPORT ON THE FRICTION SURVEY FOR RUNWAY 36R-18L,
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TABLE 7 - FRICTION SURVEYS CONDUCTED AT 20 MILES PER HOUR
USING THE RUNWAY FRICTION TESTER WITH SELF WATER SYSTEM OPERATING,
STARTING 268 FEET NORTH OF THE THRESHOLD OF RUNWAY 36R AND ENDING 284 FEET
SOUTH OF THE THRESHOLD OF RUNWAY 18L.

DATE - OCTOBER	30
EASTERN TIME	02:51 AM
RUN NUMBER	1
LOCATION OF SURVEY	12 FT RIGHT OF CENTERLINE
DISTANCE FROM 36R	FRICTION VALUES
0000 FT TO 0500 FT	78
0500 FT TO 1000 FT	72
1000 FT TO 1500 FT	56
1500 FT TO 2000 FT	58
2000 FT TO 2500 FT	68
2500 FT TO 3000 FT	78
3000 FT TO 3500 FT	78
3500 FT TO 4000 FT	76
4000 FT TO 4500 FT	74
4500 FT TO 5000 FT	74
5000 FT TO 5500 FT	72
5500 FT TO 6000 FT	72
6000 FT TO 6500 FT	80
6500 FT TO 7000 FT	68
7000 FT TO 7500 FT	68
AVERAGE MU VALUE FOR THE RUNWAY	72
AVERAGE SPEED FOR THE SURVEY	20.2 MPH

NOTE: ROUGHNESS ENCOUNTERED IN THE TOUCHDOWN ZONE OF RUNWAY 36R.

REPORT ON THE FRICTION SURVEY FOR RUNWAY 36R-18L,
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TABLE 8 - FRICTION SURVEYS CONDUCTED ON RUNWAY 36R NORTH AT THE SPEEDS INDICATED, USING THE RUNWAY FRICTION TESTER WITH SELF WATER SYSTEM OPERATING, STARTING AND ENDING AT THE POSITION INDICATED

DATE - OCTOBER	30	30
EASTERN TIME	03:32 AM	03:35 AM
RUN NUMBER	1	2
AVERAGE SPEED	30 MPH	60 MPH
LOCATION OF SURVEY	12 FT LEFT OF CENTERLINE	12 FT LEFT OF CENTERLINE
FRICTION VALUES MEASURED IN SECTION		
DISTANCE TO GO FROM RUNWAY 36R	4500 FT TO 3500 FT SECTION D	
0000 FT TO 0500 FT	42	56
0500 FT TO 1000 FT	54	35
AVERAGE MU VALUE FOR THE SECTION	48	45
AVERAGE SPEED	29.8 MPH	61.8 MPH

REPORT ON THE FRICTION SURVEY FOR RUNWAY 36R-18L,
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TABLE 9 - DRY FRICTION SURVEYS CONDUCTED AT 40 MILES PER HOUR USING THE MARK IV MU METER STARTING 268 FEET NORTH OF THE THRESHOLD OF RUNWAY 36R AND ENDING 284 FEET SOUTH OF THE THRESHOLD OF RUNWAY 18L.

DATE - OCTOBER	30	30
EASTERN TIME	00:00 AM	00:07 AM
RUN NUMBER	1	2
LOCATION OF SURVEY	12 FT RIGHT OF CENTERLINE	12 FT LEFT OF CENTERLINE
DISTANCE FROM 36R	FRICTION VALUES	
0000 FT TO 0500 FT	97	96
0500 FT TO 1000 FT	95	92
1000 FT TO 1500 FT	91	[illegible]
1500 FT TO 2000 FT	92	93
2000 FT TO 2500 FT	95	95
2500 FT TO 3000 FT	96	96
3000 FT TO 3500 FT	96	96
3500 FT TO 4000 FT	95	97
4000 FT TO 4500 FT	95	95
4500 FT TO 5000 FT	95	95
5000 FT TO 5500 FT	94	95
5500 FT TO 6000 FT	93	94
6000 FT TO 6500 FT	92	95
6500 FT TO 7000 FT	93	95
7000 FT TO FT	94	95
TOTAL LENGTH OF RUNWAY SURVEYED	7206	7164
AVERAGE MU VALUE FOR THE RUNWAY	94	96
AVERAGE SPEED FOR THE SURVEY	40.0 MPH	41.0 MPH

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